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Ultra-Low Dose Cardiac CT Angiography at 80 kV using Second Generation Dual-Source CT: Assessment of Radiation Dose and Image Quality

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Abstract

Objectives: We sought to determine the feasibility of using 80 kV in clinical cardiac CTA, by comparing radiation doses and image quality versus standardized 100 kV protocols.

Methods: In this retrospective study, a tube potential of 80 kV was used in 40 consecutive patients (BMI 22.6 ± 2.8). 40 matched patients (BMI 23.1 ± 2.8) were scanned with a tube potential of 100 kV and served as the control group. Qualitative and quantitative image quality parameters were determined in the proximal and distal segments of the coronary arteries.

Results: Similar subjective image quality scores were seen between the two protocols. The mean CNR and SNR were at 100 kV vs 80 kV (CNR 19.9 ± 6.0 vs 15.7 ± 5.5; $p < 0.01$ and SNR 17.7 ± 5.5 vs 14.4 ± 4.9). The median radiation dose for the 80 kV protocol was significantly lower compared to the 100 kV protocol (83.0 mGy x cm [58.0-134.0] vs 193.0 mGy x cm [108.5-225.0]; $p < 0.01$)

Conclusion: A tube potential of 80 kV is feasible and results in a radiation dose reduction of 57% compared to 100 kV protocols while preserving subjective image quality.

Introduction

Cardiac Computed Tomography Angiography (CCTA) offers a non-invasive diagnostic tool for evaluating patients with suspected coronary artery disease [1,2]. However, radiation exposure remains a limitation of this modality [3,4]. In an effort to address this concern, numerous methods of radiation dose reduction have been developed [5].

Advances in scanner technology and better protocols permit low radiation dose cardiac imaging with doses below one mSv [6-9]. In individuals with the suitable body size, a lower tube voltage setting may allow for a decreased radiation dose while maintaining image quality [8,10-19] because radiation exposure varies with the square of the tube potential [20].

Thus far, a BMI-based paradigm with a threshold of 30 kg/m² has been proposed to decrease cardiac CT tube potential to 100 kV [21,22]. Lower tube potentials (70 kV and 80 kV) have been commonly used in pediatric patients. The use of 80 kV has been proven feasible in adult patients with a BMI below 22.5 kg/m² [8,13]. However, limited data is available to inform recommend size or weight thresholds for 80 kV in cardiac CT. In addition, further research is needed to assess the accuracy of 80 kV protocols to evaluate coronary artery disease in small vessels before they can be reliably implemented into widespread clinical practice for cardiac CT angiography.

We sought to investigate the feasibility of 80 kV cardiac CTA in clinical adult patients, by comparing radiation doses and image quality versus standardized 100 kV protocols.

Methods

Financial disclosure

The study was approved by the human research committee of the institutional review board and compliance with the Health Insurance Portability and Accountability Act guidelines was maintained. The requirement for informed consent was waived for this retrospective study. All authors had unrestricted control of the data at all stages of the study. Full agreement for submission of this manuscript was obtained from all authors.

Patient population

This retrospective case-control study comprised of 80 adult patients who underwent cardiac CT angiography of the native coronary arteries between April 2010 and October 2011. All scans performed in this study were clinically indicated and were performed as standard of care. Cardiac-gated CTA exams that were not tailored for native coronary artery assessment (i.e. coronary bypass graft evaluation, pulmonary vein mapping, or research protocols) were excluded. Further exclusion criteria were renal dysfunction (serum creatinine level >1.3 mg/dl), hyperthyroidism, known hypersensitivity reaction to iodinated contrast agent, heart failure NYHA III–IV, and pregnancy.

Forty consecutive patients were examined using a tube potential of 80 kV (mean age 51.5 ± 16.9 years; mean BMI 22.6 ± 2.8). Forty patients (mean age 58.1 ± 14.1 years; mean BMI 23.1 ± 2.8) matched for body-mass-index, heart rate, heart rhythm, and ECG-gating acquisition

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mode, were scanned with a tube potential of 100 kV and served as the control group.

Scan protocol

Cardiac Computed Tomography Angiography (CCTA) was performed on a second-generation dual-source CT scanner (Somatom Definition FLASH, Siemens Healthcare, Forchheim, Germany) including a standard detector collimation of 128 x 0.6 mm (using a flying focal spot, z-Sharp, Siemens Healthcare, Forchheim, Germany) and a gantry rotation time of 280 milliseconds. Each CCTA exam used one of three acquisition modes: retrospective ECG-gated helical acquisition, prospective ECG-triggered axial acquisition (Adaptive Cardio Sequential, Siemens Healthcare, Forchheim, Germany), or prospective ECG-triggered high-pitch helical acquisition (FLASH Cardio, Siemens Healthcare, Forchheim, Germany). Based on heart rate and rhythm, pitch [0.2-0.5] and tube current modulation [range 75-348 mAs] varied in retrospectively ECG-gated scans.

A tube potential of 80 kV was used in the study group (n = 40) and 100 kV in the control group (n = 40). All scans were supervised by one or more physicians (radiologists, cardiologists, and trainees, all with appropriate training in cardiac CT). Tube voltage was decided based upon institutional default protocols (BMI based nomogram, specifying 80 kV / reference mAs 430 for BMI <20 kg/m^2; 100 kV / reference mAs 320 for BMI under 25 kg/m^2) as well as informed by an automated attenuation-based tube current selection algorithm [23] (CARE kV, Siemens Healthcare, Forchheim, Germany) when available after April 2011. Throughout the study period an attenuation-based tube current selection algorithm was used (CARE Dose4D, Siemens Healthcare, Forchheim, Germany). The selections regarding kV and mAs were at the final discretion of the supervising physician present at the acquisition in all cases.

To determine contrast agent administration timing, the test bolus method was used. Typically a 60 - 80 mL bolus of nonionic iodinated contrast material (Iopamidol 370 g/cm^3, Isovue 370, Bracco Diagnostics, Princeton, NJ USA), was administered at a flow rate of 5-6 mL/s (depending on patient size and intravenous access) into an antecubital vein for contrast-enhanced cardiac computed tomography angiography, followed by 40 ml saline flush at a matching rate, during a single breath-hold at end-inspiration. A dose of 5-25 mg beta-adrenergic blocking agent (metoprolol tartrate) was administered intravenously when appropriate at the performing physician's discretion. Sublingual nitroglycerine (0.6 mg) was administered unless contraindicated. The scan range covered the entire heart from the level of the carina to the diaphragm scanning in a craniocaudal direction.

Data reconstruction

All datasets chosen for image quality evaluation were reconstructed with a slice thickness of 0.75 mm at overlapping 0.4 mm increments in the available phase of the R-R interval which demonstrated the least motion artifact, using conventional filtered back projection and a medium-smooth soft-convolution kernel (B26f).

Estimation of radiation dose and data collection

Parameters including tube potential (kV), tube current-time product (mAs), volume-weighted CT dose index (CTDI$_{vol}$) and dose-length product (DLP) were extracted from the dose exposure record and dose-related parameters, including heart rate and rhythm were verified via the DICOM meta-data. Other patient and scan characteristics (use of beta blockade and nitroglycerine, volume of contrast agent (cc) and

flow rate (cc/sec), weight, height, BMI) were identified through review of clinical records and CT reports.

The effective radiation dose was estimated by multiplying dose-length-product (DLP) by the European Working Group for Guidelines on Quality Criteria in Computed Tomography conversion coefficient [k = 0.014 mSv x (mGy x cm)$^{-1}$] [24].

Measurement of chest area as a surrogate for body-mass-index

A full field-of-view DICOM image at the z-axis level of the center of the left atrium was transferred for each patient to a 3D-imaging workstation (Osirix 3.6.1, Geneva, Switzerland) and manual tracing of a region of interest (ROI) containing the cross-sectional external circumference of the chest was performed by one physician (LCE) to measure the patient's chest area, as described previously [25].

Image Evaluation

Qualitative assessment

CT data sets were transferred to an offline workstation (Leonardo, Siemens Medical Solutions, Forchheim, Germany).

Qualitative image quality was determined retrospectively by use of a 4-point Likert scale (3: Very good image quality, no artifacts; 2: Fully diagnostic image quality, minor artifacts; 1: Poor image quality; severe artifacts; 0: Non-diagnostic segment) for each coronary artery segment, according to previously described methods [25,26]. Segmentation of the coronary arteries was performed based on the American Heart Association 17-segment model [27]. All 80 cases in the study were interpreted and overall qualitative image quality was determined. For assessment of inter-observer agreement, two blinded readers [MF and GL] with at least 4 years experience in cardiac CT imaging, each evaluated all coronary segments in 20 randomly selected patients. Prior to the subjective image quality read outs, the readers were informed on the criteria of image grading and assessed 5 test cases together.

Quantitative assessment

For quantitative image quality assessment, CT data sets were sent to an off-line 3D-imaging workstation (Osirix 3.6.1, Geneva, Switzerland).

To determine signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR), the largest possible circular regions of interest [ROI] (2-4 mm^2) were placed in the coronary lumen and the adjacent connective tissue of the vessel. The measurements were performed in nine different coronary segments: proximal and distal right coronary artery [AHA segment #1and #3], left main [AHA segment #5], proximal and distal left anterior descending [AHA segment #6 and #8], first diagonal branch [AHA segment #9], proximal and distal left circumflex artery [AHA segment #11and #14], Within these regions of interest, mean CT contrast attenuation was recorded. Image noise was defined as the standard deviation of CT density in a region of interest (ROI) placed in the aortic root at a position cranial to the left main coronary artery.

CNR was obtained by dividing the difference in CT attenuation between coronary lumen and surrounding tissue by the image noise. SNR was determined by dividing the contrast of the coronary lumen by the background noise as described previously [8,10-12,14,26].

Statistical analysis

Continuous variables were expressed as mean ± standard deviations for normally distributed and median with interquartile range [IQR;

	80 kV	100 kV	p-value
Age (years), mean ± SD - range	51.5 ± 16.9 18-83	58.1 ± 14.3 21-83	0.03
Male gender %	35.0 (14/40)	47.5 (19/40)	NS
Heart rate (bpm), mean ± SD	61.7 ± 8.2	58.1 ± 9.6	0.04
- range (bpm)	55.8 - 74.3	54.4 – 64.3	
Sinus rhythm, %	95.0 (38/40)	100.0 (40/40)	NS
BMI (kg/m²), mean ± SD - range (kg/m²)	22.6 ± 2.8 15.0-27.5	23.1 ± 2.8 16.0-28.6	NS
Chest area (cm²), mean ± SD	610.1 ± 86.5	644.7 ± 114.8	NS
Contrast agent (cc), mean ± SD - Flow rate (cc/sec)	86.5 ± 22.0 5.7 ± 0.5	92.6 ± 22.2 5.9 ± 0.6	NS NS
Acquisition mode • Retrospective ECG -gated mode, % • Prospective ECG-triggered axial mode, % • Prospective ECG-triggered high-pitch helical mode, %	27.5 (11/40) 37.5 (15/40) 35.0 (14/40)	27.5 (11/40) 37.5 (15/40) 35.0 (14/40)	NS
Tube current (mAs), median [IQR]	234.5 [219.5-279.3]	225.5 [167.3-278.8]	NS
Scan length (cm), mean ± SD	16.7 ± 3.9	16.4 ± 2.8	NS

Table 1: Patient and scan characteristics.

	80 kV	100 kV	p-value
Total no. of segments	626	617	
Subjective IQ score, mean 3: Excellent, no artifacts; 2: Good, fully dx, minor artifacts; 1: Moderate, severe artifacts,still dx; 0: Poor, ≥ 1 non-dx segment	2.3±0.7	2.4±0.7	0.26
Diagnostic image quality	99.4% (622/626)	99.0% (611/617)	NS
Nondiagnostic image quality	0.6 % (4/626)	1.0% (6/617)	NS
CTDI_vol (mGy), median [IQR]	12.7 [8.6-17.9]	21.7 [14.6-23.5]	<0.01
DLP (mGy x cm), median [IQR]	83.0 [58.0-134.1]	193.0 [108.5-225.0]	<0.01
Effective dose (mSv), median [IQR]	1.2 [0.8-1.9]	2.7 [1.5-3.2]	<0.01

Table 2: Results on qualitative image quality and radiation dose.

25th and 75th percentiles] for non-normally distributed variables. Categorical variables were expressed as frequencies or percentages. The differences in continuous variables between the groups were compared using two-tailed Student's t-test (for normally distributed variables) or Wilcoxon test (for non-normally distributed variables). Categorical variables were compared using the chi-square test or Fisher's exact test. To determine inter-observer agreement for the qualitative image quality assessment, intra-class-correlation (ICC) and Pearson's correlation coefficient were calculated. A p-value less than 0.05 was considered statistically significant. Statistical calculations were performed using PASW (Predictive Analytics SoftWare) Statistics Version 18.0 (SPSS Inc., Chicago, IL).

Results

Baseline characteristics and scan parameters

Table 1 presents the baseline characteristics and scan parameters. Patients scanned with a tube potential of 80 kV were significantly younger (51.5 ± 16.9 versus 58.1 ± 14.1 years) and had a significant slightly higher heart rate (61.0 versus 58.1 beats/minute).

Qualitative image quality

A total of 1,243 segments (626 segments [80 kV] versus 617 segments [100 kV]) were assessed qualitatively. Representative examples

of different image quality scores are seen in (Figure 5). No differences in subjective image quality assessment were seen between the two groups (Table 2, Figure 2). At 80 kV, 622/626 segments and at 100 kV, 611/617 segments were deemed diagnostic.

Inter-observer agreement

The comparison of qualitative image quality by two observers showed good agreement with an ICC of 0.75.

Radiation dose

In the 80 kV protocol, the median estimated dose-length-product was 83.0 mGy x cm [58.0 - 134.1]. This radiation dose was significantly lower compared to that at 100 kV (193.0 mGy x cm [108.5 - 225.0]; p<0.01). Radiation doses stratified by acquisition mode is seen in (Table 4).

Quantitative image quality

Figure 3 shows the background noise level and the mean CT number at 80 kV and 100 kV as measured in the aorta. Table 3 illustrates the mean contrast-to-noise and signal-to-noise ratios in both groups as determined in 8 different coronary segments. The noise level in patients scanned with a tube potential of 80 kV was higher compared to the patients scanned at 100 kV (50.1 ± 12.3 HU versus 30.7 ± 6.9 HU; p<0.01). In addition, the mean CT numbers measured in the aortic root differed significantly between study and control groups, (786.6 ± 189.7 HU [80 kV] vs 574.7 ± 112.5 HU [100 kV]).

The mean contrast-to-noise ratio and signal-to-noise ratio were higher at 100 kV vs. 80 kV (CNR 15.7 ± 5.5 [80 kV] vs. 19.9 ± 6.0 [100 kV], p<0.01 and SNR 14.4 ± 4.9 [80 kV] vs.17.7 ± 5.5 [100 kV], p<0.01). Significantly higher CNR and SNR values were observed in all coronary segments at 100 kV as compared to 80 kV except for the first diagonal branch (Table 3).

Discussion

In this study, we tested the feasibility of 80 kV protocols and

	80 kV	100 kV	p-value
Proximal RCA			
CNR SNR	17.9±5.5 16.3±5.0	21.9±5.6 19.2±5.0	<0.01 <0.01
Distal RCA			
CNR SNR	14.5±6.0 13.4±5.7	20.4±5.5 18.6±4.7	<0.01 <0.01
Left main			
CNR SNR	15.6±5.7 15.3±5.0	20.0±5.5 18.6±4.7	<0.01 <0.01
Proximal LAD			
CNR SNR	16.4±5.5 15.0±4.8	20.9±5.5 18.6±4.9	<0.01 <0.01
Distal LAD			
CNR SNR	16.0±4.6 14.3±3.8	20.3±6.0 17.9±5.1	<0.01 <0.01
First diagonal			
CNR SNR	13.1±5.4 11.4±4.9	14.6±5.6 12.9±5.6	NS NS
Proximal LCX			
CNR SNR	16.9±4.6 15.4±4.1	20.9±5.3 18.7±4.9	<0.01 <0.01
Distal LCX			
CNR SNR	15.2±4.5 13.8±3.8	19.2±5.9 16.8±5.3	<0.01 <0.01

Table 3: Mean contrast-to-noise ratio (CNR) and signal-to-noise (SNR) in patients scanned with 80 kV and 100 kV.
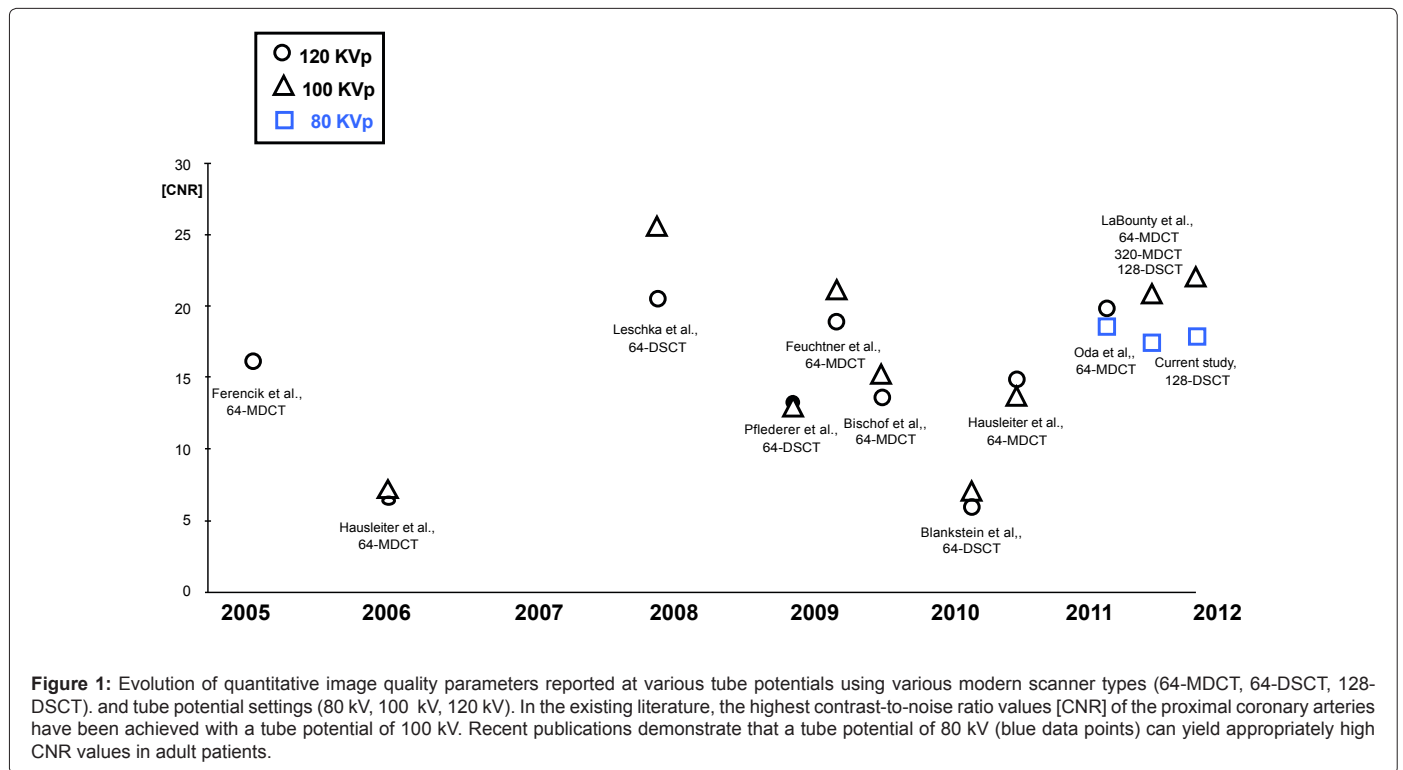
Figure 1: Evolution of quantitative image quality parameters reported at various tube potentials using various modern scanner types (64-MDCT, 64-DSCT, 128-DSCT). and tube potential settings (80 kV, 100 kV, 120 kV). In the existing literature, the highest contrast-to-noise ratio values [CNR] of the proximal coronary arteries have been achieved with a tube potential of 100 kV. Recent publications demonstrate that a tube potential of 80 kV (blue data points) can yield appropriately high CNR values in adult patients.
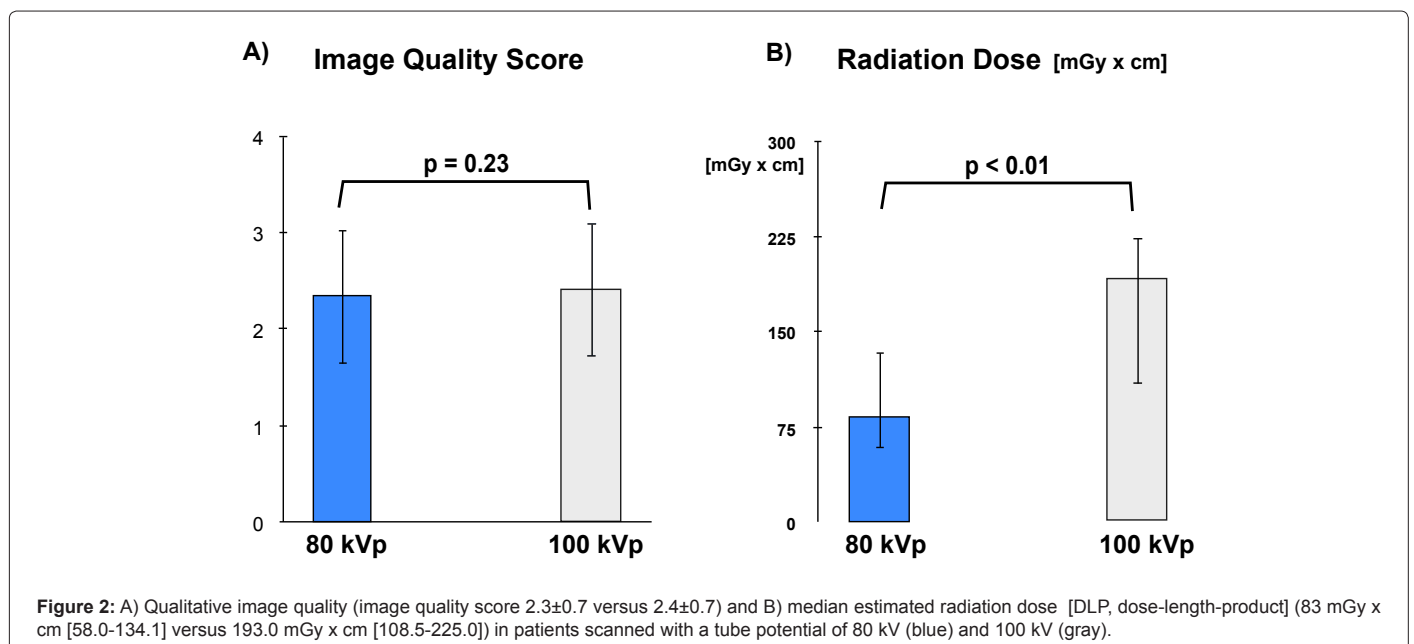

Figure 2: A) Qualitative image quality (image quality score 2.3±0.7 versus 2.4±0.7) and B) median estimated radiation dose [DLP, dose-length-product] (83 mGy x cm [58.0-134.1] versus 193.0 mGy x cm [108.5-225.0]) in patients scanned with a tube potential of 80 kV (blue) and 100 kV (gray).

demonstrated a significant reduction of radiation dose of 57% versus 100 kV protocols (1.2 mSv [0.8-1.9] versus 2.7 mSv [1.5-3.2]). Quantitative measures of quality showed increased noise and decreased CNR in the 80 kV group, but diagnostic image quality was preserved in the 80 kV group.

In recent years, various dose-saving techniques have been introduced to cCTA [6,11,15,23,26,27-32], with the most effective being prospectively ECG-triggered acquisition modes [6,7,28,33,34]. The use of prospective triggering, however, generally requires a low (<

65 beats per minute) and stable heart rate, and is therefore not possible in all patients [34,35].

Extensive work has verified and proven the feasibility of empiric tube potential reduction [10,12-15,17-19,36,37]. Image noise is proportional to 1/(tube potential) [20], and thus a reduced kV carries the downside of an increase in image noise [38,39]. Despite this relation, a decreased radiation dose is usually not achieved at the expense of diagnostic image quality. Quite the contrary, studies published by Feuchtner [10] and Blankstein [15] both demonstrate higher CNR and SNR values at 100
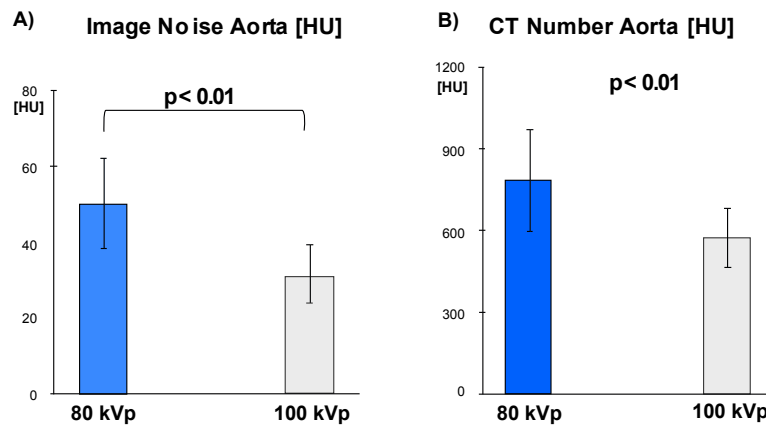
Figure 3: A) Mean image noise (50.1±12.3 HU versus 30.7±6.9 HU) and **B)** mean signal intensity of the aorta (786.6±189.7 HU versus 574.7±112.5 HU) in patients scanned with a tube potential of 80 kV (blue) and 100 kV (gray).
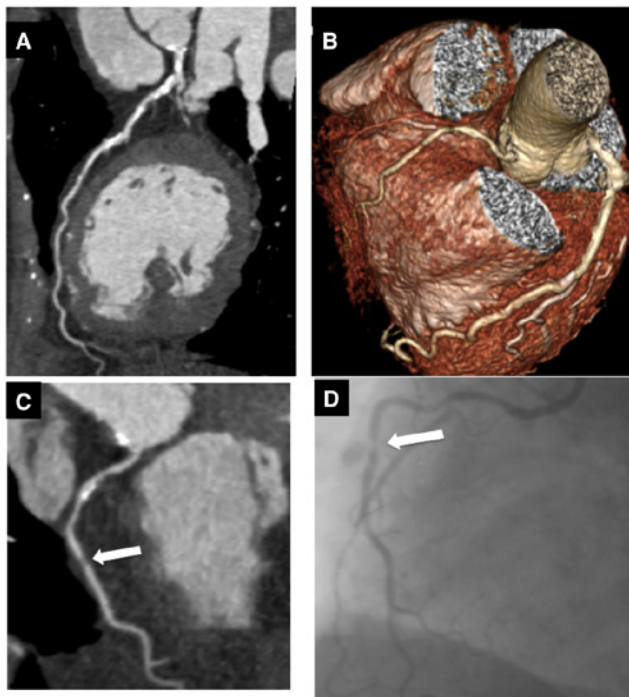
Figure 4: Diagnostic cardiac CT angiography using prospectively ECG-triggered high pitch helical acquisition (pitch = 3.4) in a 64-year-old female patient with chest pain and suspected coronary artery disease (BMI 23 kg/m², chest area 496.7 cm², heart rate 56 beats/minute, sinus rhythm). Tube potential 80 kV, tube current 238 mAs. Contrast-to-noise ratio (left main): 28.2, signal-to-noise ratio (left main): 31.3. Total radiation dose: DLP 41.0 mGy x cm, CTDI$_{vol}$ 8.0 mGy, effective dose 0.6 mSv (using a conversion coefficient of 0.014 mGy x cm²⁴).

(A) Curved multiplanar reconstruction of the left main and the left anterior descending coronary arteries shows the presence of partially calcified plaque but no significant luminal narrowing.
(B) Volume-rendered 3D reconstruction.
(C) Curved multiplanar reconstruction of the right coronary artery. A partially calcified plaque is present in the proximal segment of the artery. Significant luminal narrowing in the mid segment is caused by a non-calcified plaque (white arrow).
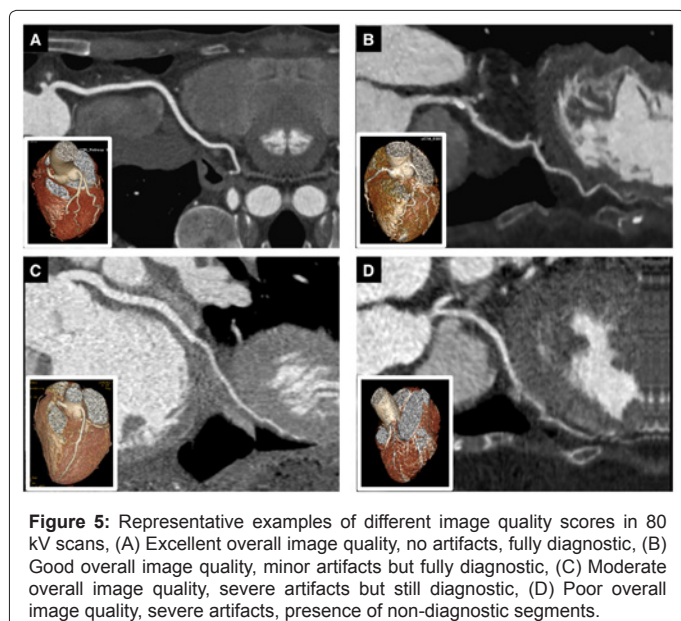 **(D)** Corresponding invasive coronary angiography confirms the presence of significant stenosis in the mid RCA (white arrow). The patient underwent percutaneous coronary intervention with a stent resulting in subsequent relief of symptoms.

kV versus 120 kV settings, when used in selected non-obese patients, thus allowing a substantial dose reduction [10,15]. Similarly, Stolzmann et al. [33] demonstrated a mean radiation dose reduction of 51% with significant improved image quality when comparing a 100 kV protocol with a 120 kV protocol using first generation dual-source CT [12]. In the largest study to date assessing image quality and radiation dose, PROTECTION II, Hausleiter et al. [40] reported a 31% dose reduction at 100 kV with preserved image quality in non-obese patients [11].

A preserved or even increased CNR can be achieved at a lower kV despite increased image noise because of the higher CT numbers measured in materials with higher electron density (i.e. calcium or iodine) due to greater photoelectric effects and decreased Compton scattering [12,41]. However, to maintain a constant noise level at a lower tube potential setting, the tube current-time product (mAs) usually requires an upward adjustment [5,42]. In our study, patients whom underwent the 80 kV exam had a similar tube current compared to the 100 kV control group (234.5 mAs [219.5-279.3] versus 225.5 mAs [167.3-278.8]) which resulted in a significantly higher noise level. This might explain the lower quantitative image quality parameters (i.e. contrast-to-noise and signal-to-noise ratios). Consequently the increase in attenuation of contrast medium at 80 kV may not have outweighed the increase in the image noise and as a result, the use of 80 kV demonstrated significantly lower contrast-to-noise and signal-to-noise values when compared to 100 kV.

Therefore our results confirm the findings of a recently published randomized controlled multicenter study by LaBounty et al. [43]. In overall 205 patients, who were prospectively randomized to either 80 kV or 100 kV using 4 different scanner types, no differences were seen in subjective image quality assessment. Of note, measures for CNR and SNR in the proximal coronary artery in Labounty's study were almost the same compared to the present study. Other measures of quality were also similar despite our higher frequency of retrospective ECG-gated acquisition (27.5% versus 7.0%) due to a higher mean heart rate in this study (61.7 ± 8.2 bpm versus 54.3 ± 6.3 bpm). Additional image quality measurements in this study, including distal and smaller vessel segments, showed better results for the 100 kV protocol except for the first diagonal branch. However this advantage did not translate into a clinically relevant better subjective image quality score.

Our observations regarding quantitative image quality are discordant with the results from Oda et al. [13], who recently published

Figure 5: Representative examples of different image quality scores in 80 kV scans, (A) Excellent overall image quality, no artifacts, fully diagnostic, (B) Good overall image quality, minor artifacts but fully diagnostic, (C) Moderate overall image quality, severe artifacts but still diagnostic, (D) Poor overall image quality, severe artifacts, presence of non-diagnostic segments.

		80 kV	100 kV
Retrospective ECG -gated mode, %	CTDI$_{vol}$ (mGy)	14.5 [8.6-17.9]	21.7 [14.6-23.5]
	DLP (mGy x cm)	116.5 [58.0-134.5]	193.0 [108.5-225.0]
	ED (mSv)	1.6 [0.8-1.9]	2.7 [1.5-3.2]
Prospective ECG-triggered axial mode,	CTDI$_{vol}$ (mGy)	13.5 [11.4-14.9]	17.6 [15.3-22.6]
	DLP (mGy x cm)	86.0 [68.0-116.0]	161.0 [135.0-180.0]
	ED (mSv)	1.2 [1.0-1.6]	2.3 [1.9-2.5]
Prospective ECG-triggered high-pitch helical mode	CTDI$_{vol}$ (mGy)	8.6 [6.6-15.0]	13.7 [11.1-17.3]
	DLP (mGy x cm)	50.5 [40.5-63.0]	94.5 [73.3-159.8]
	ED (mSv)	0.7 [0.6-0.9]	1.3 [1.0-2.2]

Table 4: Radiation dose stratified by acquisition mode.

a direct comparison between 80 kV protocols versus standard 120 kV protocols in adult patients using retrospectively ECG-gated helical acquisition; they demonstrated similar CNR and SNR values for both tube potential settings with a 55% dose reduction with the low-dose 80 kV-protocol [13].

A possible reason for this discrepancy versus our findings might be the fact that generally 100 kV is associated with better CNR and SNR values than a tube potential of 120 kV (Figure 1) [10,12,15,44]. In another study, the use of 80 kV demonstrated similar signal-to-noise ratios compared to both 100 kV and 120 kV [8]. However, the BMI (BMI ≤ 22.5), and presumably the chest area, was smaller than those of our current study perhaps due to differing body habitus in each population.

Despite lower quantitative image quality parameters, a tube potential setting of 80 kV resulted in acceptable CNR and SNR values throughout the coronary tree. To put our findings into perspective, our measured CNR of 17.9 in the proximal RCA was higher than the values reported using both 100 kV and 120 kV in prior studies by Hausleiter et al. [11,40], Bischoff et al. [44] and Pflederer et al. [14] (Figure1).

Of note, the differences regarding CNR and SNR between the two cohorts in our study were smaller in distal vessel branches, and no differences were seen in the first diagonal branch.

In a 64-slice MDCT study published by Abada et al. [45], the use of 80 kV resulted in dose reductions up to 88% without impairment of image quality [45]. However, despite including only 11 small patients (body weight below 60 kg), the reported image noise (64 HU on average) was higher and SNR (11 on average) was lower compared to our results.

To our knowledge, our reported median radiation dose of 84 mGy x cm in the 80 kV group, is among the lowest reported radiation doses in a consecutive (n=40) series of adults undergoing clinically indicated cardiac CTA exams.

Others have shown that in selected patients (BMI ≤ 22.5 and/or a body weight <100 kg and /or a heart rate < 60 beats/min), cardiac CTA is able to achieve even lower doses in the sub-millisievert range, given a consistent use prospective ECG-triggered high-pitch helical acquisition [6-8]. An example of an sub-millisievert scan is seen in (Figure 4).

Although our study highlights the feasibility of 80 kV protocols in adult patients, our analysis has several limitations. First, only a relatively small number of patients were included. Second, not all patients in our study underwent invasive coronary angiography to clarify the diagnostic accuracy for detecting coronary stenosis, an inescapable limitation of retrospective cohort studies. Nevertheless, even if invasive angiography were performed, given the established high accuracy of CTA, the number of patients needed to provide enough power to detect differences in diagnostic accuracy would likely be very large. Third, a tube potential of 80 kV was only used for patients with a BMI ≤ 27.5 kg/m^2. Since cardiac CTA exams of obese patients (BMI ≥ 30 kg/m^2) may result in poorer image quality due to scattering and absorption of photons, we presume that our findings would not be reproducible in obese or overweight patients. Finally, we did not evaluate the limits with respect to chest area or BMI of the 80 kV tube potential setting, nor did we analyze the impact of the factors such as coronary calcium or stents on image quality, factors which are known to complicate cCTA interpretation.

In conclusion, our data demonstrates that in selected non-obese patients, an ultra-low dose protocol using a tube potential of 80 kV is feasible and results in a substantial radiation dose reduction of 57% compared to 100 kV protocols in matched controls. Image quality was found to be diagnostically acceptable in all cases. Further research is needed in order to clarify the diagnostic accuracy for detecting coronary stenosis when using a tube potential of 80 kV, and the upper limits of body size to use 80 kV for maintaining acceptable image quality.

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