



Research paper

A prospective national survey of coronary CT angiography radiation doses in the United Kingdom



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ABSTRACT

Background: Little real-world radiation dose data exist for the majority of cardiovascular CT. Some data have been published for coronary CT angiography (coronary CTA) specifically, but they invariably arise from high-volume centres with access to the most recent technology.

Objective: The aim of this study was to document real-world radiation doses for coronary CTA in the United Kingdom, and to establish their relationship to clinical protocol selection, acquisition heart rate, and scanner technology.

Methods: A dose survey questionnaire was distributed to members of the British Society of Cardiovascular Imaging and other UK cardiac CT units. All participating centres collected data for consecutive coronary CTA cases over one month. The survey captured information about the exam conducted, patient demographics, pre-scan details such as beta-blocker administration, acquisition heart rate and scan technique, and post-scan dose indicators – series volumetric CT dose index (CTDI_{vol}), series dose-length product (DLP), and exam DLP.

Results: Fifty centres provided data on a total of 1341 coronary CTA exams. Twenty-nine centres (58%) performed at least 20 coronary CTA scans in the collection period. The median BMI, acquisition heart rate and exam DLP were 28 kg/m², 60 bpm and 209 mGycm respectively. The corresponding effective dose was estimated as 5.9 mSv using a conversion factor of 0.028 mSv/mGycm. There was no statistically significant difference in radiation dose between low and high-volume centres. Median exam DLP increased with the acquisition heart rate due to the selection of wider temporal windows. The highest exam DLPs were obtained on the older scanner technology.

Conclusion: This study provides baseline data for benchmarking practice, optimizing radiation dose and improving service quality locally.

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Abbreviations: BSCI, British Society of Cardiovascular Imaging; BSCC, British Society of Cardiovascular CT; CTA, CT angiography; CTDI_{vol}, volumetric CT dose index; DLP, dose-length product; NICE, National Institute for Health and Care Excellence; UK, United Kingdom.

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1. Introduction

The demand for cardiovascular CT in the United Kingdom (UK) continues to increase: coronary CT angiography (coronary CTA) was incorporated into National Guidelines in 2010¹ for the assessment of coronary artery disease burden in stable chest pain, and cardiovascular CT is becoming an established technique in the assessment of patients with other forms of cardiovascular disease.^{2–8} Nevertheless concerns remain about the associated radiation dose,⁹ in particular with potentially high-dose techniques

such as retrospective ECG gating.

There is little evidence documenting real-world radiation dose data for the majority of cardiovascular CT; however some data does exist for coronary CTA specifically. The PROTECTION studies^{10–12} report median exam dose-length products (DLP) for coronary CTA of 885 mGycm (interquartile range 568–1259 mGycm) in 2009.¹⁰ Subsequently, advances in technology have led to lower doses with the PROTECTION III study demonstrating DLPs of 252 (\pm 147) mGycm for a standard coronary CTA in 2012.¹²

Whilst the scientific literature suggests that recent technological developments¹³ and the availability of optimisation guidelines^{14,15} for coronary CTA have resulted in significant dose reductions, the data presented may be biased as these data invariably arise from high-volume centres, often with access to the most recent technology. Therefore these results probably do not represent real-world practice or doses. The objective of this pilot observational study was therefore to establish typical radiation doses for coronary CTA practice in the UK, and the relationship of these doses to clinical protocol decisions, including the choice of ECG gating technique and acquisition heart rate, and scanner technology.

2. Methods

2.1. Data capture

Members of the British Society of Cardiovascular Imaging (BSCI), which incorporates the British Society of Cardiovascular CT (BSCCT), were invited to take part in a coronary CTA radiation dose survey. A spreadsheet questionnaire was distributed to approximately 200 members and to other UK cardiac CT centres that expressed an interest in taking part. This approach targeted the majority of cardiac CT departments in the UK. The questionnaire was completed for all coronary CTA exams performed during the month of March 2014. The questionnaire captured the following information:-

- Scanner model.
- Exam details: date and type of examination.
- Patient demographics: year of birth, weight, height and BMI.
- Pre-scan details: use of beta-blockers prior to scan.
- Scan technique selected: acquisition heart rate and type of ECG gating selected, categorised into prospective gating without padding, prospective gating with padding, retrospective gating with constant tube current, or retrospective gating with tube current pulsing.
- Dose parameters: volumetric CT dose index (CTDI_{vol}) and DLP for each scan series performed, and total exam DLP.

2.2. Data analysis: individual centre statistics

Data analysis was firstly carried out on the exam data from each participating centre. Centres were instructed to check their data for integrity and completeness and to delete exams with missing data. Coronary CTA exams were identified and analysis was carried out on these alone. The median, first and third quartile values of beta-blocker usage, BMI, acquisition heart rate and exam DLP were calculated to provide the *centre exam statistics*. Note that, for centres performing a coronary calcium scan, the exam DLP includes the contribution from this series. The coronary CTA exam data were then filtered according to the scan technique chosen. The median, first and third quartile values of the exam DLP were calculated for each scanning technique category to provide the *centre scan technique statistics*. Finally, coronary CTA exams carried out on patients with a BMI between 25 and 31 kg/m² were selected and sub-

divided according to three acquisition heart rate categories: 55 bpm or less, 55–65 bpm and 65 bpm or greater. The median, first and third quartile values of CTDI_{vol} and DLP for each series (coronary calcium scan if performed and coronary CTA scan) and for exam DLP were calculated for each heart rate category to provide the *centre heart rate statistics*. A flow-chart of the statistical analysis carried out for each centre is shown in Fig. 1.

2.3. Data analysis: community statistics

Individual centre statistics were collated and analysed to provide statistical measures of typical practice across the cardiac CT community. Firstly, from the *centre exam statistics* for centres that had submitted 20 coronary CTA exams or more, the median, first and third quartile values of the centre median values of beta-blocker usage, BMI, acquisition heart rate and exam DLP were calculated to provide the *community exam statistics*. The analysis was repeated on the *centre exam statistics* for all the centres in the survey cohort. Secondly, centres with 20 or more exams in one scan technique category were selected from the survey cohort. From the *centre scan technique statistics* for centres in this sub-cohort, the median, first and third quartile values of the centre median exam DLP were calculated for each scan technique to provide the *community scan technique statistics*. Thirdly, centres that had submitted 8 or more exams in one heart rate category for patients with a BMI between 25 and 31 kg/m² were selected from the survey cohort. From the *centre heart rate statistics* for centres in this sub-cohort, the median, first and third quartile values of the centre median series CTDI_{vol}, series DLP (coronary calcium scan if performed and coronary CTA scan) and exam DLP were calculated for each heart rate category to provide the *community heart rate statistics*. Finally, the *centre exam statistics* for centres that had submitted 20 coronary CTA exams or more were analysed against the scanner technology used, specifically that recommended by the National Institute for Health and Care Excellence (NICE) for cardiovascular CT¹⁶ and newer, versus older technology. A flow-chart of the statistical analysis for the cardiac CT community is shown in Fig. 1.

The Student's t-test was used to establish significant differences in the mean values of samples taken from the distribution of the various centre median statistics. Prior to conducting Student t-tests, a normal plot was used to confirm that the data followed a normal distribution. The mean and standard deviation of the various centre median statistics were then calculated.

3. Results

Data on a total of 1341 exams were provided by 50 centres. For comparison, there are 154 acute National Health Service trusts in England and 15 Health Boards in Scotland, although not all provide a cardiovascular CT service. It is therefore likely that at least one third of cardiovascular CT centres contributed to the survey. Four out of 50 centres did not provide weight or BMI but the exam data were otherwise complete; their responses have been retained in the data set.

3.1. Community exam statistics

Twenty-nine centres submitted data for 20 or more coronary CTA exams. The community median (interquartile range) percentage of patients administered beta-blockers, BMI, acquisition heart rate and exam DLP were 69% (59–80%), 28.0 (27.0–28.7) kg/m², 60 (58–62) bpm and 209 (133–318) mGycm respectively for this sub-cohort (Table 1).

Centre median BMI and acquisition heart rate were normally distributed. Mean and standard deviation values are given in

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