

Coronary CT angiography: Is it possible to reduce radiation dose with different techniques and individual approach to each patient?

FRÍÐRIKSDÓTTIR H.Í.¹, MÝRDAL G.² & GUNNARSSON G.P.^{1,3}

¹Akureyri Hospital, Eyrarlandsveggi, IS-600 Akureyri, Iceland

²Landspítali University Hospital, Hringbraut, IS-101 Reykjavik, Iceland

³University of Iceland, Faculty of Medicine, Reykjavik, Iceland

Objective

The objective of our study was to see if radiation dose for coronary CT angiography could be reduced by individual approach to each patient and using prospective gating when possible.

Background

Today, the use of computed tomographic (CT) imaging of the heart is widespread for quantification of coronary artery calcification as an indirect measure of coronary plaque (1, 2). Nowadays, coronary artery disease (CAD) is one of the leading cause of death, accounting for more than 17 million deaths every year (3). Coronary CT angiography can be an accurate test to evaluate coronary artery disease (CAD) but the major drawback is high radiation dose compared to other examinations. It is known that in many centers, patients have access to those examinations without any physician referral (1). The outcome has been higher radiation dose to the public (4, 5). As high radiation doses are associated with CT imaging, this has created concerns for those patients who need to undergo coronary CT (6, 7).

In 2007, the Icelandic Directorate of Health reported increasing number of coronary CT angiography from 2005. Information also indicated the coronary CT seemed to be more widely used in Iceland compared to neighbouring countries (8).

Research has shown that clinics that do not apply thorough and standardized protocols for coronary CT angiography tend to use high radiation exposure levels to minimize image noise and increase image quality. This has led to wide variation in radiation doses to patients, depending on the personnel each time. Despite of higher exposure values it has not always made a difference in the final outcome (4, 9, 10). It might implicate that some members of the health profession who work with coronary CT angiography do not realize how much radiation dose their patients are receiving (11).

In this study, the effective dose (E) was found by the formula $E = k * DLP$. DLP stands for dose length product and the coefficient k is relative to the radiated body part in the CT examination. The coefficient k is recommended from equivalent dose (w_r) from ICRP (**The International Commission on Radiological Protection**: ICRP-26 (1977), ICRP-60 (1991) and ICRP-103 (2007) (12-14). Some variations have been in recommended coefficients

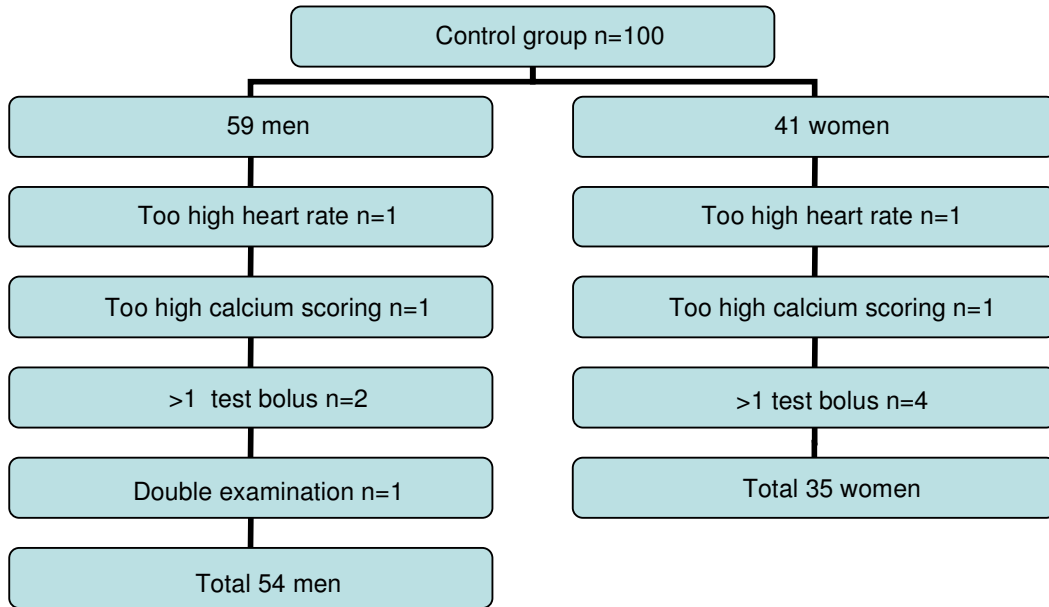
(k-values) which makes it difficult to compare different studies.

In this study, we used the coefficient $k = 0,017$ (4).

Material and methods

All patients in both control and comparison groups underwent coronary CT in Akureyri Hospital, Akureyri, Iceland. A control group of 100 patients (59 men and 41 women) was chosen by random from a total of 276 patients undergoing coronary CT from January 2009-November 2010. Eleven patients were excluded, leaving the total number 89 patients, 54 men (mean age 52,06 years +/- 7,14) and 35 women (mean age 58,17 years +/- 8,25). All the patients in control group were examined using retrospective gating. Table 1 shows the exclusion criteria in the control group.

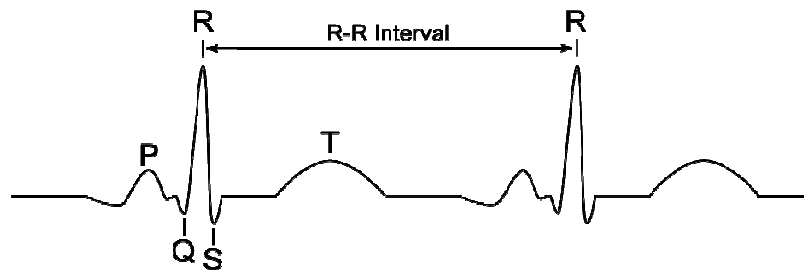
Table 1. Exclusion criteria in the control group.



In February 2011 all protocols for coronary CT at Akureyri Hospital were reviewed in cooperation with Minneapolis Heart Institute. A comparative group of thirty patients was enrolled, 17 men (mean age 51,53 years +/-7,91) and 13 women (mean age 57,23 years +/-6,92) suspected of having coronary artery disease. The patients were divided into two groups: prospective and retrospective. Classification into groups depended on which technique was assumed to suit each individual. Comparison was made on effective dose (E) to patients in addition to gender and range of age between groups.

All examinations were performed using a 128-slice CT system (Siemens Somatom Definition A/S) at Akureyri Hospital.

CTDI was measured in the 128-slice CT-scanner in for controlling the CTDI-values on the operation console screen. TLD measurements in a humanoid phantom were performed for both prospective gated and for retrospective gated examinations of thorax. Both the displayed CTDI values and the TLD-values were compared for both methods of gating.



Picture 1. R-R interval is the time between two R-waves in a single heartbeat. eleceng.dit.ie

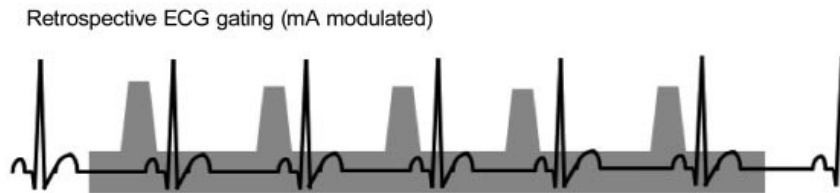
Cardiac cycle and gating

Cardiac cycle refers to all heart activity in a single heartbeat. Each cardiac cycle divides into systole and diastole. In a CT cardiac examination the patient is connected to ECG-controlled dose modulation. Potential difference in the myocardium produces waves on the ECG which interpret the

cardiac cycle. The waves are called P, Q, R, S og T (15). Systole spans from the beginning of Q or R-wave through approximately the middle of T-wave. Diastole covers the middle of T-wave to the next Q or R-wave (16, 17). Picture 1 shows the R-R interval and different heart waves.

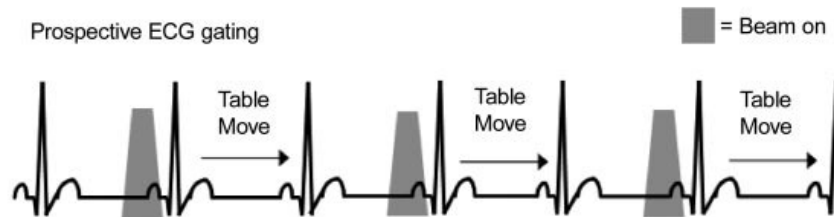
Gating in cardiac CT refers to synchronized heart beat of the patient with the CT scanner so it is possible to control data acquisition in the cardiac cycle. Thus is possible to choose data from the diastolic period of the heart cycle which has the least movement. Gating can reduce radiation dose and can be divided into prospective gating and retrospective gating (18).

In retrospective gating, the x-ray beam is turned on throughout the R-R interval. This requires helical technique and thus the data acquisition becomes continuous. Selected pitch is 0,2-0,5 depending on heart rate and the CT system (single or dual-source) (4). The patient is connected to ECG which is synchronized with the CT system.



Picture 2. Retrospective gating. The x-ray beam is turned on throughout the R-R interval. radiology.rsna.org

In prospective gating the assumed best heart phase is fixed. The patient is connected to ECG which is synchronized with the CT system. In fact, the CT system is monitoring the patient's heartbeat, turning the x-ray beam on at a fixed period of time in the cardiac cycle.



Picture 3. Prospective gating. The x-ray beam is turned on for only a short portion of diastole, and it is turned off during the rest of the R-R interval. radiology.rsna.org

Statistics

The control group was chosen with SPSS program in the University of Akureyri. Microsoft Office Excel 2007 was used in other calculations and descriptive statistics. T-test was used when comparison was made on continuous variables and assumed for equal variance. A p-value <0,05 was considered significant.

Ethics

This study was approved by the institutional ethics committee. Informed consent was obtained from all patients in the comparison group.

Results

Reduction in radiation dose was considerable. Compared to control group the effective dose (E) reduced by:

- 58,4% in the comparative group as a whole
- 69,9% in the comparative group where prospective gating was used
- 38,3% in the comparative group where retrospective gating was used

Table 2 shows radiation doses all of the participants in this study: The control group, comparative group and divided comparative group.

Table 2. Radiation doses in control group and comparison group.

	CTDI _{vol}	DLP	E	p-value
	Mean (range)	Mean (range)	Mean (range)	
Control group (n=89)	65,3 (38,0-97,3)	693,7 (383-1188)	11,8 (6,5-20,2)	
Comparison group (n=30)	27,5 (10,7-58,3)	289,1 (100-659)	4,9 (1,7-11,2)	p<0,0001*
Retrospective (n=11)	38,7 (13,3-51,8)	427,6 (174-659)	7,3 (3,0-11,2)	p<0,0001*
Prospective (n=19)	21,0 (10,7-58,3)	208,9 (100-523)	3,6 (1,7-8,9)	p=0,000174*

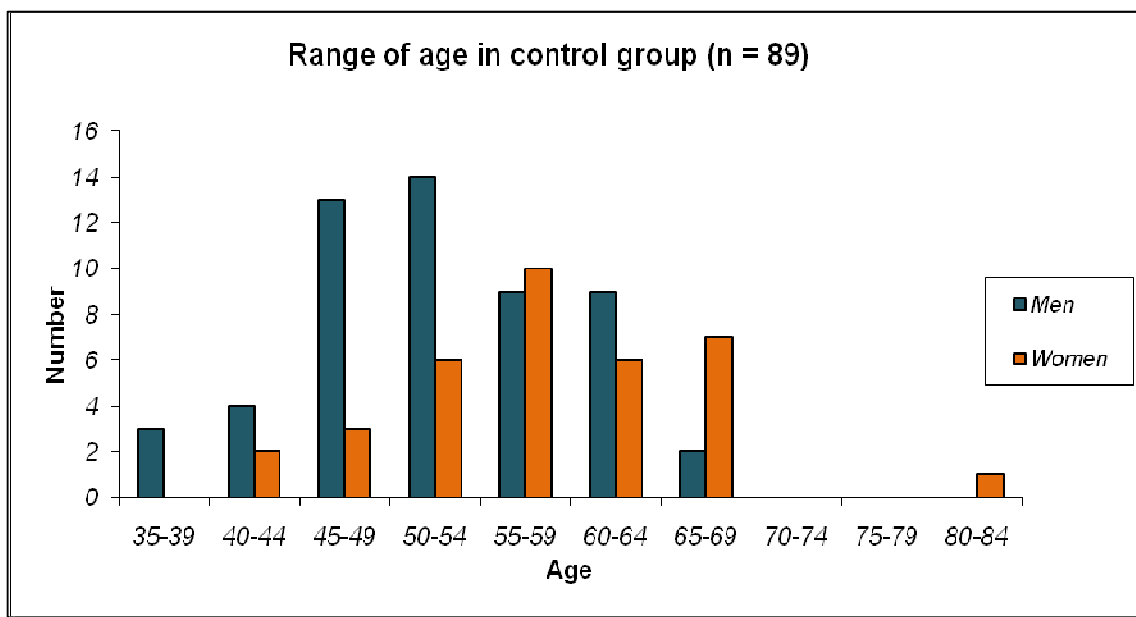
CTDI_{vol} (mGy): Computed Tomography Dose Index

DLP (mGy*cm): Dose Length Product

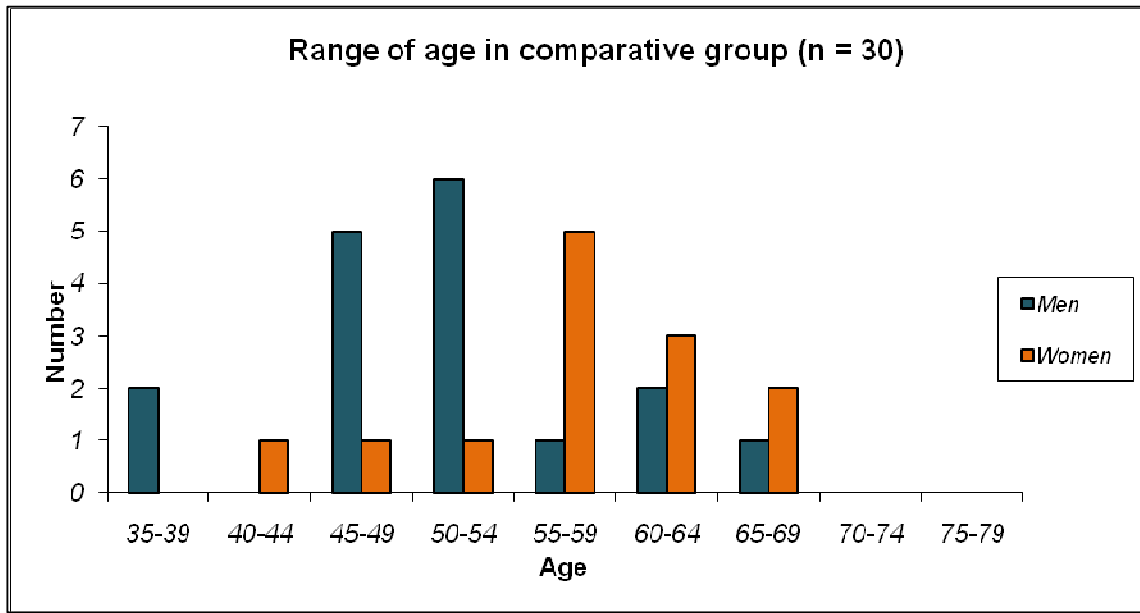
E (mSv): Effective dose

*Compared to control group

Picture 4 and 5 shows range of age for men and women in the control and comparative group, respectively. There was not a significant difference in the mean age for men (p=0,80) or women (p=0,72) between these two groups.



Picture 4. Range of age men and women in control group.



Picture 5. Range of age men and women in comparative group.

No registration about patient's height and weight were made in the control group so it was not possible to compare BMI (body mass index) between control group and comparative group. Table 3 shows BMI and gating technique in comparative group. One male who underwent retrospective gating had notably higher BMI than others (BMI 49,50) and the range went down to (26,64-38,06) when he was excluded. BMI calculations without him were nevertheless significant, that is, $p=0,025$ (all BMI) and $p=0,0028$ (men BMI).

Table 3. Comparative group, BMI and gating technique.

	Retrospective gating	Prospective gating	p-value
All BMI (number/range)	32,8 (11 / 22,0-49,5)	26,9(18 / 20,6-35,5	0,01
Men BMI (number/range)	36,6 (5 / 26,6-49,5)	27,0 (12 / 23,8-31,9)	0,0018
Women BMI (number/range)	29,6 (6 / 22,0-38,4)	26,7 (6 / 20,6-35,5)	0,41

Study limitations

- Few patients in comparison group.
- Not possible to compare BMI between control group and comparative group.
- No assessment was made on image quality. (Gunnar Þór Gunnarsson considered all prospective gating examinations acceptable despite of lower radiation doses).
- This study did not assess the rightness of criteria for CT angiography. Still, that would not have changed patient's radiation doses.

Conclusion

By using individual approach to each patients the radiation dose could be reduced by 38,3%.

Prospective gating causes much less radiation doses than retrospective gating but does not suit all patients. Thorough preparation increases the likelihood that a patient can undergo the prospective method. It is evident that there is great benefit to send patients who fit the criteria for prospective gating in that kind of examination instead of retrospective gating with twice as much radiation dose.

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