IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 18, Issue 5 Ser. 13 (May. 2019), PP 62-71
www.iosrjournals.org

Radiation Exposure. A Serious Concern With cardiovascular imaging (Role of Radiologist Inreducing This Radiation Burden)

Dr Mir SaiqaShafi[1], Dr Sabeeha Gul[2], Dr Naseer Choh[3]
Department(s) and institution(s)
[1]MD (Radiodiagnosis), Department of Radiodiagnosis, Government medical collegeAnantnag , Jammu & Kashmir, 190001, India.
[2]MD (Radiodiagnosis), Department of Radiodiagnosis, JLNM Hospital, Jammu & Kashmir, 190001, India.
[3]MD Associate Professor, Department of Radiodiagnosis,SKIMS, Soura
Gul, MD Radiodiagnosis , Department of Radiodiagnosis,JLNM Hospitalsrinagar, Jammu & Kashmir, 190010, India. R/O:Rawalpora, srinagar, Jammu & Kashmir ,190005,India.
Corresponding Author: Dr. Sabeeha Gul

Abstract
***Background**: Nowadaysamong non communicable diseases Coronary artery disease heads in both in mortality and morbidity.Its early detection and hence cure needs multimodal diagnostic tools CT scan being among the latest modality.The diagnostic value of conventional coronary angiography has been challenged by the emergence & fast growing use of a less invasive imaging technique, multislice computerised tomography (MSCT) angiography to avoid radiation hazard. From time to time ,the manufacturers have implemented strategies to reduce the radiation exposure and these include ECG-gated dose modulation, automated exposure control,lowering the tube voltage,& increasing the pitch value with the use of dual source CT scanners.The non-invasiveness of this technique being highly desirable replacing conventional invasive coronary angiography. Hence reducing risk of radiation exposure hence health care threats.*
***Aim:** The aim of our study was to assess & compare the radiation doses between the prospective & retrospective ECG-gated coronary CT angiography in CAD patients.*
***Methods:** We performed our study ,a prospective comparative study conducted in the Department of Radiodiagnosis & Imaging of a tertiary institute at Srinagar,Kashmir,India after taking due clearance from the Institutional Ethical Committee(IEC).**Inclucluded** Patients were low to intermediate risk for CAD and patients with high risk for CAD but were reluctant for undergoing an invasive procedure.99 patients were enrolled in the study for a total period of two years, underwent contrast-enhanced ECG-gated CT coronary angiography by either of the two methods.*
***Results:** In this study, we compared a new method of coronary CTA based on prospectively gated sequential axial acquisition(PGA CTA) with the retrospectively gated helical acquisition (RGH CTA) as the reference method in a total of 99 patients.We demonstrated an important and significant decrease in radiation dose by PGA CTA with an equivalent image quality and number of assessable segments compared with RGH CTA.*
***Conclusion:** with adequate preparation & careful patient selection, most patients can have a diagnostic CCTA exam with prospective gating &their effective radiation dose & subsequent risk of developing a radiation-induced malignancy can be greatly reduced. . Prospectively-gated acquisition (PGA CTA) has been specifically designed to reduce the of coronary CT angiography by limiting X-ray exposure to a brief predetermined diastole window & eliminating overlapping areas of exposure.*
***Summary**: Lower dose reduces the long-term risk to the patient of developing a radiation-induced malignancy. Consequently, reducing the radiation burden to the lowest level without compromising the diagnostic image quality should be the persistent goal for the radiologist.*
***Key Words:** multislicecomputerised tomography, angiography, radiation dose*

Date of Submission: 10-05-2019 Date of acceptance: 27-05-2019

I. Introduction

The National Research Council's Committee on the Biological Effects of Ionising Radiation recent report (BEIR VII) concluded that a dose of 10mSv would cause an average of 1 in 1,000 lifetime cancers(1).Lower dose reduces the long-term risk to the patient of developinga radiation-induced malignancy(2,3). Consequently,. In CAD diagnostic, the value of conventional coronary angiography has been challenged by the emergence & fast growing use of a less invasive imaging technique, multislicecomputerised tomography (MSCT) angiography,(4,5)the non-invasiveness of this technique being highly desirable.

Despite these facts, still the major limitation in the widespread use of CCTA remains the high radiation exposure. Effective doses for a conventional coronary angiogram range from 5-12mSv,(6,7) whereas effective doses for a standard retrospectively gated helical CCTA(RGH CTA) range from 12- 28 mSv.(8,9)From time to time ,the manufacturers have implemented strategies to reduce the radiation exposure and these include ECG-gated dose modulation, automated exposure control,lowering the tube voltage,& increasing the pitch value with the use of dual source CT scanners.Prospectively-gated acquisition (PGA CTA) has been specifically designed to reduce the radiation dose of coronary CT angiography by limiting X-ray exposure to a brief predetermined diastole window & eliminating overlapping areas of exposure. With retrospective ECG-gating as the standard protocol , raw data are acquired using the spiral/helical mode at a very low pitch. At the same time, the patient's ECG is recorded. Using the ECG tracing, images are reconstructed to create image stacks at any desired phase of the cardiac cycle. On the other hand, prospectively- triggered cardiac CT uses a step-and-shoot data acquisition in which a series of transverse images are acquired while the patient is stationary,& the patient translates to the next position while the X-ray beam is off. With prospective ECG-triggering, a signal is derived from the R-wave of the patient's ECG . Using this trigger, scanning is performed over a finite portion of the R-R interval, usually in diastole, during the period of least cardiac motion. Thus, prospective-gated acquisition (PGA) protocol by using the ‘ step and shoot technique ’ or the sequential technique avoids the extraneous radiation dose by completely turning off the X-ray beam during most of the cardiac cycle. Prospectively-triggered technique for cardiac CT has been adapted for use on several current CT scanners ,including the 64- & 320-row MDCT,& on the dual-source CT.(10,11)

A number of studies have already established that while the PGA protocol results in reduced effective doses to the patient by as much as 80% ,the image quality and the assessment of the luminal size are similar between the two in patients with a heart rate of <70bpm. Mean patient radiation dose from the actual examination z-axis length for prospective gating is 6.2±2.0(range ,2.3-11.9); for retrospective gating this dose was 26.7mSv ±6.1(range ,17-43.8mSv).(12)Prospective ECG-triggering has been confirmed to be one of the most efficient techniques for radiation dose reduction in cardiac CT angiography.(13) Consequently, reducing the radiation burden to the lowest level without compromising the diagnostic image quality should be the persistent goal for the radiologist.To conclude, with adequate preparation & careful patient selection, most patients can have a diagnostic CCTA exam with prospective gating & their effective radiation dose ,& subsequent risk of developing a radiation-induced malignancy can be greatly reduced. .(14)

II. Methods

This study was a prospective comparative study conducted in the Department of Radiodiagnosis & Imaging at a tertiary institute of Srinagar,Kashmir,India after taking due clearance from the Institutional Ethical Committee(IEC).

Subjects: Inclusion criteria: Patients with a low to intermediate risk for CAD (as assessed by the referring clinician on the basis of clinical/lab findings) and patients with high risk for CAD but were reluctant for undergoing an invasive procedure like conventional coronary angiography were included in the study.99 patients were enrolled in the study for a total period of two years. After proper clinical evaluation and work-up as per set proforma, all patients underwent contrast-enhanced ECG-gated CT coronary angiography by either of the two methods(Group 1:n=66, retrospective ECG-gating; Group 2:n=33,prospective ECG-triggering).

Exclusion criteria

1)-pregnancy,
2)-contrast allergy,
3)-CKD patients,
4)-patients with severe arrhythmias,
5)-Inability to follow instructions , lay supine & motion-less,
6)-observed heart rate fluctuation of >10bpm during observation at the scanner prior to the performance of coronary CT angiographic sequence ,
7)-patients with uncontrolled tachycardia,
8)-post-operative state of valve replacement,
9)-high coronary calcium scores (CAC score> 600).

EXAMINATION TECHNIQUES & IMAGING PROTOCOLS:

All coronary CTA examinations were conducted on a 64-slice Cardiac CT scanner (Somatom Sensation 64 Cardiac,Siemens Medical Systems, Forchheim,Germany). Premedication with an oral β-blocker was used to lower the heart rate in those patients with a baseline heart rate of >75bpm, 30-60 minutes prior to the scan with an additional dose of intravenous β-blocker (metaprolol) in an attempt to achieve a target heart rate of ≤70bpm.None of these patients had any contra-indication for β-blocker. Prior to scanning, a technologist instructed all patients regarding breath hold. The scanning direction was craniocaudal& extended from the level of carina to diaphragm . The scanning sequence included obtaining the scout scannogram followed by CAC scoring sequence and contrast enhanced angiography.For CAC scoring, prospectively triggered imaging was used with a tube voltage & an effective tube current of 120 kVp& 200 mAs, respectively.The calcium score was generated in Agatston units using SYNGO software(Siemens Medical Systems, Forcheim ,Germany).Coronary calcification was categorized into following groups: no/minimal coronary calcium(0-10),low calcium(11-99),moderate calcium(100-299) & elevated calcium (≥300) for a patient-based analysis.For contrast angiography,low-osmolar iodinated contrast agent (viz,Iopamidol, Iohexol, Iopamiro) was administered via a dedicated pressure injector(Mallinckrodt Puritan Bennett injector) at a rate of 4.5-5.5ml/sec, followed by a 25 ml of saline bolus chase injected at the same rate. Retrospective CT angiography was performed with the following parameters:helical scanning direction,a fixed pitch of 0.2,use of dose modulation (peak tube current of 650mA during 40-80% of the R-R interval & minimal tube current of 300mA during the rest of the scan),64x0.625mm collimation,330 ms gantry rotation time,120-140 kVp tube voltage. Prospective CT angiography data was acquired with a 40mm axial scan(64x0.625mm) when the table was stationary. Thereafter, the table was moved 35mm, thereby allowing a 5mm overlap for next examination (Step and shoot axial scanning direction). Scan beam-on time was centered at 65-75% of the R-R interval, with a constant tube current of 650mA with tube voltage of 120-140 kVp. The images were reconstructed with a section thickness of 0.625mm or 0.75mm & a reconstruction section interval of 0.4mm or 5mm respectively, with the use of a small or medium sized cardiac field of view. . Reconstructions were individually optimised to minimise the coronary artery motion artefact& then transferred to a work station (Leonardo Siemens Medical Solutions) for further analysis. Post-processing of data was performed using Circulation,3D-post processing & In-Space softwares.

Statistical Analysis.

Statistical analysis was performed using SPSS software (version 20.0). Comparison of the patient data between the two groups was performed by using a t-test for continuous covariates ,such as age, and by using a Chi-square test for categorical data

III. Results

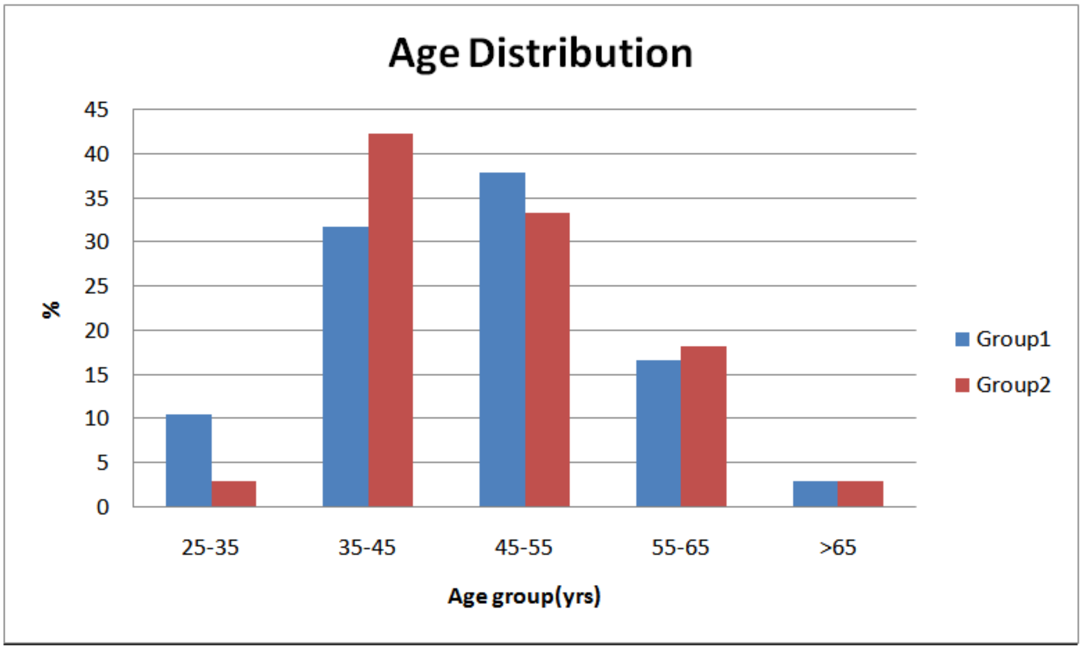

Figure 1

Table 1 summarises the age distribution of the two patient groups

Study Group	Age group (years)					Total
	25-35	35-45	45-55	55-65	> 65	
Group 1	7(10.6)	21(31.8)	25(37.9)	11(16.7)	2(3.0)	66(100)
Group 2	1(3.0)	14(42.4)	11(33.3)	6(18.2)	1(3.0)	33(100)
Total	8(8.1)	35(35.4)	36(36.4)	17(17.2)	3(3.0)	99(100)

(Data in parentheses are percentages)Chi-square:2.417;p-value:0.660

There was no statistically significant difference in the age distribution between the two study groups table and fig 1.No significant difference in the mean age of patient population between the two study groups(p-value:0.56)

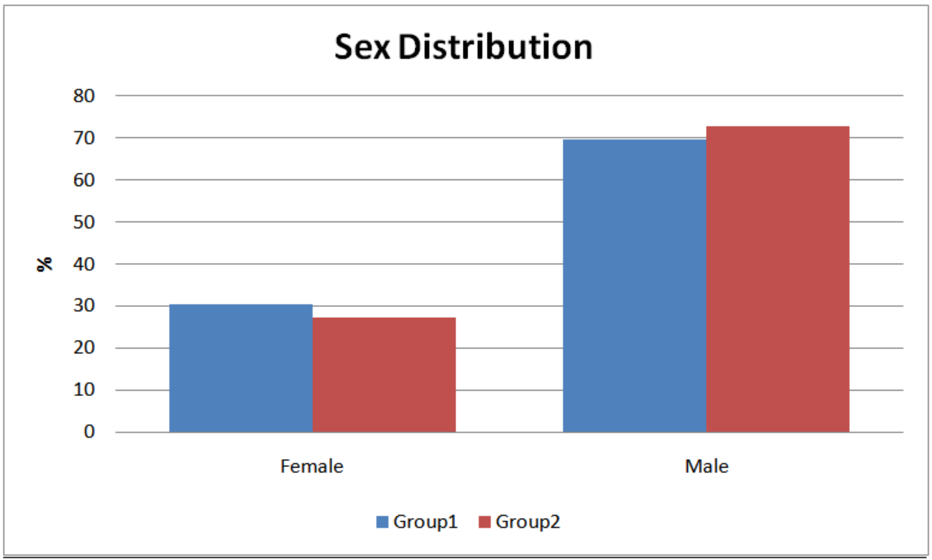

Figure 2

Table 2: Sex Distribution of the Patient Population

Study Group	Sex		Total
	Female	Male	
Group 1	20(30.3)	46(69.7)	66(100)
Group 2	9(27.3)	24(72.7)	33(100)
Total	29(29.3)	70(70.7)	99(100)

(Data in parentheses are percentages)Chi-square: 0.098, p-value: 0.755

There was no statistically significant difference in the sex distribution between the two study groups, with majority of patients belonging to the male group table/fig.2

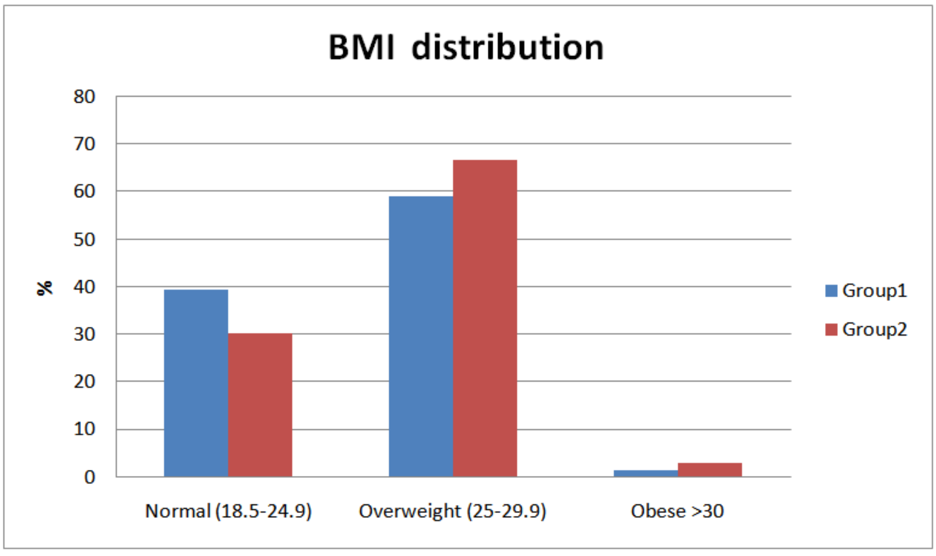

Fig. 3

Table 3: BMI of the Patient Population

Study Group	BMI (kg/m²)			Total
	Normal (18.5-24.9)	Overweight (25-29.9)	Obese (>30)	
Group 1	26(39.4)	39(59.1)	1 (1.5)	66(100)
Group 2	10(30.3)	22(66.7)	1 (3.0)	33(100)
Total	36(36.4)	61(61.6)	2 (2.0)	99(100)

Data in parentheses are percentages) Chi-square: 0.955, p-value: 0.620

Mean BMI of Group 1 patients was 25.78±2.15kg/m^2 & for Group 2 patients ,it was 26.35±1.87kg/m^2.On statistical analysis, there was no significant difference in the mean BMI between the two study groups(p-value:0.20) table/fig. 3.

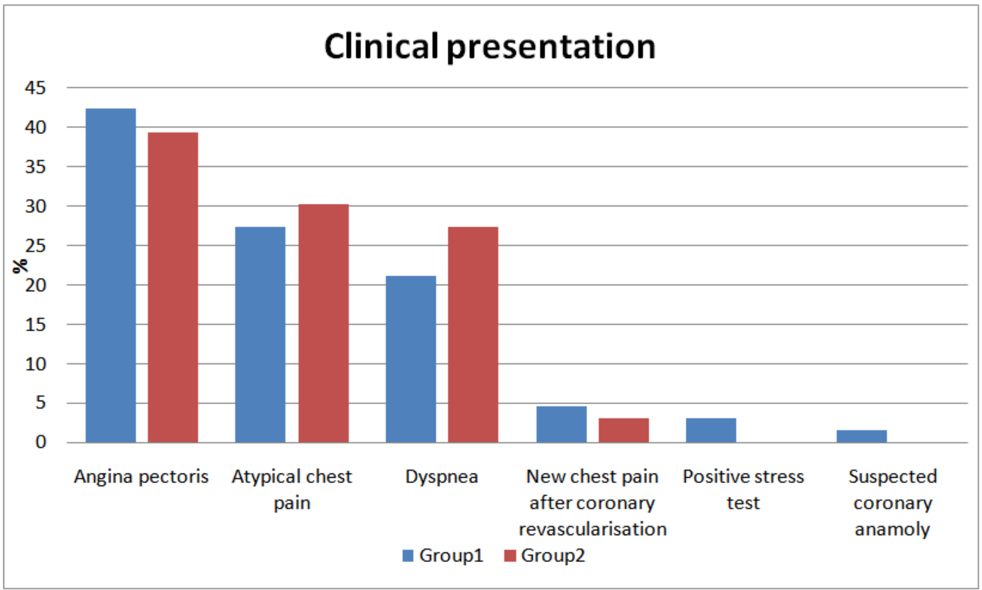

Figure 4

Table 4: Clinical Indication for Coronary CT Angiography

Clinical Indication	Group 1 (n=66)	Group 2 (n=33)
Angina pectoris	28 (42.4)	13 (39.4)
Atypical chest pain	18 (27.3)	10 (30.3)
Dyspnea	14 (21.2)	9 (27.3)
New chest pain after coronary revascularisation	3 (4.5)	1 (3.0)
Positive stress test	2 (3.0)	0
Suspected coronary anamoly	1 (1.5)	0

(Data in parentheses are percentages)Chi-square: 2.09.p-value:0.835

Table5 : Risk Stratification in the Patient Population

Study Group	Framingham Risk Groups			Total
	High	Intermediate	Low	
Group 1	5(7.6)	40(60.6)	21(31.8)	66(100)
Group 2	2(6.1)	21(63.6)	10(30.3)	33(100)
Total	7(7.1)	61(61.6)	31(31.3)	99(100)

(Data in parentheses are percentages)
Chi-square :0.120,p-value: 0.942

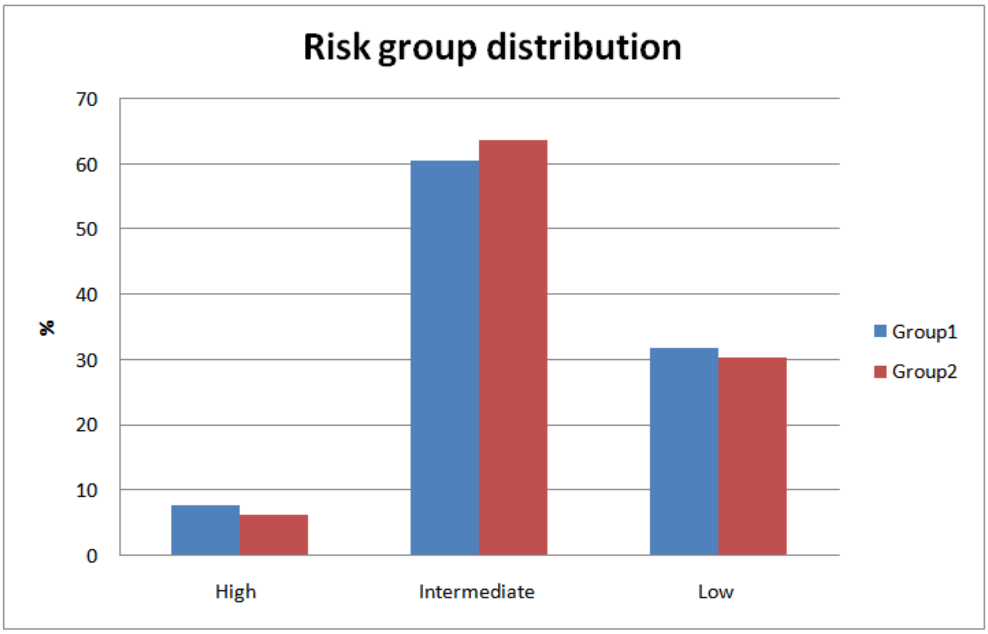

Figure 5

There was no statistically significant difference in risk statification between the two study groups, table /fig. 5.

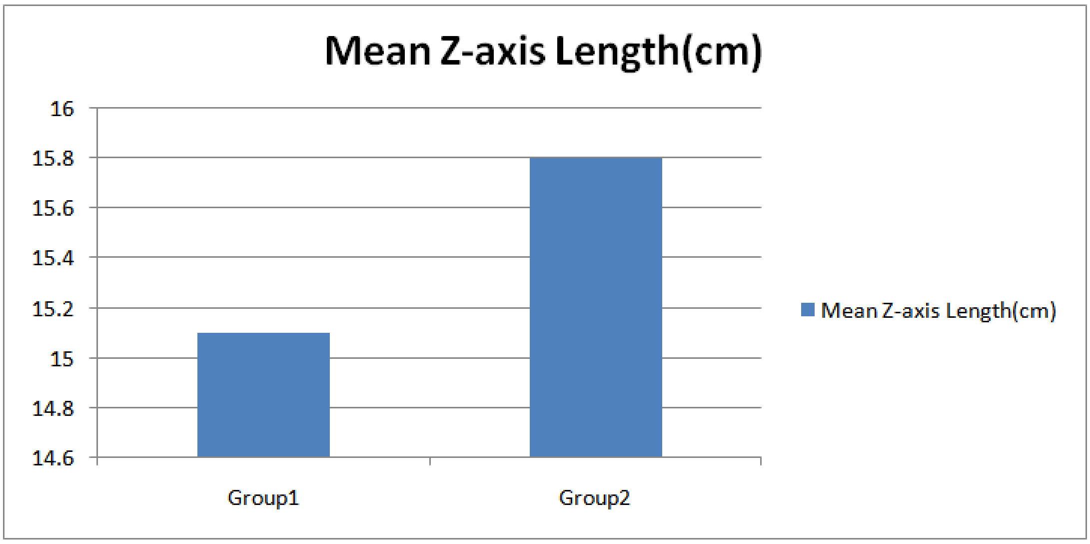

Figure 6

Table 6: Actual Z-axis(scan)length.

Study Group	N	Mean Z-axis Length(cm)	Std. Deviation
Group 1	66	15.10	2.45
Group 2	33	15.80	3.17

Independent t-test;p-value:0.230

There was no statistically significant difference in Mean Z-axis Length(cm) between the two study groups, table /fig. 6.

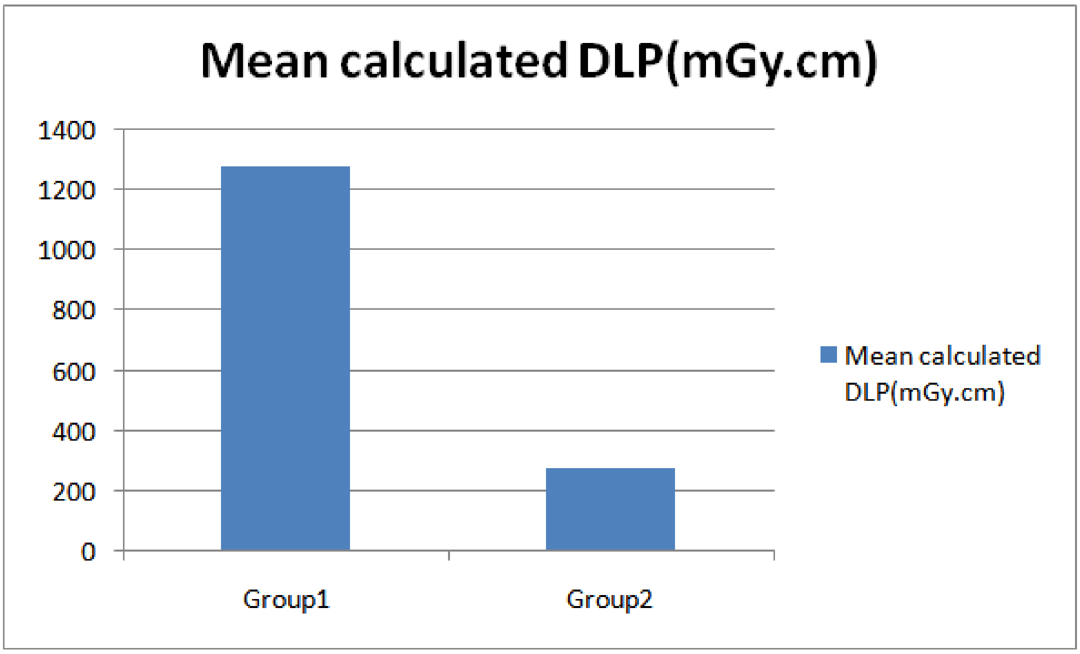

Figure 7

Table 7: Calculated DLP (dose-length product).

Study Group	N	Mean calculated DLP(mGy.cm)	Std.Deviation
Group 1	66	1280.39	208.90
Group 2	33	278.18	65.18

Independent t-test; p-value:≤0.0001(highly significant) The mean calculated dose length product (DLP) as displayed on the CT unit was 1280.39±208.90 mGy.cm for study Group 1 & 278.18±65.18 mGy.cm for Group 2.There was a highly significant difference in the mean calculated DLP between the two patients groups. However, the actual Z-axis (scan) length was comparable between the two groups as in table /fig 7.

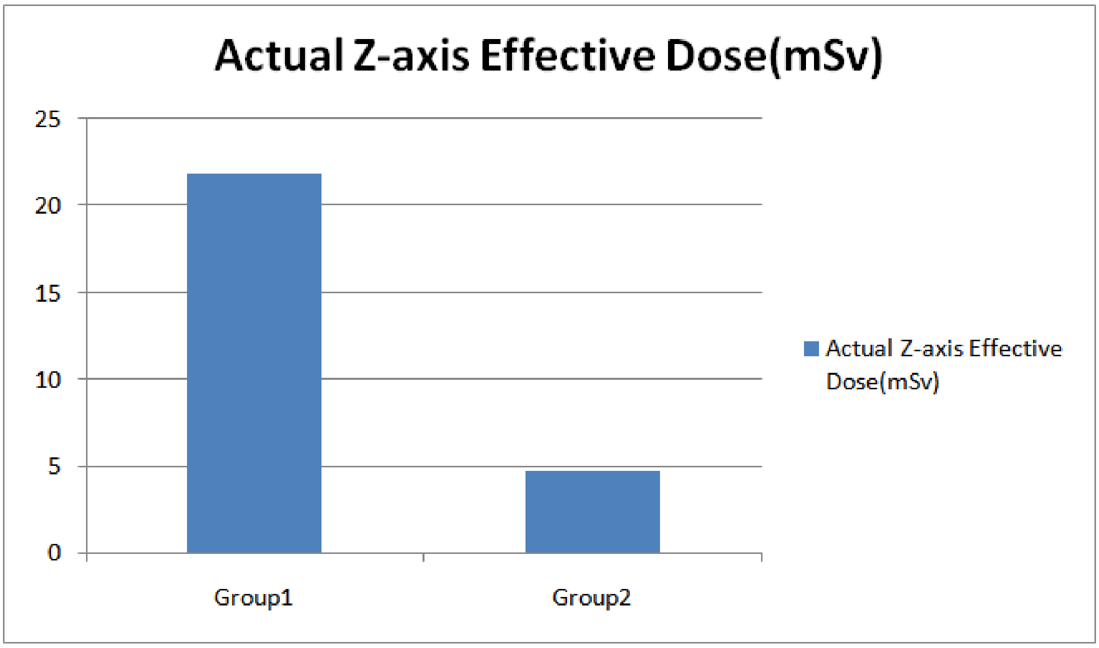

Figure 8

Table 8: Actual Z-axis Effective Dose(mSv).

Study Group	N	Actual Z-axis Effective Dose(mSv)	Std. Deviation
Group 1	66	21.84	3.51
Group 2	33	4.73	1.11

Independent t-test;p-value:≤0.0001(highly significant) Table /fig. 8summarises the mean actual Z-axis effective dose(mSv) of the two patient groups.The actual Z-axis effective dose was 21.84±3.51 mSv for study Group 1 & 4.73±1.11 mSv for Group 2.There was a statistically significant difference in the actual z-axis effective doses between the two study groups with the study Group 1 receiving far more radiation dose when compared to the Group 2.

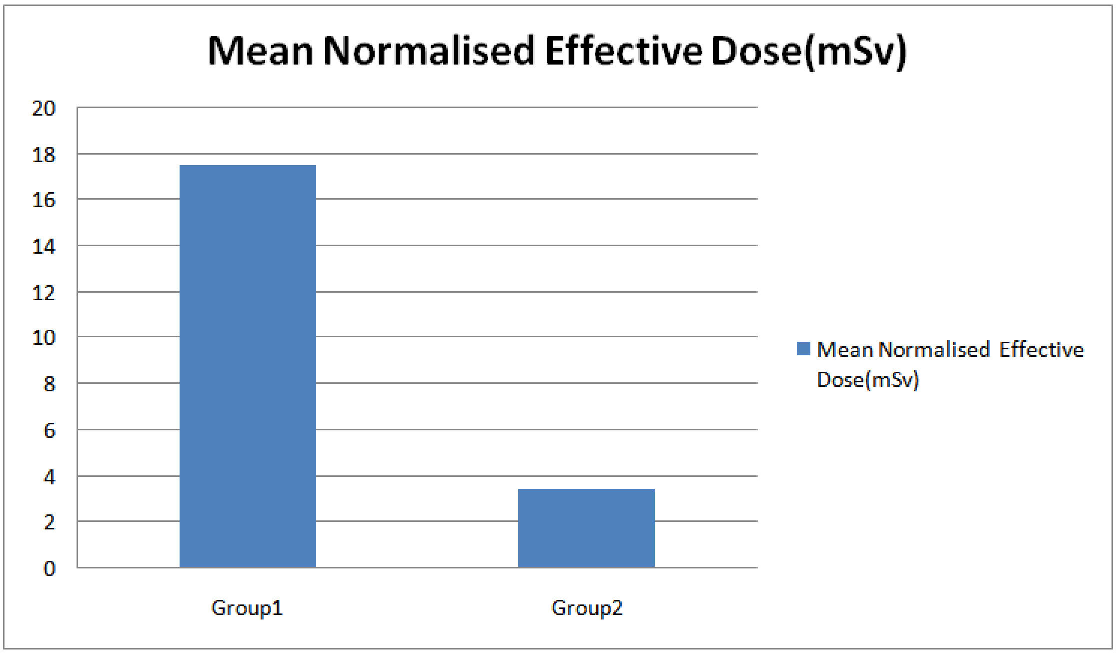

Figure 9

Table 9: Normalised Z-axis Effective Dose(12 cm scan length)

Study Group	N	Mean Normalised Effective Dose(mSv)	Std. Deviation
Group 1	66	17.50	2.17
Group 2	33	3.47	0.63

Independent t-test;p-value:≤0.0001 Table /fig. 9summarises the mean normalized Z-axis effective dose in the two study groups.Thenormalised z-axis effective dose was 17.50±2.17mSv for Group 1 & 3.47±0.63 for Group 2.There was a statistically significant difference in the normalised Z-axis effective dose between the two groups.Thenormalised Z-axis effect axis effective dose in group 1 patients was far higher than that in group 2 patients.

IV. Discussion

Despite its diagnostic advantages, the high effective dose [2,3,15]& potential adverse consequences of coronary CT angiography[5] are a cause for concern & have limited the general applicability of this test. Thus, the radiation exposure associated with MSCT angiography is considered the Achilles' heel of this technology. Prospective ECG-triggering has been confirmed to be one of the most efficient techniques for radiation reduction in cardiac CT angiography.[26]The use of prospective ECG-triggering with 64-slice or dual-source CT has been reported to reduce the effective radiation dose by upto 90% when compared to the retrospective ECG-gated technique, with diagnostic image quality being achieved in more than 90% of the cases.[6,7,8,16,26]

In this study, we compared a new method of coronary CTA based on prospectively gated sequential axial acquisition(PGA CTA) with the retrospectively gated helical acquisition (RGH CTA) as the reference method in a total of 99 patients.We demonstrated an important and significant decrease in radiation dose by

PGA CTA with an equivalent image quality and number of assessable segments compared with RGH CTA.

Radiation Dose:_MDCT is usually performed in a helical mode with overlapping pitch that enables adaptive multicycle reconstruction with resultant high temporal resolution.However, this overlapping pitch results in redundant exposure of chest tissue.Reported radiation doses with the conventional RGH CTA have ranged from 11 to 27 mSv[17,18],which is two to four times the radiation exposure of a typical diagnostic invasive angiography.[19,20]The optimisation of the radiation dose has become a major issue since MDCT scanners were introduced.[21,22]The use of reduced tube voltage has been shown to significantly reduce the effective radiation dose,but it is appropriate only in those patients with a small body habitus.Although the continuous table movement of RGH scans requires X-ray exposure during the entire R-R interval,the most useful interval of the cycle for evaluating the coronary artery is the quiescent ,mid-diastolic phase in patients with a low heart rate.The PGA protocol we evaluated in this study consists of delivering radiation to the patient only during the mid-diastolic phase.[23,24,25]This technique results in a significant decrease in the radiation dose(4.7± 0.8mSv),achieving values close to those observed in invasive angiography(2-5mSv)[19,20] and significantly lower than helical MDCT angiography values(15.1±1.9mSv).

The radiation dose in our study was assessed in terms of DLP (dose-length product), actual Z-axis effective dose &normalised 12-cm Z-axis effective dose. The mean calculated DLP was 1280.39±208.90 mGy.cm in Group 1(RHG CTA) & 278.18±65.18mGy.cm in Group 2 (PGA CTA)patients. There was a highly significant difference in the dose-length products between the two study groups (p-value ≤0.0001) .Our results were consistent with those of Hirai et al[26] who found a significant difference in the dose-length products for retrospective CT angiography (1175 ± 205 mGy.cm) & prospective CT angiography (240±105mGy.cm) [p-value<0.001]. The variations in the calculated DLP for respective patient groups between their study & ours could be attributed to different scanner settings or variations in the scan length. In a recent systematic review of coronary CT angiography with the use of prospective ECG-triggering versus retrospective gating, by Sun Z et al,[27] the variability in the DLP was striking between different study sites. The DLP ranged from 129 to 337 mGy.cm for prospective ECG-gated axial coronary CT angiography. Median DLP at highest dose sites was more than 3 times than at the lowest dose sites.

Mean actual Z-axis effective dose was 21.84±3.51 mSv for Group 1 & 4.73±1.11 mSv for Group 2 & this difference was statistically significant (p-value ≤ 0.0001).Our results were consistent with those of Shumann et al[12] who obtained an actual Z-axis effective dose of 6.2mSv±2.0 for prospective gating & 26.7mSv±6.1 for retrospective gating (p-value<0.01)].The difference in the mean actual Z-axis effective dose for respective study groups between their study & ours was likely related to the greater mean scan length for both retrospective & prospective groups in their study compared to ours(18.0±4.9 cm & 17.9±3.7cm versus 15.10±2.45cm & 15.80±3.17cm respectively).

The mean normalized Z-axis effective dose was 17.50±2.17mSv for RGH CTA& 3.47±0.63 mSv for PGA CTA in our study group..There was a statistically significant reduction in the normalized Z-axis effective dose in Group2 patients with respect to Group 1.Our results were consistent with those of Shumann et al[15] who observed a 12cm normalized Z-axis effective doses(18.1 mSv ±3.0) for retrospective CT angiography & (4.2 mSv ±1.5) for prospective CT angiography [p-value<0.01].Similarly, Earls et al[23] observed a mean effective dose of 2.8 mSv for a 12.8cm length and a 12 cm normalised dose of 2.6mSv.Husmann et al[28] and Scheffel al[29] reported mean effective doses of 2.1mSv and 2.5 mSv for scan lengths of 13.0 & 14.1cm,respectively by PGA.Corresponding 12-cm normalised doses result in effective doses of 1.9 & 2.1 mSvrespectively.Hirai et al[24] obtained a mean effective dose of 4.1 mSv for the PGA protocol but no information was provided about the Z-axis length.Most recently, Maruyama et al [30] reported mean effective doses of 4.3mSv for PGA acquisition and 21.1 mSv for RGH.

There was an 80% reduction in the radiation dose in PGA CTA compared to the RGH CTA in our study . Our results compared favourably with those of Shumann et al[18] and Hirai N et al[24]& who reported a radiation dose reduction of 77% & 79% respectively in prospective CT angiography with respect to retrospective CT angiography, performed on 64-slice CT scanner. Oliver Klass et al[31] reported radiation dose savings of > 80% using prospective gating compared to retrospective gating. The higher degree of dose reduction in their study could be attributed to the lack of ECG-based tube current modulation with retrospective gating .

Conflict of Interests: The authors declare that there is no conflict of interests regarding publication of this paper.

References

[1]. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation; Nuclear and Radiation Studies Board ,Division on Earth and Life Studies, National Research Council of the National Academies.Health risks from exposure to low levels of ionizing radiation: BEIR VII phase 2. Washington:The National Academies Press,2006.

[2]. Einstein AJ, Henzlova MJ, Rajagopalan S. Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography.JAMA 2007;298:317-323.

[3]. Brenner DJ, Hall EJ. Computed tomography- an increasing source of radiation exposure. N Engl J M 2007;357:2277-2284.

[4]. McCollough CH, Zink FE. Performance evaluation of a multi-slice CT system .Med Phys 1999;26:2223-2230.

[5]. Achenbach S, Giesler T, Ropers D, Ulzheimer S, Derlien H, Schulte C, Wenkel F, Moshage W, Bautz W, Daniel WG, Kalender WA, Baum U. Detection of coronary artery stenosis by contrast-enhanced ,retrospectively electrocardiographically-gated,multi-slice spiral computed tomography. Circulation 2001;103:2535-2538.
[6]. KatritsisD,Efstathopoulos E, Betsou S, et al . Radiation exposure of patients and coronary arteries in the stent era: a prospective study. Catheter CardiovascInterv 2000 Nov; 51 (3):259–264
[7]. Watson LE, Riggs MW, Bourland PD .Radiation exposure during cardiology fellowship training. Health Phys 1997;73(4):690–693
[8]. TraboldT ,Buchgeister M, KuttnerA,et al . Estimation of radiation exposure in 16-detector row computed tomography of the heart with retrospective ECG-gating. Rofo 2003 Aug;175 (8):1051–1055
[9]. Mori S, Nishizawa K, Kondo C et al. Effective doses in subjects undergoing computed tomography cardiac imaging with the 256-multislice CT scanner. Eur J Radiol. 2008 Mar;65(3):442–448.
[10]. McColloughCH,SchuelerBA.Calculation of effective dose.Med Phys.2000 May;27(5):828-837.
[11]. NiemanK,OudkerkM,RensingBJ,et al Coronary angiography with multi-slice computed tomography.Lancet.2001;1357(9256):599-603.
[12]. Shuman WP,BranchKR,May JM, et al.Prospective versus retrospective ECG gating for 64-detector CT of the coronary arteries:comparison of image quality and patient radiation dose.Radiology .2008;248(2):431-437. doi: 10.1148/ radiol.2482072192.
[13]. Schoenhagen P. Back to the future: coronary CT angiography using prospective ECG triggering. Eur Heart J 2008; 29:153-4
[14]. EarlsJP,BermanEL,Urban BA ,et al.Prospectively gated transverse coronary CT angiography versus retrospectively gated helical technique:improved image quality and reduced radiation dose.Radiology 2006;246:742- 753. doi: 10.1148/ radiol.2463070989.
[15]. Shuman WP,BranchKR,May JM, et al.Prospective versus retrospective ECG gating for 64-detector CT of the coronary arteries:comparison of image quality and patient radiation dose.Radiology .2008;248(2):431-437. doi: 10.1148/ radiol.2482072192.
[16]. Van derZaag-Loonen HJ, Dikkers R, de Bock GH, Oudkerk M .The clinical value of a negative MDCT angiography in patients suspected of coronary artery disease; A meta-analysis .EurRadiol. 2006;May 23[E pub ahead of print].
[17]. Mollet NR, Cademartiri F, van Mieghem CA, RunzaG,McFadden EP, Baks T, et al. High-resolution spiral computed tomography coronary angiography in patients referred for diagnostic conventional coronary angiography.Circulation 2005;112:2318–23.
[18]. Shuman WP, Branch KR, May JM, Mitsumori LM, Lockhart DW, Dubinsky TJ, et al. Prospective versus retrospective ECG gating for 64-detector CT of the coronary arteries:comparison of image quality and patient radiation dose.Radiology 2008;248:431–7.
[19]. Betsou S, Efstathopoulos EP, Katritsis D, Faulkner K,Panayiotakis G. Patient radiation doses during cardiac catheterization procedures. Br J Radiol 1998;71:634–9.
[20]. Hunold P, Vogt FM, Schmermund A, Debatin JF, KerkhoffG, Budde T, et al. Radiation exposure during cardiac CT:effective doses at multi-detector row CT and electron-beam CT. Radiology 2003;226:145–52.
[21]. Einstein AJ, Henzlova MJ, Rajagopalan S. Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography. J Am Med Assoc 2007;298:317–23.
[22]. Hurwitz LM, Reiman RE, YoshizTT, Goodman PC,Toncheva G, Nguyen G, et al. Radiation dose from contemporary cardiothoracic multidetector CT protocols with an anthropomorphic female phantom: implications for cancer induction. Radiology 2007;245:742–50.
[23]. Earls JP, Berman EL, Urban BA, Curry CA, Lane JL,Jennings RS, et al. Prospectively gated transverse coronaryCT angiography versus retrospectively gated helical technique:improved image quality and reduced radiation dose.Radiology 2008;246:742–53.
[24]. Hirai N, Horiguchi J, Fujioka C, Kiguchi M, Yamamoto H,Matsuura N, et al. Prospective versus retrospective ECG gated 64-detector coronary CT angiography: assessment of image quality, stenosis, and radiation dose. Radiology 2008;248:424–30.
[25]. Hsieh J, Londt J, Vass M, Li J, Tang X, Okerlund D. Step-and-shoot data acquisition and reconstruction for cardiac x-ray computed tomography. Med Phys 2006;33:4236–48.
[26]. Hirai N,HoriguchiJ,Fujioka C, et al.Prospective versus retrospective ECG-gated 64-detector coronary CT angiography:assessment of image quality, stenosis, and radiation dose.Radiology.2008;248(2):424-430.
[27]. Sun Z, Ng KH. Prospective versus retrospective ECG-gated multislice CT coronary angiography: A systematic review of radiation dose and diagnostic accuracy.*Eur J Radiol* 2012;81:e94-e100.
[28]. Husmann L, Valenta I, Gaemperli O, Adda O, TreyerV,Wyss CA, et al. Feasibility of low-dose coronary CTangiography: first experience with prospective ECG-gating.Eur Heart J 2008;29:191–7.
[29]. Scheffel H, Alkadhi H, Leschka S, et al. Low-dose CT coronary angiography in the step-and –shoot mode: Diagnostic performance.Heart 94:1132-1137.doi:10.1136/hrt.2008.149971.
[30]. Maruyama T, Takada M, Hasuike T, Yoshikawa A,Namimatsu E, Yoshizumi T. Radiation dose reduction and coronary assessability of prospective electrocardiogramgated computed tomography coronary angiography: comparison with retrospective electrocardiogram-gated helical scan. J Am CollCardiol 2008;52:1450–5.
[31]. OliverKlass, Martin Jeltsch, Sebastian Feuerlein, et al. Prospectively gated axial CT coronary angiography: preliminary experiences with a novel low-dose technique.*EurRadiol* 2009;19: 829-836.

Dr. Sabeeha. "Radiation Exposure. A Serious Concern With cardiovascular imaging (Role Of Radiologist Inreducing This Radiation Burden)." IOSR Journal of Dental and Medical Sciences (IOSR-JDMS), vol. 18, no. 05, 2019, pp 62-71.