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MSCT (MULTISLICE CT TECHNOLOGY) ANGIOGRAPHY FOR DETECTION OF OBSTRUCTIVE CORONARY ARTERY DISEASE IN THE MAJOR EPICARDIALVESSELS IN NORTHERN INDIA

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ABSTRACT

Background: Coronary artery disease (CAD) has emerged as the Epidemic of modern era leading both to mortality and morbidity. The Gold standard of reference for diagnosing CAD has been invasive coronary angiography, newly been challenged by the emergence & fast growing use of a less invasive imaging technique, multislice computerised tomography (MSCT) angiography. The diagnostic accuracy of MSCT angiography in CAD has been significantly augmented with the increased performance of MSCT from early generation of the 4-slice CT to 16-slice,64-slice,dual-source CT & the latest models such as 256-slice & 320-slice CT scanners, in conjunction with aggressive beta-blockade to reduce the heart rate during imaging has shown promise for detection of obstructive CAD in the major epicardial vessels. **Aim: T**o assess & compare the image quality on a per segment basis 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 at 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 (Group 1:n=66, retrospective ECG-gating; Group 2:n=33,prospective ECG-triggering). **Results:** The comparison of segment-wise image quality scores between the PGA CTA & RGH CTA techniques revealed significant difference in the image quality scores for majority of the segments between the two study groups. Image quality was significantly better in the RGH CTA as compared to PGA CTA for certain segments like(1, 2, 3, 4a, 10, 11, 12a , 12b, 13 & 14), whileas it was comparable between the two groups for the rest. **Conclusion:** Prospectively gated axial coronary CT angiography appears to be a robust diagnostic examination for coronary artery disease Patient selection & preparation is of utmost importance so far as the image quality is concerned. When performed in patients with stable heart rates typically less than 60 bpm, PGA yields image quality equivalent to retrospectively gated coronary CY angiography. **Summary:** 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 with above results.

KEYWORDS: coronary artery disease, multislice computerised tomography, angiography.

INTRODUCTION

CAD diagnostic, the 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,[1-3] the non-invasiveness of this technique being highly desirable. Imaging of the heart and the coronary arteries has always been technically challenging due to the hearts continuous motion. Over the last decade, great strides have been made in the field of non-invasive coronary imaging modalities.[4-7] The diagnostic accuracy of MSCT angiography in CAD has been significantly augmented with the increased performance of MSCT from early generation of the 4-slice CT to 16-slice,64-slice,dual-source CT & the latest models such as 256-slice & 320-slice CT scanners.[2,3,8-12] Evidence with newer multislice CT technology in conjunction with aggressive beta-blockade to reduce the heart rate during imaging has shown promise for detection of obstructive CAD in the major epicardial vessels.[13] This is mainly demonstrated by the improved spatial & temporal resolution from the latest MSCT scanners such as 64 or more slice scanners. In particular, MSCT angiography has been reported to demonstrate a very high negative predictive value (more than 95%).[14] indicating that it can be used as a reliable technique for excluding patients suspected of CAD, thereby reducing the need for invasive coronary angiography. Furthermore, CCTA is capable of much more than lumenography and its unique strengths are providing new insights into the evaluation of patients with suspected CAD. The assessment of plaque composition (calcified, non-calcified and mixed) by the CCTA is an exciting area of focus, and studies have demonstrated a significant correlation between the type of plaque and risk of clinically significant CAD and risk of future events.[15] Similarly ,ability of CT angiography to detect vulnerable plaques (those with low attenuation and presence of vascular remodelling at the site of the plaque) is believed to be more clinically relevant. Thus, it is possible that CTA-based patient evaluation may provide more clinically relevant information on which to base the risk assessment compared with the conventional lumenography.[16] The coronary artery calcium score (CACS) has been shown to be a good marker of total coronary artery atherosclerotic burden.[17] Studies have shown that CAC score provides incremental CHD risk prediction beyond the traditional risk factors,& patients with advanced CAC burden (CAC scores≥300 or 400) have the greatest risk.[18-23]

Prospectively gated cardiac CT has several limitations for clinical use however. Images obtained with this technique cannot be used for either regional or global functional analysis of the heart because the number of reconstructed phases typically covers only a small portion of the cardiac cycle. Further, image quality degrades at higher heart rates, so a maximum heart rate of 65-75 beats per minute (bpm) has been recommended.[11,26,28,30,33)] This can be attributed to the fact that with increasing heart rates, the time point of best image quality shifts from mid-diastole to end-systole. However, late systolic phase images are usually not available with prospective gating because the trigger is usually set around 70-75% of the cardiac cycle. So, higher heart rates are likely to influence the image quality & hence diagnostic accuracy of prospectively-triggered CTCA much more than retrospective ECG-gated CTCA. Therefore, it is critical to have a lower heart rate to maximise image quality & diagnostic accuracy. Similarly, image quality may also degrade due to heart rate fluctuation during acquisition.[32] To conclude, with adequate preparation & careful patient selection, most patients can have a better diagnostic CCTA exam with prospective gating modality.[33]

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.

CT Image Quality Analysis: All coronary arteries, with a luminal diameter of 1.5mm or larger were classified according to a modified 17-segment American Heart Association model of vessel disease[42] and were included in the analysis.

1- Proximal segment of RCA,	9-Diagonal branch (D1),
2- Mid segment of RCA,	10-Diagonal branch (D2),
3-Distal segment of RCA,	11-Proximal LCX,
4a-Atrioventricular branch,	12a-High lateral branch,
4b-Posterior descending artery(PDA),	12b-Obtuse marginal artery,
5- Left main coronary artery(LMCA),	13-Diatal LCX,
6- Proximal segment of LAD,	14-Posterolateral LV branch,
7-Mid segment of LAD,	15-PDA (originating from LCX)
8-Distal segment of LAD,	

All CT images for both study groups were reviewed by two separate experienced cardiac radiologists, who were blinded to the coronary CT angiography algorithms & patient information.

Segmental image quality was scored with a four-point Likert scale.

Score 4: Poor image quality, lack of vessel wall definition due to marked motion artefact, poor vessel opacification, prominent structural discontinuity or high image noise related blurring that resulted in absence of diagnostic information. Segments with image quality score of 4 were regarded as non-evaluable/non-diagnostic segments.

Evaluable/assessable segments were scored as-
Score 3: Some motion artefacts or noise- related blurring, fair vessel opacification and minimal structural discontinuity.

Score 2: Minor motion artefacts or noise- related blurring, good vessel opacification and no structural discontinuity.

Score 1: Excellent image quality, absence of motion artefacts or noise related blurring, excellent vessel opacification and no structural discontinuity.

Assessment of Coronary Artery Stenosis by MDCT
Coronary artery segments with acceptable image quality (score of 3 or more) were assessed for the presence of stenosis. In all cases, quantitative CT angiographic analysis was performed (manually or semi-automatically) to have an estimate of percent luminal diameter stenosis & the segments were placed into the following categories:
Category 1: absence of plaque, no luminal stenosis;
Category 2:1-49% stenosis;
Category 3:50-75% stenosis;
Category 4: >75% stenosis.

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.

RESULTS

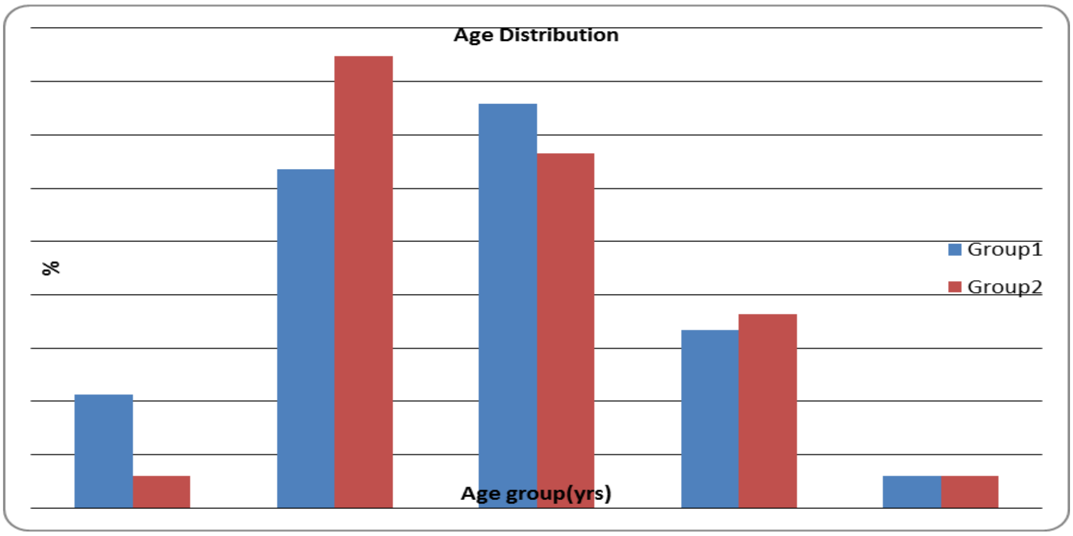


Figure 1:

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)

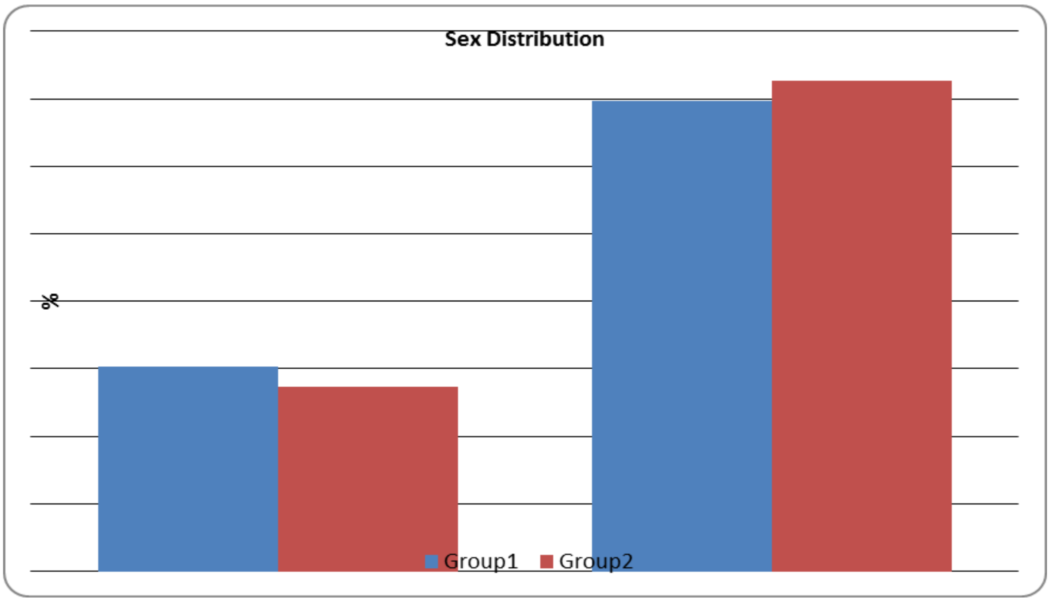


Figure 2:

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.

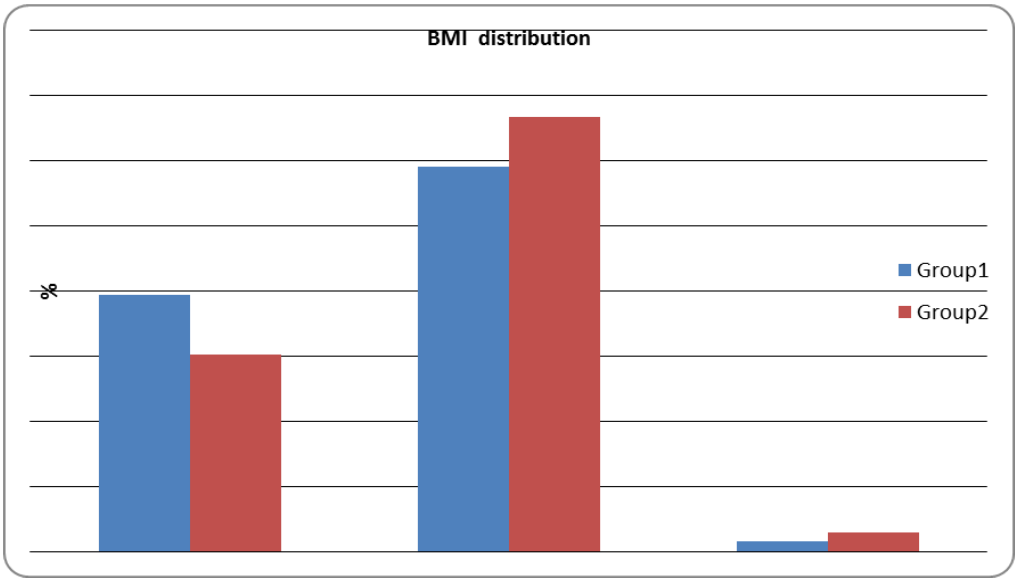


Fig. 3

Table 3: BMI of the Patient Population.

Study Group	BMI(kg/m^2)			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.

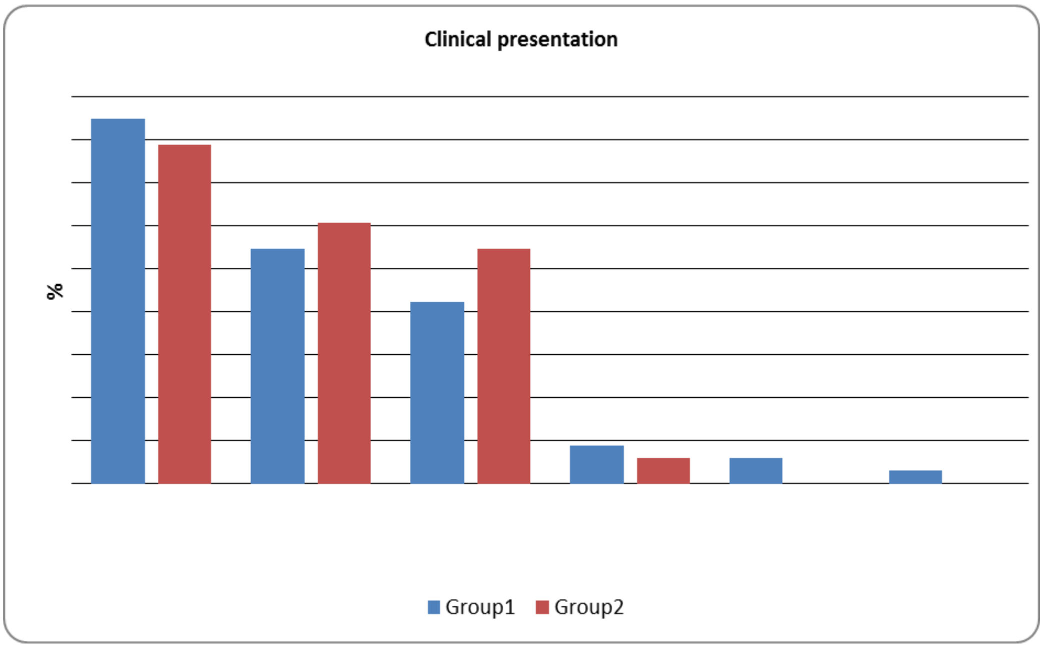


Figure 4:

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

Table 5: Mean Heart Rate of Group 1 vs Group 2.

Study Group	N	Mean Heart Rate (bpm)	Std. Deviation
Group 1	66	62.35	3.99
Group 2	33	63.24	4.25

Independent t-test; p-value: 0.307

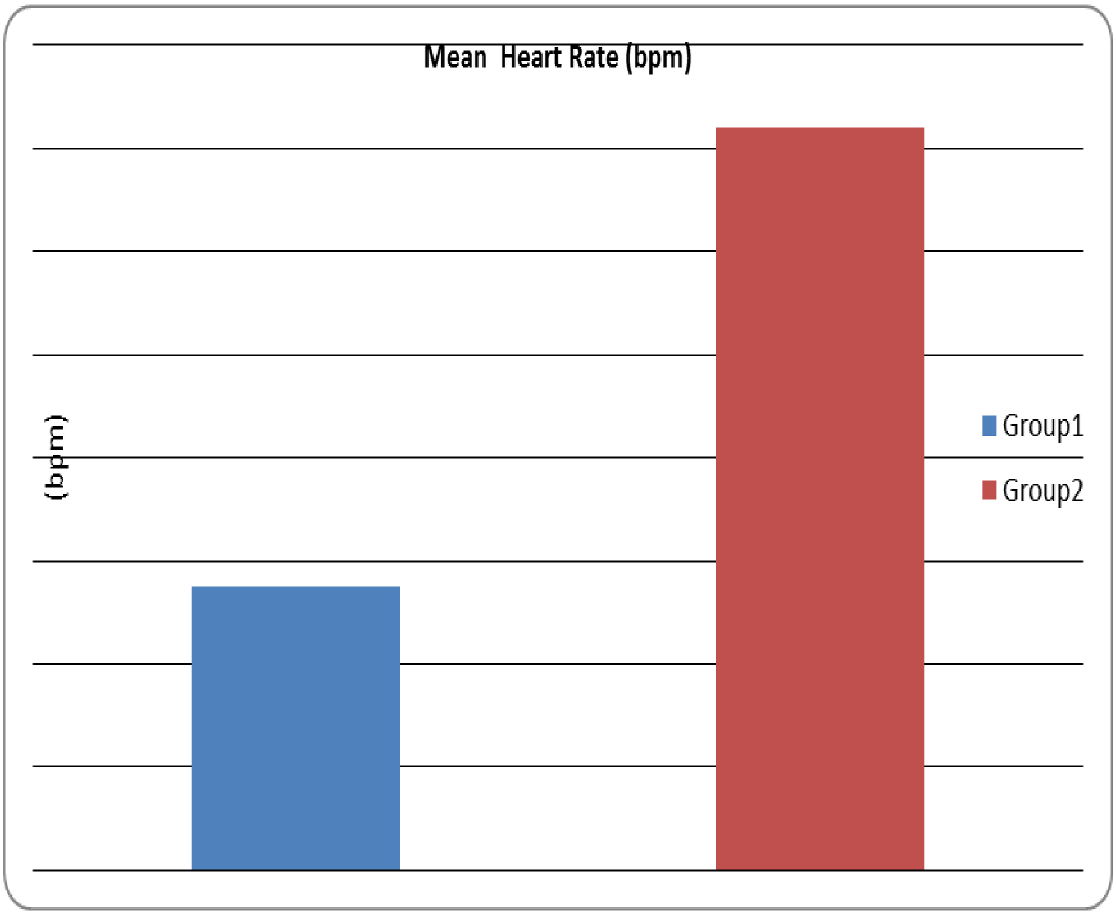


Figure 5: Mean Heart Rate of study groups.

There was no statistically significant difference in the mean heart rate between the two study groups, table /fig. 5.

Table 6: Heart Rate Variability of Group 1 vs Group 2.

Study Group	N	Mean Heart Rate Variability(bpm)	Std. Deviation
Group 1	66	4.33	1.29
Group 2	33	4.28	1.27

Independent t-test,p-value:0.851

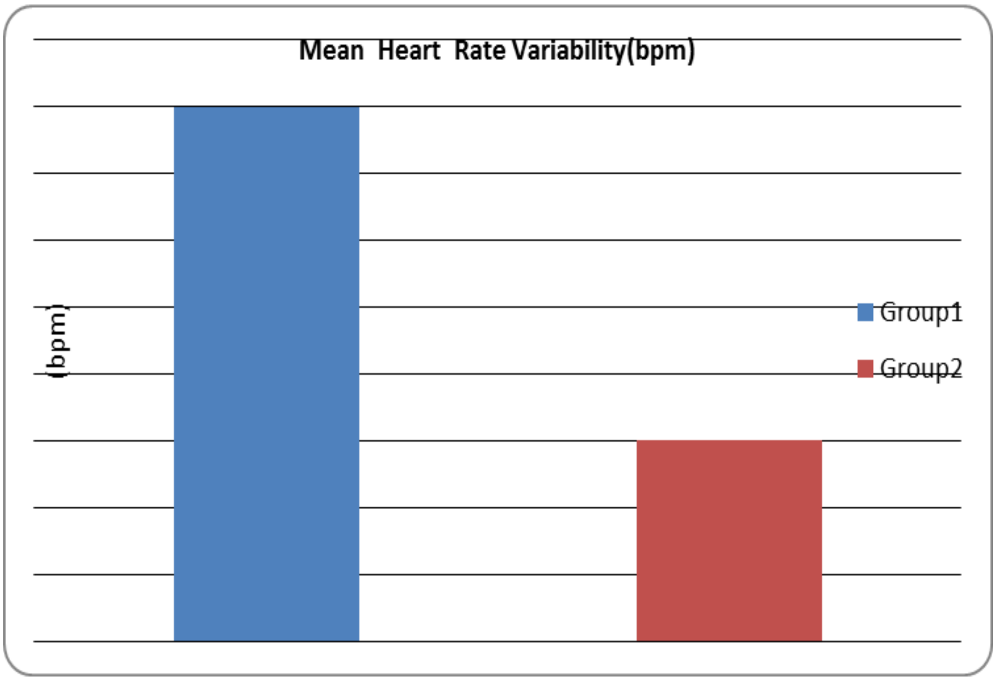


Figure 6: Mean Heart Rate Variability.

There was no statistically significant difference in the mean heart rate variability between the two study groups, table /fig. 6.

Table 7: 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

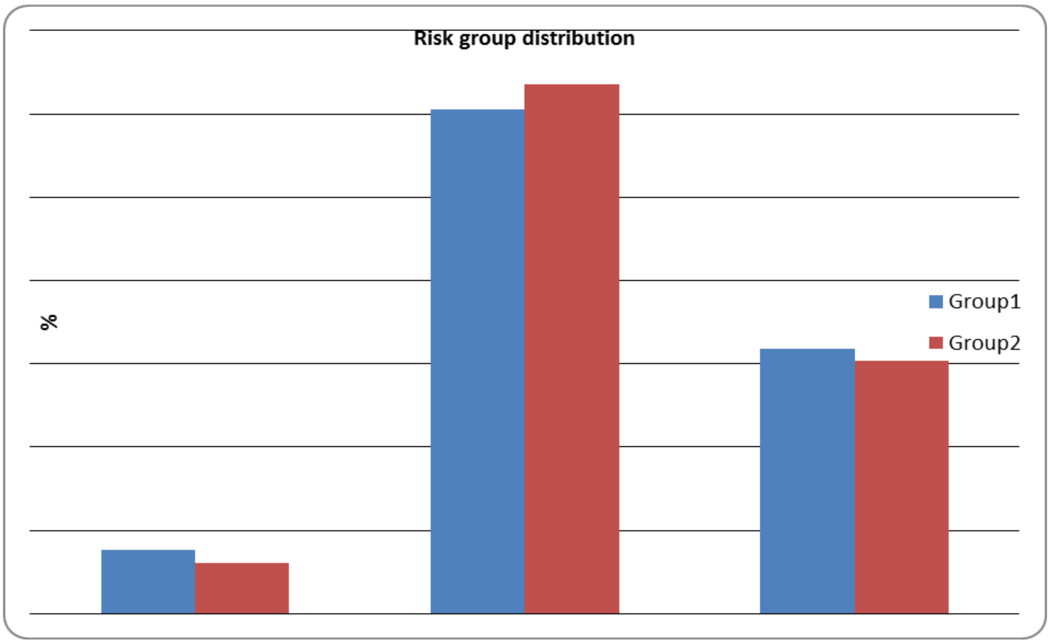


Figure 7:

There was no statistically significant difference in risk statification between the two study groups, table /fig. 7.

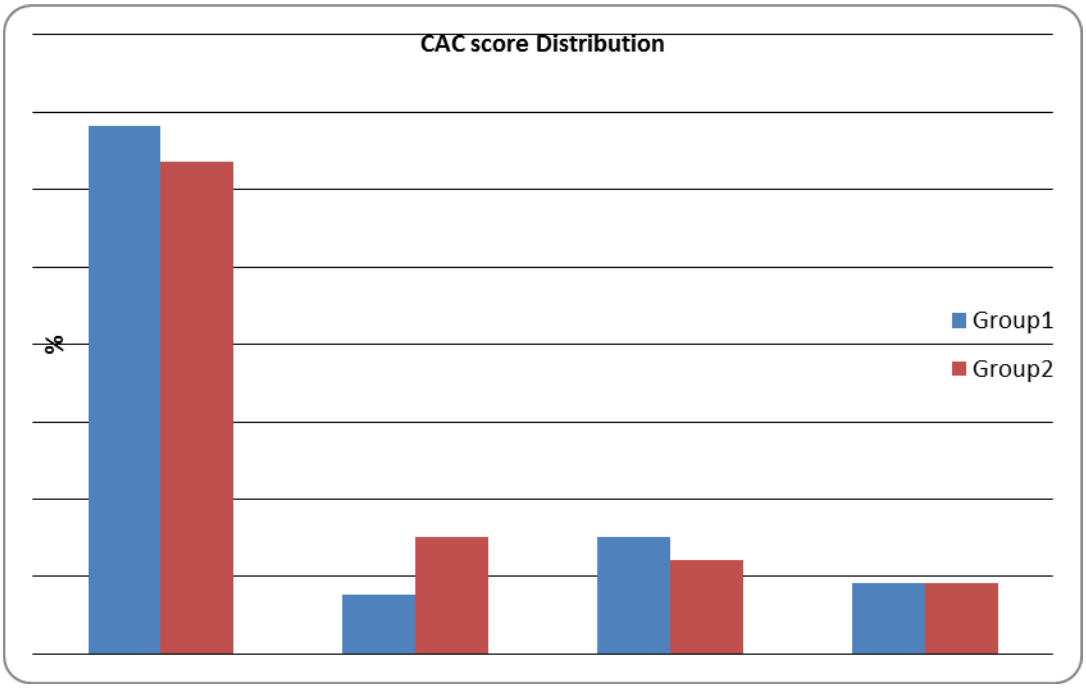


Figure 8:

Table 8: Coronary artery calcium(CAC) Score in patient population.

Study Group	CAC score (Agatston Score Equivalent)				Total
	A(0-10)	B(11-99)	C(100-299)	D(≥300)	
Group 1	45(68.2)	5(7.6)	10(15.2)	6(9.1)	66(100)
Group 2	21(63.6)	5(15.2)	4(12.1)	3(9.1)	33(100)
Total	66(66.7)	10(10.1)	14(14.1)	9(9.1)	99(100)

(Data in parentheses are percentages)
Chi –square :1.461; p-value:0.691

There was no statistically significant difference in CAG score distribution between the two study groups, table /fig. 8.

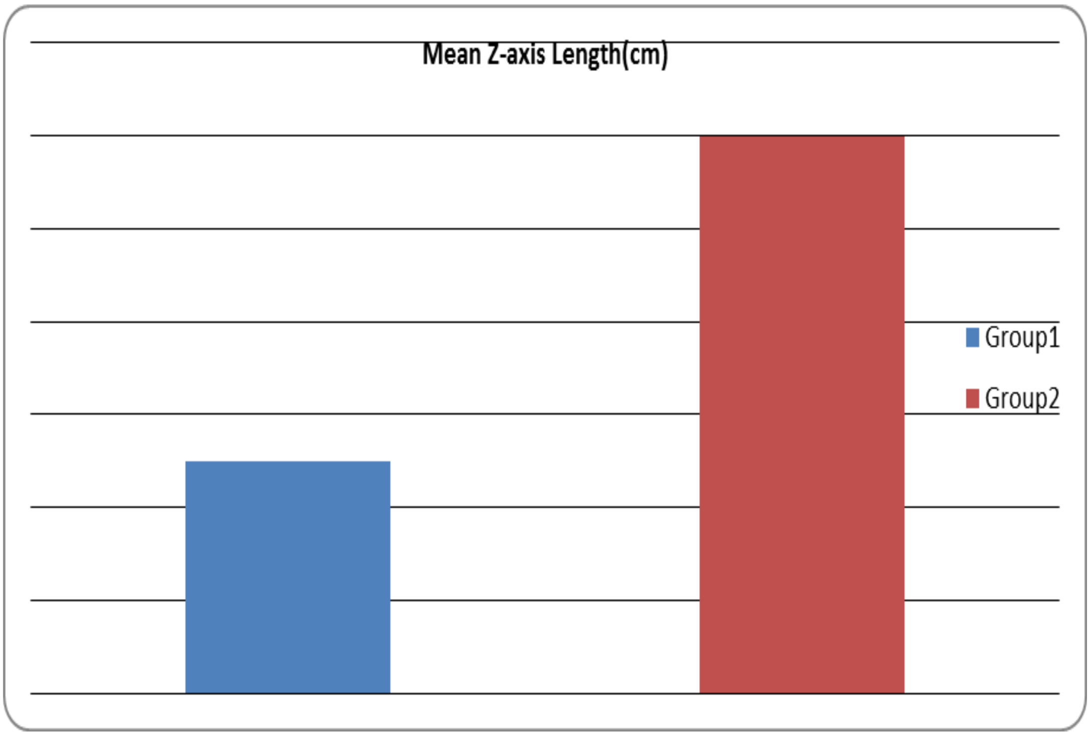


Figure 9:

Table 9: 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 CAG score distribution between the two study groups, table /fig. 9.Image Quality Per Segment (Prospective versus Retrospective) For Different Coronary Artery Segments.

Table 10: Segment 1(Proximal RCA).

Study Group	Image Quality Score (IQS)				Total
	Grade 1	Grade 2	Grade 3	Grade 4	
Group 1	54(81.8)	3(4.5)	5(7.6)	4(6.1)	66(100)
Group 2	18(54.5)	7(21.2)	4(12.1)	4(12.1)	33(100)
Total	72(72.7)	10(10.1)	9(9.1)	8(8.1)	99(100)

(Data are numbers of segments & data in parentheses are percentages)

Chi-square: 9.80;p value:0.020

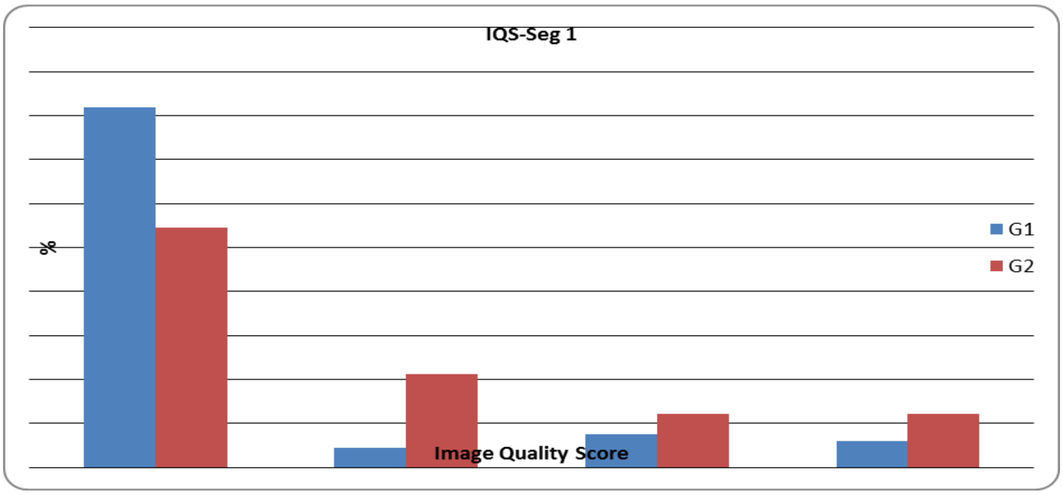


Figure 10:

Table/fig 10 summarises the image quality scores of Group 1 patients versus Group 2 patients for segment 1. There was a statistically significantly difference in the image quality score between the two groups, with Group 1 having significantly better image quality.

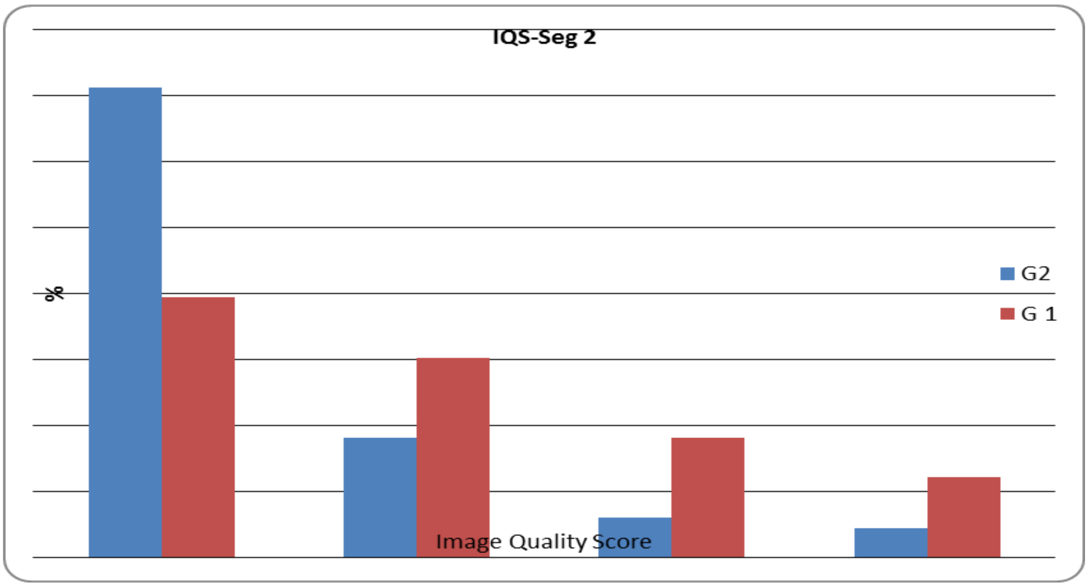


Figure 11:

Table 11: Segment 2(Mid-RCA).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	47(71.2)	12(18.2)	4(6.1)	3(4.5)	66(100)
Group 2	13(39.4)	10(30.3)	6(18.2)	4(12.1)	33(100)
Total	60(60.6)	22(22.2)	10(10.1)	7(7.1)	99(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 10.11,p-value: 0.018.

Table/fig 11 summarises the image quality score of Group 1 patients versus Group 2 patients for segment 2.There was a statistically significant difference in the image quality between the two groups, with Group 1 having better image quality scores than Group 2.

Table 12: Segment 3 (Distal RCA).

Study Group	Image Quality Score				Total
	Score 1	Score 2	Score 3	Score 4	
Group 1	46(69.7)	12(18.2)	6(9.1)	2(3.0)	66(100)
Group 2	13(39.4)	7(21.2)	7(21.2)	6(18.2)	33(100)
Total	59(59.6)	19(19.2)	13(13.1)	8(8.1)	99(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square:12.21; p-value:0.007.

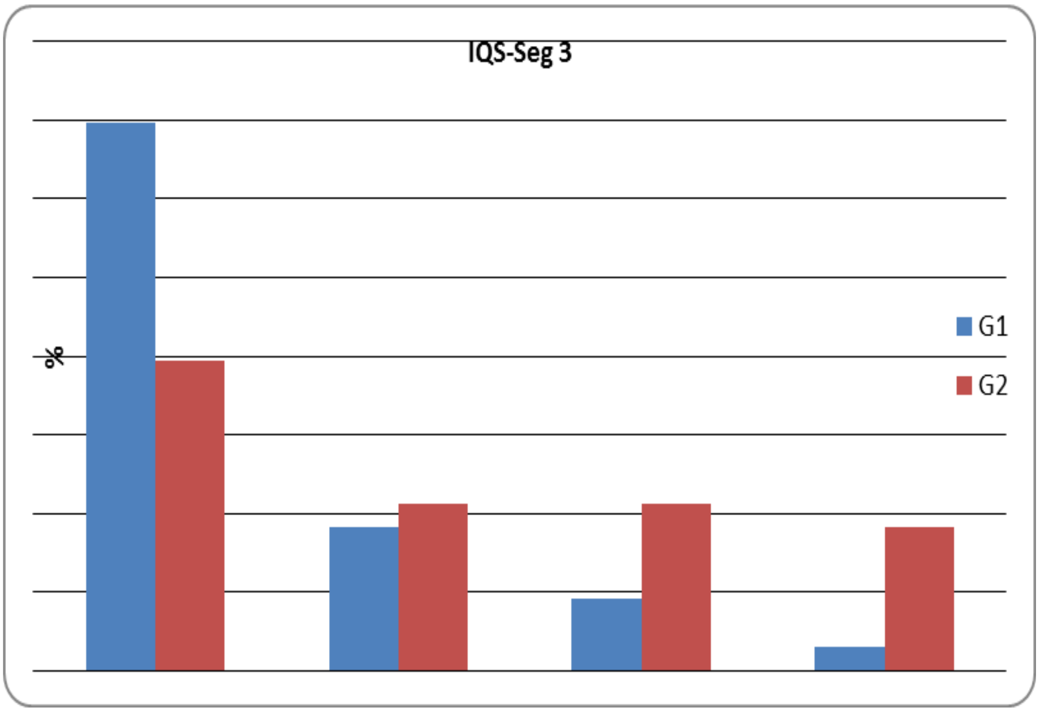


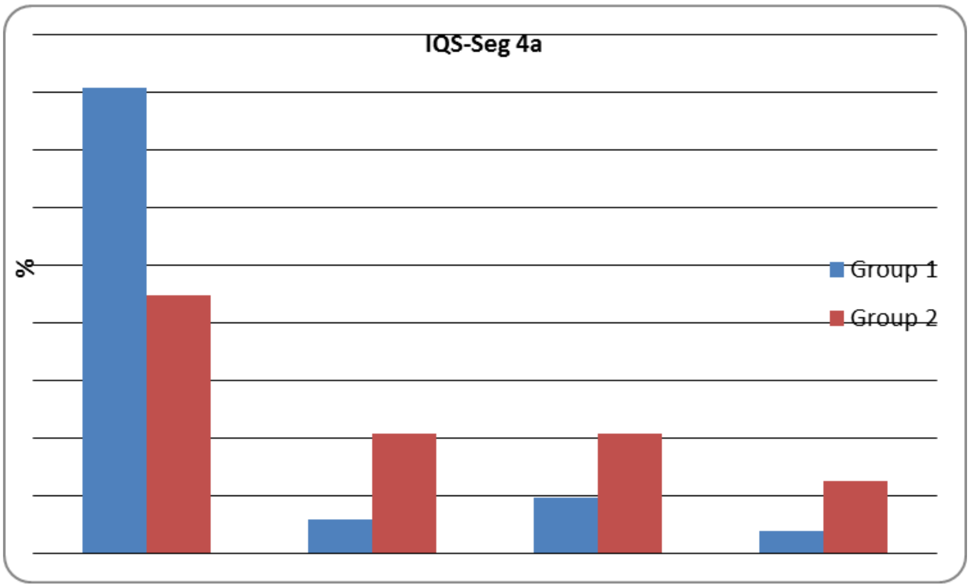
Figure 12:

Table/fig.12 summarises the image quality scores of Group 1 versus Group 2 for segment 3.There was a statistically significant difference in the image quality scores between the two patient groups,with Group 1 having better image quality than Group 2.

Table 13: Segment 4a (Atrioventricular branch).

Study Group	Image Qulaity Score				Total
	1	2	3	4	
Group 1	42(80.76)	3(5.76)	5(9.61)	2(3.8)	52(100)
Group 2	11(44.8)	5(20.8)	5(20.85)	3(12.5)	24(100)
Total	53(69.73)	8(10.52)	10(13.16)	5(6.57)	76(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square:76.00; p-value:≤0.0001.



Graph 13: Image Quality Score of Segment 4a.

Table /graph 13 summarises the image quality scores of Group 1 versus Group 2 for segment 4a.There was a statistically significant difference in the image quality between the two groups, with Group 1 having far better image quality than Group 2.

Table 14: Segment 4b (PDA).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	37(62.7)	9(15.3)	8(13.6)	5(8.5)	59(100)
Group 2	17(56.7)	7(23.3)	4(13.3)	2(6.7)	30(100)
Total	54(60.7)	16(18.0)	12(13.5)	7(7.9)	89(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square:0.92;p-value: 0.819

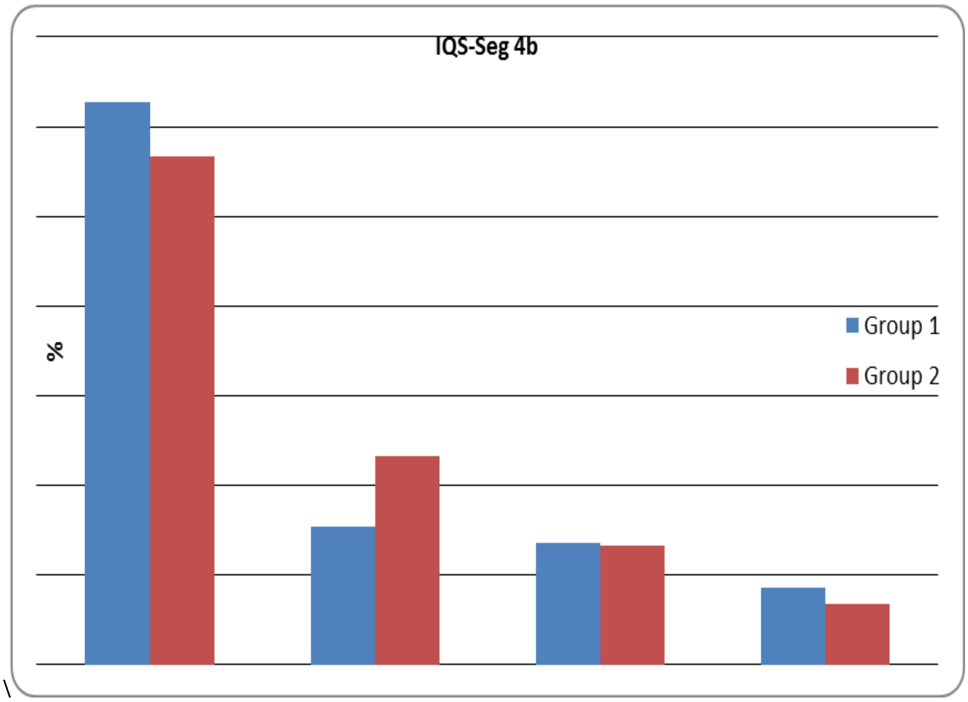


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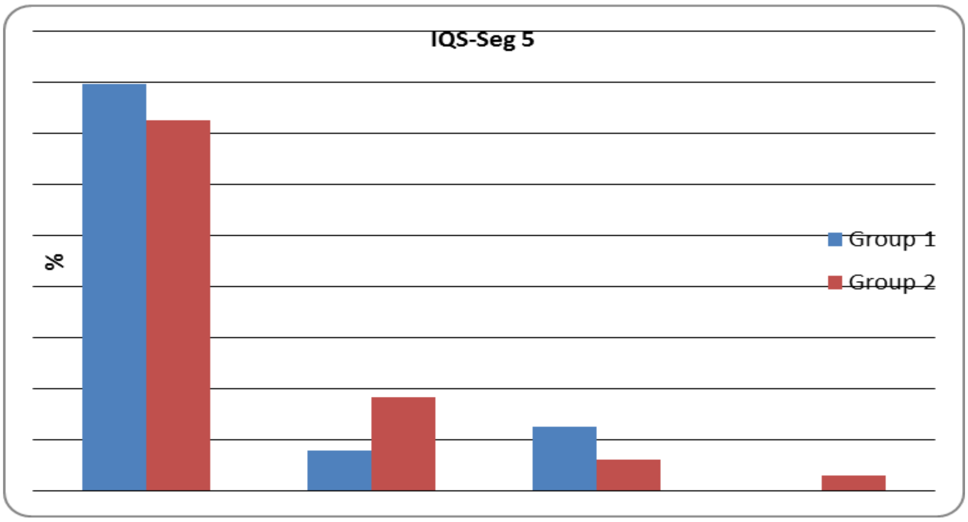
Figure 14:

Table /fig 14 summarises the image quality scores of segment 4b in the two patient groups. On statistical analysis,there was no significant difference in the image quality score between the two groups.

Table 15: Segment 5 (LMCA).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	51(79.7)	5(7.8)	8(12.5)	0(0)	64(100)
Group 2	24(72.7)	6(18.2)	2(6.1)	1(3.0)	33(100)
Total	75(77.3)	11(11.3)	10(10.3)	1(1.0)	97(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square:5.016;p-value:0.171



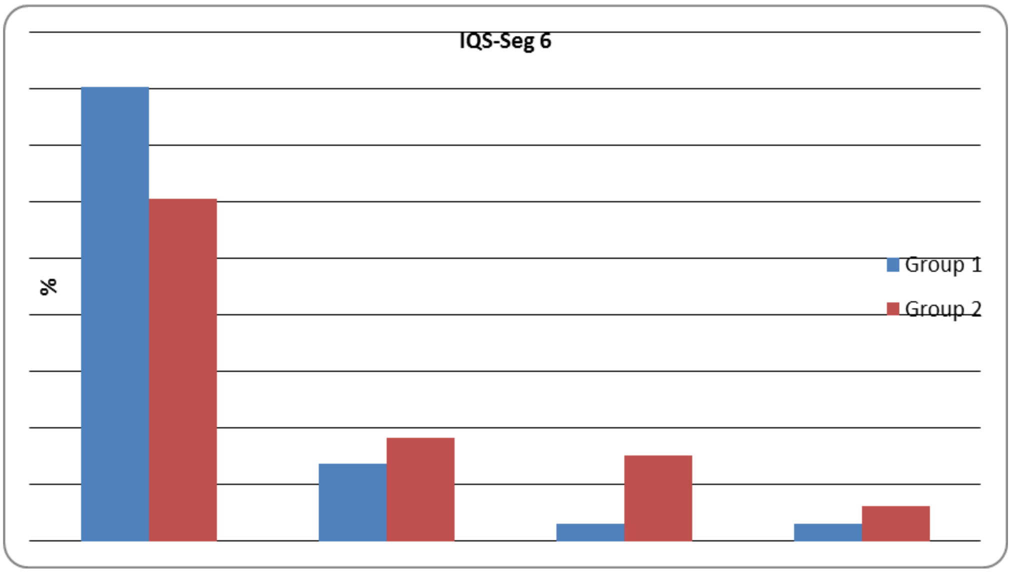
Graph 15: Image Quality Score of segment 5.

Table/Graph 15 summarises the image quality scores of segment 5 in the two study groups. On statistical analysis,there was no significant difference in the image quality scores between the two study groups for segment 5 (LMCA).

Table 16: Segment 6(Proximal LAD).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	53(80.3)	9(13.6)	2(3.0)	2(3.0)	66(100)
Group 2	20(60.6)	6(18.2)	5(15.2)	2(6.1)	33(100)
Total	73(73.3)	15(15.2)	7(7.1)	4(4.0)	99(100)

(Data are numbers of segments & data in parentheses are percentages)
Chi-square: 6.529;p-value: 0.089



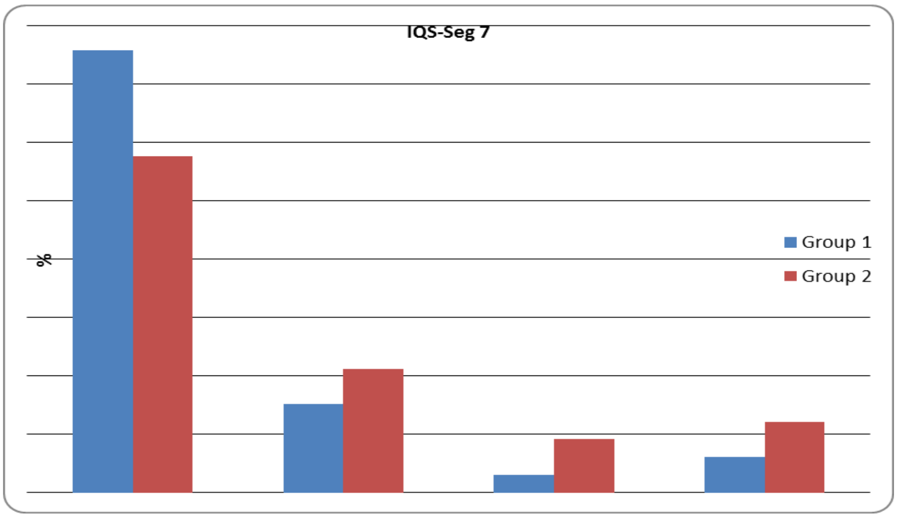
Graph 16: Image Quality Score of Segment 6.

Table /graph 16 summarises the image quality scores of proximal LAD in the two study groups.On statistical analysis, there was no significant difference in the image quality scores of proximal LAD between the two patients groups, although greater percentage of Group 1 patients had IQS of 1 as compared to Group 2.

Table 17: Segment 7(Mid-LAD).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	50(75.8)	10(15.2)	2(3.0)	4(6.1)	66(100)
Group 2	19(57.6)	7(21.2)	3(9.1)	4(12.1)	33(100)
Total	69(69.7)	17(17.2)	5(5.1)	8(8.1)	99(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 4.114; p-value: 0.249



Graph 17: Image Quality Score of segment 7.

Table /graph 17 summarises the image quality scores of mid-LAD in the two study groups.On statistical analysis, there was no significant difference in the image quality of mid-LAD between the two study groups.

Table 18: Segment 8 (Distal LAD).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	42(63.6)	14(21.2)	5(7.6)	5(7.6)	66(100)
Group 2	18(54.5)	6(18.2)	6(18.2)	3(9.1)	33(100)
Total	60(60.6)	20(20.2)	11(11.1)	8(8.1)	99(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 2.690; p-value: 0.442

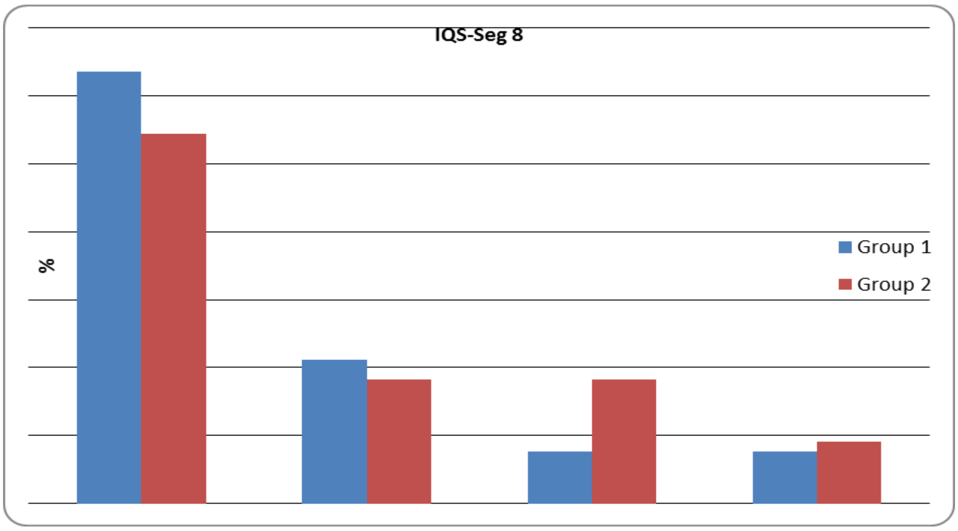


Figure 18

Table /graph 18 summarises the image quality scores of distal LAD (seg 8) in the two study groups. On statistical analysis,there was no significant difference in the image quality of segment 8 between the two study groups.

Table 19: Segment 9 (First Diagonal Branch, D1)

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	40(66.7)	12(20.0)	4(6.7)	4(6.7)	60(100)
Group 2	16(59.3)	5(18.5)	4(14.8)	2(7.4)	27(100)
Total	56(64.4)	17(19.5)	8(9.2)	6(6.9)	87(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 1.539; p-value: 0.673

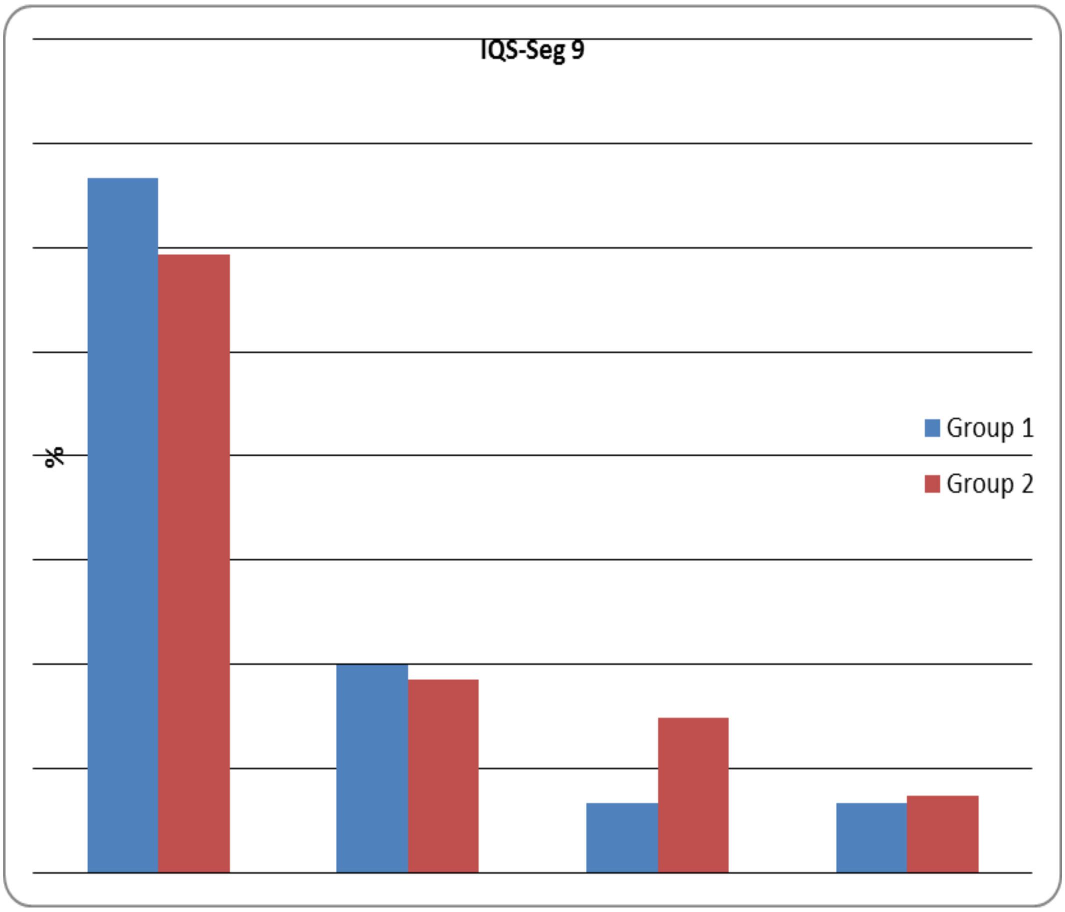


Figure 19

Table/fig 19 summarises the image quality scores of first diagonal branch (D1) in the the two study groups. On statistical analysis, there was no significant difference in the image quality of first diagonal branch (D1) between the two study groups.

Table 20: Segment 10(Second diagonal branch, D2).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	41(82.0)	4(8.0)	3(6.0)	2(4.0)	50(100)
Group 2	13(48.1)	6(22.2)	5(18.5)	3(11.1)	27(100)
Total	54(70.1)	10(13.0)	8(10.4)	5(6.5)	77(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 9.605; p-value: 0.022

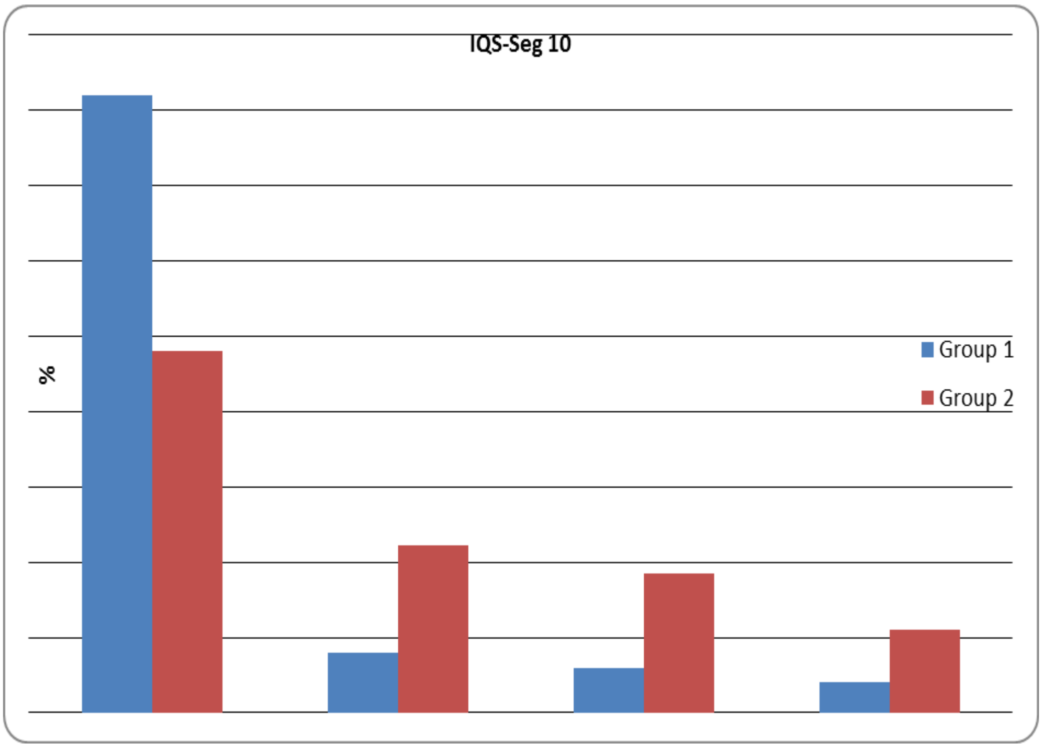


Figure 20

Table /fig.20 summarises the image quality score of segment 10 (D2 branch) in the two study groups.On statistical analysis, there was a significant difference in the image quality of D2 branch between the two study groups,with Group 1 having better image quality scores than Group 2.

Table 21: Segment 11(Proximal LCX)

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	50(75.8)	9(13.6)	4(6.1)	3(4.5)	66(100)
Group 2	13(39.4)	11(33.3)	3(9.1)	6(18.2)	33(100)
Total	63(63.6)	20(20.2)	7(7.1)	9(9.1)	99(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 13.582; p-value: 0.004

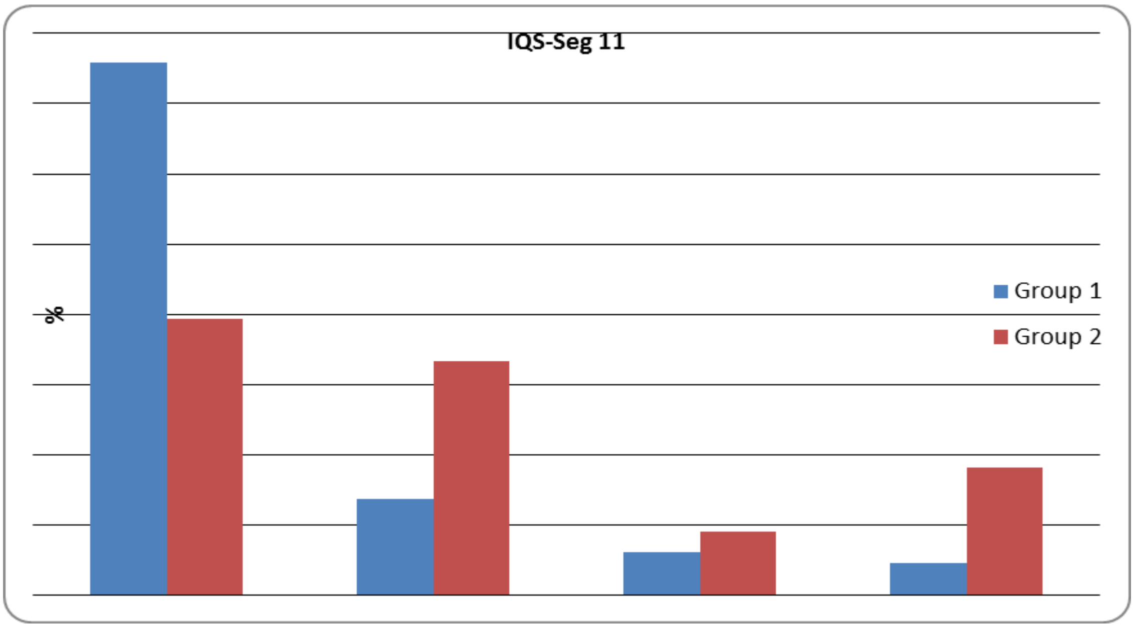


Figure 21

Table/fig. 21 summarises the image quality scores of proximal LCX in the two study groups.On statistical analysis, there was a significant difference in the image quality of proximal LCX between the two study groups, with Group 1 having better image quality than Group 2.

Table 22: Segment 12a(High Lateral Branch).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	36(81.8)	4(9.1)	2(4.5)	2(4.5)	44(100)
Group 2	11(47.8)	3(13.0)	6(26.1)	3(13.0)	23(100)
Total	47(70.1)	7(10.4)	8(11.9)	5(7.5)	67(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 10.046; p-value: 0.018

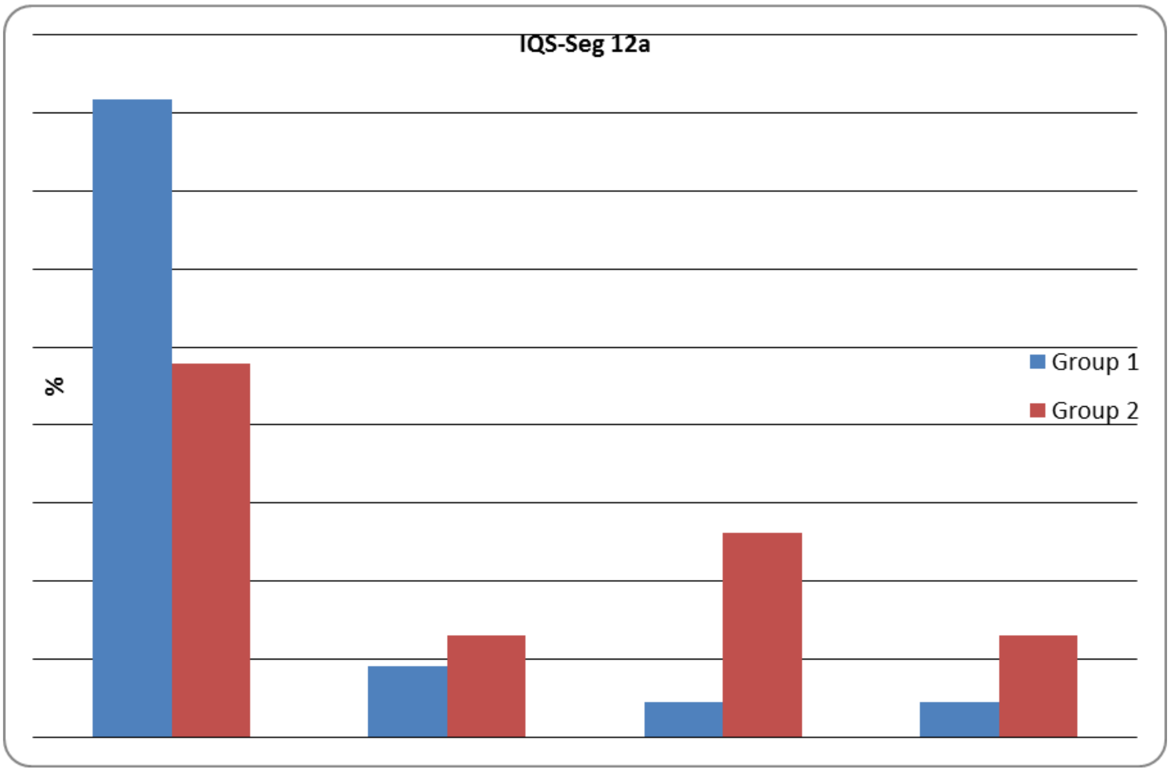


Figure 22:

Table /figure 22 summarises the image quality of segment 12a in the two study groups. On statistical analysis, there was a significant difference in the image quality score of segment 12a between the two study groups, with Group 1 patients having significantly better image quality than Group 2 subjects.

Table 23: Segment 12b (Obtuse Marginal Branch).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	43(75.4)	8(14.0)	3(5.2)	3(5.2)	57(100)
Group 2	18(54.5)	5(15.2)	8(24.2)	2(6.1)	33(100)
Total	61(67.8)	13(14.4)	11(12.2)	5(5.6)	90(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 90.00; p-value:≤ 0.0001

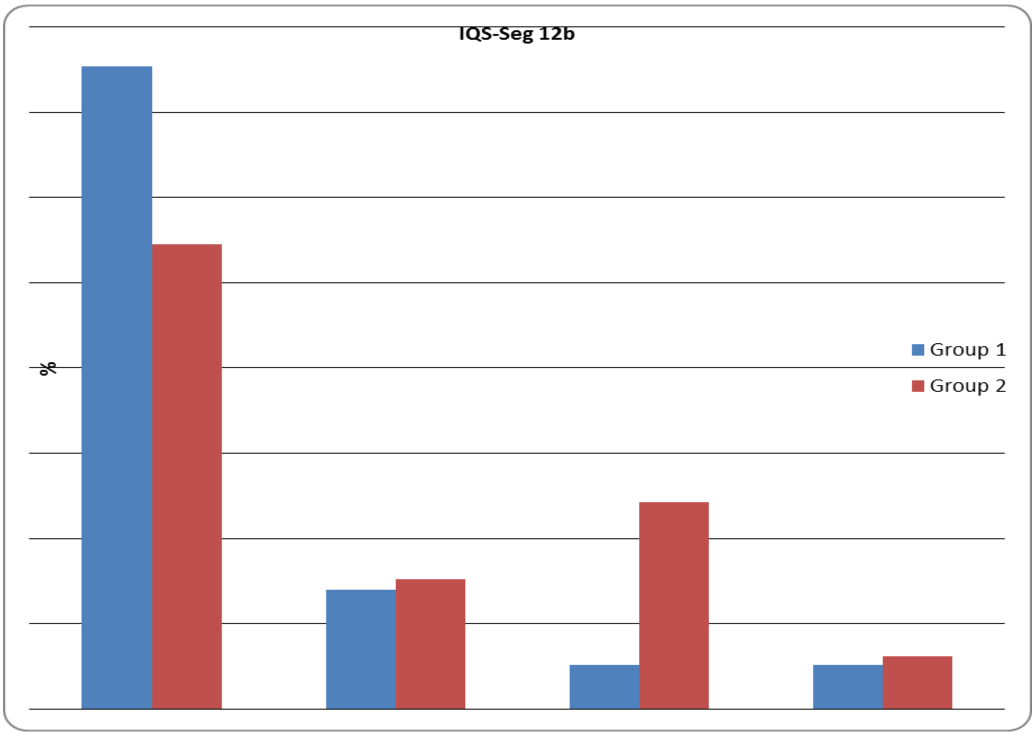


Figure 23:

Table /fig. 23 summarises the image quality scores of segment 12b in the two study groups. On statistical analysis, there was a highly significant difference in the image quality of segment 12b between the two study groups, with Group 1 having far better image quality than Group 2.

Table 24: Segment 13(Distal LCX).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	46(75.0)	10(16.4)	2(3.3)	3(4.9)	61(100)
Group 2	14(42.4)	6(18.2)	8(24.2)	5(15.2)	33(100)
Total	60(63.8)	16(17.0)	10(10.6)	8(8.5)	94(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square:94.00; p-value: ≤0.0001.

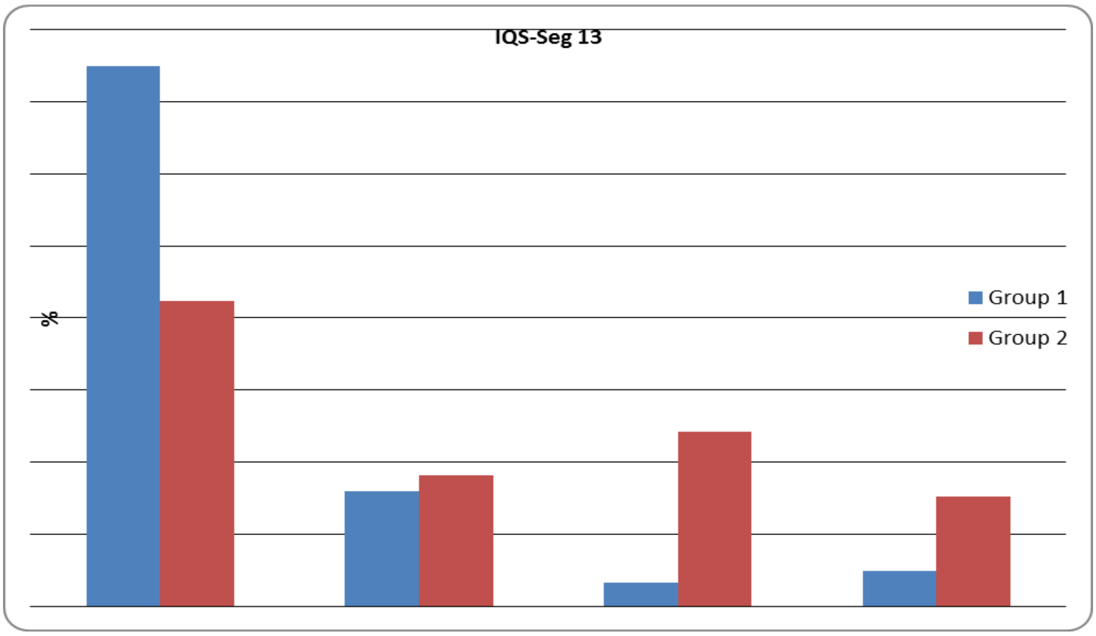


Figure 24.

Table /figure 24 summarises the image quality score of distal LCX in the two study groups. On statistical analysis, there was a highly significant difference in the image quality of distal LCX between the two study groups, with Group 1 patients having far better image quality score than Group 2 subjects.

Table 25: Segment 14 (Posterolateral LV branch).

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	50(81.9)	8(13.1)	1(1.6)	2(3.3)	61(100)
Group 2	16(64)	2(8.0)	3(12.0)	4(16.0)	25(100)
Total	66(76.7)	10(11.6)	4(4.7)	6(7.0)	86(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 86.00; p-value:≤0.0001

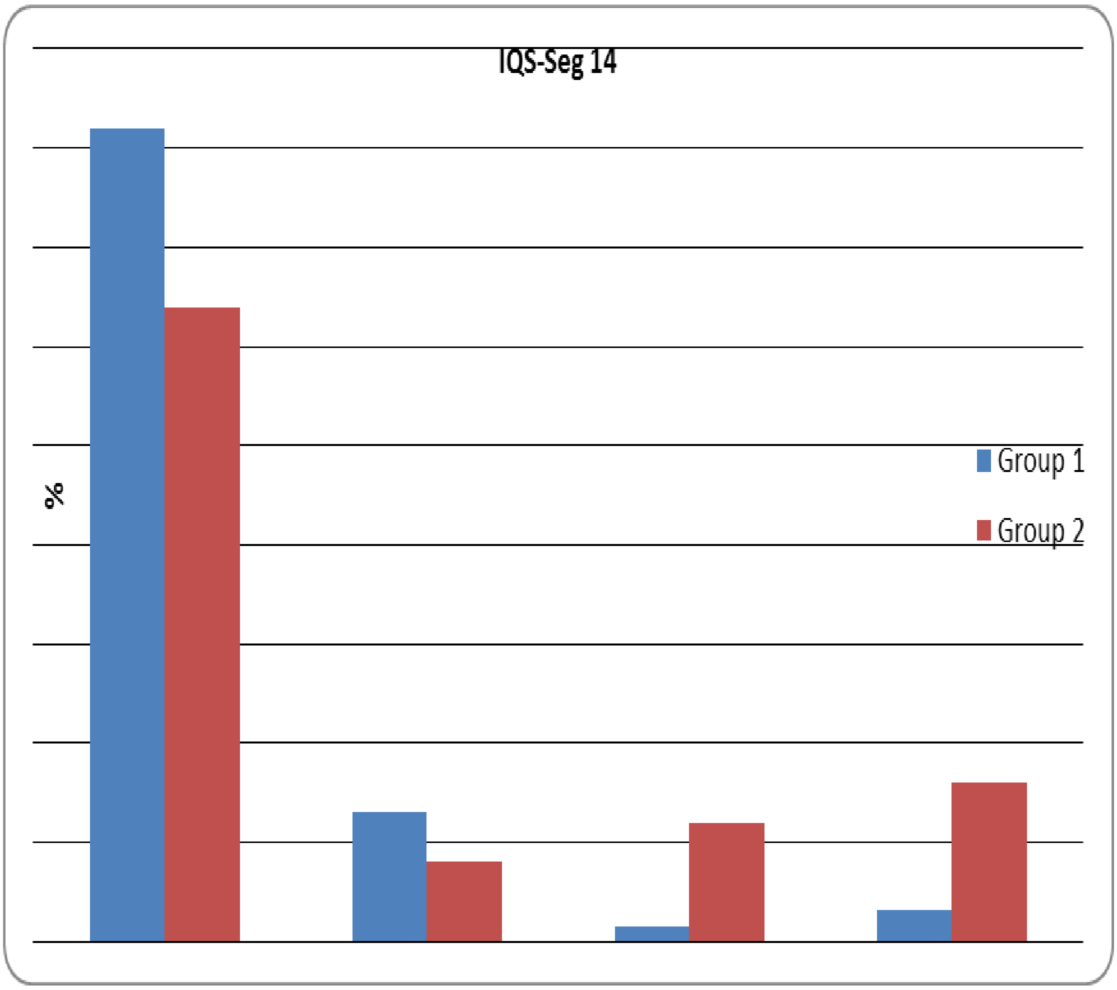


Figure 25:

Table /fig. 25 summarises the image quality of segment 14 in the two study groups. On statistical analysis, there was a highly significant difference in the image quality score of segment 14 between the two study groups, with Group 1 patients having better image quality than Group 2 patients.

Table 26: Segment 15.

Study Group	Image Quality Score				Total
	1	2	3	4	
Group 1	5(62.5)	2(25.0)	1(12.5)	0(0)	8(100)
Group 2	2(40.0)	1(20.0)	2(40.0)	0(0)	5(100)
Total	7(53.8)	3(23.1)	3(23.1)	0(0)	13(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square: 1.331;p-value:0.514

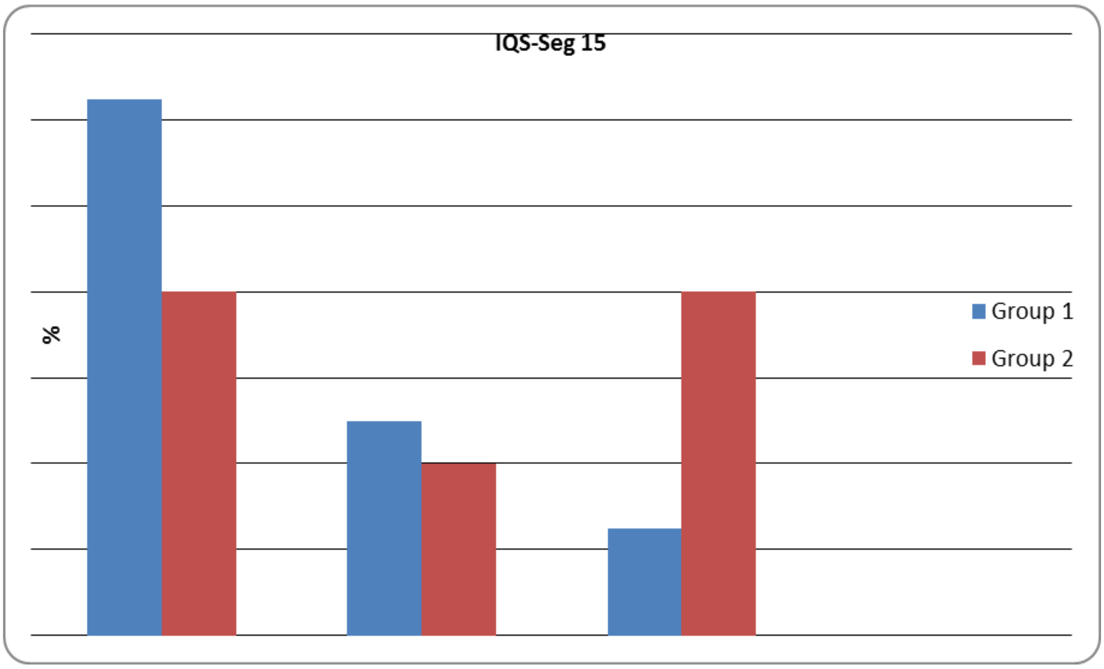


Figure 26:

Table / figure 26 summarises the image quality score of segment 15 in the study groups. On statistical analysis,there was no significant difference in the image quality of segment 15 between the two study groups.

If one summarises the above findings in terms of three main coronary arteries, we can conclude that while there was a statistically significant difference in the image quality of RCA(including segments 1,2&) & LCX(including segments 11&13) between the two study groups, there was no significant difference in the image quality of LMCA (segment 5)& LAD(including segments 6,7 & 8) between the two study groups.

Table 27: Image Quality Score (in terms of total number of segments).

Study Group	Image Quality Score				Total No. of Segments
	1	2	3	4	
Group 1	733(74.9)	134(13.7)	65(6.6)	46(4.7)	978(100)
Group 2	256(52.1)	100(20.4)	81(16.5)	54(11.0)	491(100)

(Data are numbers of segments & data in parentheses are percentages) Chi-square:85.32;p-value:≤0.0001.

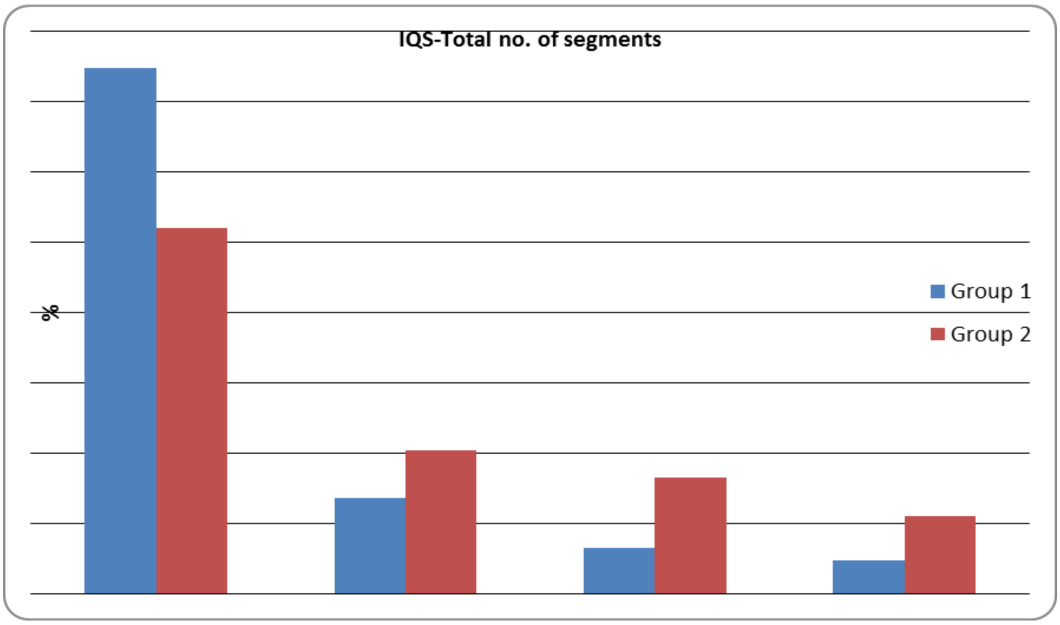


Figure 27

Table /fig. 27 summarises the image quality in terms of total number of segments in the two study groups. On statistical analysis, there was a significant difference in the image quality per segment in terms of total number of segments between the the two study groups, with Group 1 patients having significantly better image quality scores than Group 2 patients. In other words, one can infer that the rate of non-assessable segments (those segments with an IQS of 4) was significantly more in Group 2 patients as compared to Group 1 patients.

DISCUSSION

Coronary CT angiography has been increasingly used in the diagnosis of coronary artery disease owing to rapid technological advances which is reflected in the improved spatial and temporal resolution of the images.High diagnostic accuracy has been achieved with multislice CT scanners (64 slice and higher).In selected patients coronary CT angiography is regarded as a reliable alternative to invasive coronary angiography. Despite its diagnostic advantages, the high effective dose.[27,29,34,35] & potential adverse consequences of coronary CT angiography.[3] 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.[36] 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.[12-16,24,25,34]

Image Quality: The comparison of segment-wise image quality scores between the PGA CTA & RGH CTA techniques revealed significant difference in the image quality scores for majority of the segments between the two study groups. Image quality was significantly better in the RGH CTA as compared to PGA CTA for segments 1, 2, 3, 4a, 10, 11, 12a, 12b, 13 & 14 whileas it was comparable between the two groups for rest of the segments. Our results were not consistent with Hirai N et al[38] who reported comparable image quality between retrospective & prospective CCTA for all the 17 segments studied. Similarly, Oliver Klass et al.[39] found comparable image quality between the two groups.

Overall, 1469 coronary artery segments were included in the analysis.There was a statistically significant difference in the number of non-assessable segments between the RGH & PGA groups (4.7% & 11.1% of the total number of segments respectively). Unlike our study, Shumann et al,[37] found no significant difference in the non-evaluable segments between the retrospective & prospective gating techniques (1.5% vs 1.1%, p-value: 0.53). This discrepancy between our study & others could be attributed to the availability and use of temporal padding in the respective cardiac CT scanners used in these studies. "Padding" turns the tube on prior to and leaves it on after the minimum required scan beam-on time (180° plus a fan angle). This allows the reconstruction to adapt to minor heart rate variations and produce consistent image quality, since the reconstruction window can be modified retrospectively to ensure identical cardiac phase from scan to scan. Shumann et al.[37] in their study, used 100msec of padding in addition to the required beam-on time so that images could be adaptively reconstructed earlier or later than anticipated in the event of small heart rate irregularities. In the study by Earls JP et al.[40] a 75% (mid-diastole) phase was targeted for all subjects with prospective ECG-gating and depending on the amount of perceived beat-to-beat variability, additional ''padding'' of tube-on time was used. Actual padding in the study ranged from 0 ms in very stable patients to 200 ms in less stable heart rates; this was chosen by the technologist based on the observation of the ECG rhythm. Furthermore, mean heart rate in our study population was 63.24±4.25 beats per minute & 62.35±3.99 beats per minute for prospective & retrospective groups respectively, whereas the mean heart rate was on the lower side in the study by Hirai N et al.[38] (57.1bpm ±7.8 for prospective CT angiography & 57.7 bpm ± 7.1 for retrospective CT angiography).Similarly, in the study by Oliver Klass et al[39] the mean heart rate was lower as compared to our study (56bpm±4 for prospective CT angiography & 60bpm±4 for retrospective CT angiography). This could be one of the reasons for decreased image quality inPGA CTA with respect to RGH CTA in our study. This assumption is supported by Buechel et al.[41] who concluded that non-diagnostic segments were significantly less common with a HR below 62beats/minute (1.2%) compared with an HR above or equal to 62 beats/minute (8.4%, p-value: <0.001) in prospective ECG-triggering. Similarly, Herzog et al[42] concluded that image quality seems to be more prone to degradation by a high heart rate using prospective ECG-triggered CTCA. Lars Husmann et al.[31] while studying the feasibility of low-dose coronary CT angiography, found a cut-off heart rate of 63 beats per minute below which low-dose CCTA (prospective-triggering) is feasible in 93% of the patients with diagnostic image quality.

We further analysed the image quality of RGH CTA versus PGA CTA in terms of total number of segments, separately for two different heart rate groups. There was no significant difference in the image quality between RGH CTA & PGA CTA in patients with a heart rate of ≤ 60 bpm.There was a significant difference in the image quality between the two groups with a heart rate of >60 bpm. Thus, we can conclude that while the image quality (in terms of total number of segments) was comparable between the study groups for patients with a heart rate of ≤ 60bpm, the image quality was significantly better with retrospective gating in patients with a heart rate >60 bpm.

In terms of main coronary arteries, we found a significant difference in the image quality of RCA (including segments 1, 2 & 3) & LCX (including segments 11 &13) between the two study groups. The image quality of RCA & LCX was significantly better with retrospective gating. However, there was no significant difference in the image quality of LMCA (segment 5) & LAD (segments 6, 7 & 8) between the two groups. This can be explained on the basis of the observation made by Lu B et al,[43] who studied the coronary artery motion during the cardiac cycle to determine the optimal ECG trigger for coronary artery imaging & concluded that the optimal ECG-trigger time varied widely between different heart rate groups for RCA, that the motion characteristics of LCX were quite similar to those of RCA, & that the LAD had no significant differences in motion throughout the cardiac cycle. One can infer that there will be no significant improvement or change in the image quality of LMCA & LAD using widely available range of reconstruction intervals (0-90%) available with retrospective gating as compared to prospective triggering (with a typical reconstruction window between 65-75% of the cardiac), while the same may be a limiting factor for RCA & LCX. Similarly, Giesler et al[44] found that the right coronary artery was most severely affected by motion on MDCT, because the vessel displays the fastest velocity during the cardiac cycle, followed by LCX, LAD & LMCA in that order. Similarly, Wintersperger et al[45] concluded that mean image quality was significantly better for LAD than for RCA (p-value <0.0001) & LCX (p-value<0.01).

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

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