Original Article

Relationship between Radiation Doses with Anthropometric Characteristics during Cardiac Catheterization Procedures in Iraqi Patients with Ischemic Heart Disease

Marwa Abd AL-Redha Abd Al-Khaliq and Najeeb Hassan Mohammed

ABSTRACT

Objective: To investigate relationship between radiationdose received during cardiac catheterization and patients' anthropometric characteristics, particularly body mass index.

Study Design: A cross-sectional study

Place and Duration of Study: This study was conducted at the Single-plane catheterization laboratory at Ibn-Al-Bittar-Centre-Baghdad/Iraq from 1st May 2024 31st August 2024.

Methods: This is a cross-sectional, study with prospective data collection; cardiac-catheterization was done in Single-plane catheterization laboratory at Ibn-Al-Bittar-Centre-Baghdad/Iraq vide letter No. 478 dated 30th April 2024 and 110 patients were enrolled.

Results: There were 39 females and 71 males. 63.6% underwent coronary-angiography and 36.4%underwent percutaneous coronary intervention. The mean age was 58.6 years and body mass index was 30.3±4.9kg/m². The mean dose area product by body mass index group was 19.3, 65.6, 66.1, 112.3, 92.2and 52.1Gy·cm², respectively. The corresponding mean kinetic energy released perunitmass (KERMA) values were: 277.7, 878.2, 1102.4, 1606.8, 1719.9, and 850.9mGy, respectively. Normality tests for both kinetic energy released per unit mass and dose-area-product showed significant differences across body mass index group($p<0.05$), indicating that radiation dose data were not normally distributed. However, ANOVA tests showed no statistically significant differences in dose-area-product ($p=0.415$) or kinetic energy released per unit mass ($p=0.580$) among age groups.

Conclusion: There is a clear association between body mass index and radiation dose. Higher body mass index levels are linked with increased kinetic energy released per unit mass and dose area product values.

Key Words: Cardiac catheterization, dose area product (DAP), kinetic energy released per unit mass (KERMA), Anthropometric characteristics

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INTRODUCTION

When coronary arteries become narrowed or blocked, blood cannot adequately supply heart muscle, a condition known as ischemic heart disease (IHD). It's a leading cause of mortality worldwide. The most common causes of coronary artery diseases are hypertension, Diabetes mellitus, hyperlipidaemia, smoking, positive family history of IHD etc.[1]

Department of physiology, College of Medicine, University of Baghdad, Iraq.

Correspondence: Marwa Abd AL-Redha Abd Al-Khaliq Department of physiology, College of Medicine, University of Baghdad, Iraq.
Contact No: 07705358133
Email: marwa.abd2208m@comed.uobaghdad.edu.iq

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Radiation is increasingly being used in cardiac catheterisation, which necessitates real-time-imaging in both.

Coronary angiography (CA) is an invasive diagnostic procedure in which radio-contrast is injected into the coronary arteries (5-12ml) under X-ray guidance to display the coronary anatomy and possible luminal obstruction.[2]

Percutaneous coronary intervention (PCI) is a widely utilised non-surgical-procedure designed to treat this condition by enhancing blood flow through narrowed arteries. It involves inserting a catheter through a small skin incision to access the coronary arteries. PCI encompasses techniques like balloon angioplasty and stent insertion to relieve arterial narrowing.[3] It exposes patients to high doses of radiation during complicated procedures.[4] Fluoroscopy time affects radiation dose, in addition to many other, such as patients' anthropometric-characteristics, operator experience, the quality of fluoroscopy machines, and other conditions.[5] Radiation dose management is essential to help minimise the health risks associated with the use of

ionising radiation during cardiac catheterisation procedures.[6] This is important for the following reasons: health risks include deterministic effects like skin burns and tissue damage etc.[7] Cumulative exposure, patients with IHD often undergo multiple imaging and interventional procedures over their lifetime, which can lead to significant cumulative dose. Proper dose management helps limit this exposure, reducing the associated risks.[8] Safety of healthcare staff in cardiac catheterisation laboratories are also exposed to radiation. Managing radiation doses ensures that these exposures remain within safe limits, protecting the health of healthcare professionals over their careers.[9]

Image quality and diagnostic accuracy consisted of efficient dose management aims to reduce radiation exposure while maintaining or improving the quality of diagnostic imaging. Following the ALARA "As Low As Reasonably Achievable".[10] The influence of body mass index(BMI) and body surface area(BSA) on radiation exposure during cardiac catheterisation is a topic of considerable research interest, as anatomical variations can severely affect procedural safety and efficacy. Understanding specific patient characteristics that influence radiation doses is imperative for optimising procedural protocols. Studies have attempted to dissect the respective roles of BMI and BSA on radiation exposure during cardiac catheterisation, with a greater focus on BMI. A close study of more than 8,000 patients, for example, showed that both BMI and BSA are related to DAP, This sets up basic links between body measurements and radiation dose.[11]

Radiation dose measurement typically quantified using several different parameters to assess exposure. Key measurements include: DAP also known as KERMAarea product(KAP), this measures the total amount of radiation energy delivered to a specific area. It is a product of the dose and the area exposed, usually expressed in ($Gy \cdot cm^2$). DAP accounts for both the dose at a specific point expressed area exposed, making it useful for assessing overall patient exposure during a procedure.[12]Air KERMA refers to the kinetic energy from ionizing radiation deposited per unit mass of air, typically measured at a reference point in the X-ray beam.It's measured inmGy. Air KERMA provides an indication of the intensity of the radiation field.[13]The kilo voltage (kV) and milli ampere (mA) are two crucial parameters in fluoroscopy, controlling the x-ray beam's energy and intensity, respectively.[14]Fluoroscopy time is the total amount of time that fluoroscopy is used during a procedure. Increased fluoroscopy time correlates with higher radiation exposure. It is often used alongside other measurements to give context to the radiation exposure.[15]

METHODS

This prospective, single centre cross-sectional observational analytical study enrolled 110 patients include both genders who have IHD selected through successive sampling from Ibn-Al Bittar Centre for Cardiac Surgery, Baghdad Iraq from 1st May 2024 to 31st August 2024. Patient of both gender aged >30 years old with IHD were included while pregnant women and children were excluded. Angiogram was done in Single plane catheterisation lab (Philips Allura X per FD & Phillips Azurion release 2.2(L7)).The major coronary arteries were image as followed:

Left anterior descending (LAD) artery major branch of the left coronary artery supplying a significant portion of the left ventricle which is visualizing in a: Cranial (40°): (A view angled towards the cranial end of the patient); Fishbone (40°-40°); and spider (40°-40°).

Left circumflex (LCX) artery another major branch of the left coronary artery supplying the lateral wall of the left ventricle which is visualized in right anterior oblique [RAO] (30°) – caudal (20°); caudal (40°); and spider (40°-40°).

Right coronary artery (RCA) supplying the right ventricle and parts of the posterior left ventricle which visualizing in RAO (30°): right anterior oblique; and left anterior oblique [LAO] (60°-40°): LAO.

Since the fluoroscopy real time imaging its generates more than 40 image per second, Kv and mA change every second, to standardize measurements, the Kv and mA for LAO view was consider. Patient information, including age, gender were collected from self-reported entries in questionnaire filled out at the time of Cardiac catheterization, height was measured by Stadiometer, and weight were measuring using a scale. BMI calculated by ($BMI = weight/height^2$) then divided into 6 groups, underweight<18.5, normal 18.5-24.9, overweight 25-29.9, obesity 30-34.9, obesity 35-39.9, extreme obesity>40.BSA calculated by the DuBois formula (BSA=0.007184×height 0.725m×weight 0.425kg. Patient radiation exposure was measured by the catheterisation lab system the radiation metrics like Air KERMA, fluoroscopy time, and DAP are taken from radiation log of Individual procedure for that particular patient. Statistical Analysis done by IBM SPSS-26, descriptive statistics, Normality tests (Kolmogorov-Smirnov and Shapiro-Wilk), box plot, Spearman's rho correlation and ANOVA test.

RESULTS

The data is categorized by age groups and gender. For females, in the age group under 40 years no participants, in the 40–60 years age group, the number of participants were19 with a mean of 53.05 years, In the over 60 year's age group, the number of participants was also 19, with a mean of 65.73 years. For males, in the age group under 40 years, number of participants was 3, with a mean of 35.33 in the 40–60 years age group, there were 33 participants, with a mean of 50.71. In the over 60 year's age group, number of participants was 36, with a mean of 65.83 (Table 1).

KERMA and DAP values increase with BMI, but Extreme obesity group shows a decrease due to smaller sample size (n=7), making the mean less reliable. This is due to the increasing prevalence of obesity and the need for more accurate measurements. The kV shows a general increasing with increasing BMI, while mA shows less of a clear trend (Table 2).

Most BMI categories and both radiation dose variables, the p-values are <0.05 for both tests. This strongly evident that the radiation dose data within each BMI group is not normally distributed. The exceptions are KERMA, extreme obesity. The p-value is above 0.05 for both tests (n=5), suggesting normality cannot be rejected. However, the small sample size limits the test's power. DAP, extreme obesity. The Shapiro-Wilk test is close to significant (p=0.048), suggesting a possible deviation from normality. The small sample size again needs to be considered (Table 3).

The horizontal axis represents the BMI categories, while vertical axis indicates KERMA values. Each box plot demonstrates the range of radiation exposure for the corresponding BMI group. The boxes highlight the interquartile range (IQR), which encompasses the middle 50% of data points, with the median value marked by a line within the box. Extending from the boxes are vertical lines, which depict the minimum and maximum values within a reasonable range. Outside these lines, outlier'scases with radiation levels that deviate significantly from the majority (Fig. 1).

As BMI increases, there is a general increase in KERMA values, indicating that individuals with higher BMI have greater radiation exposure. This is particularly evident in the obesity- category, where the range of KERMA values is remarkably wide, suggesting significant variability in exposure levels within this group. Similarly, the extreme obesity category shows consistently high KERMA values, although the sample size appears smaller, leading to less variability. In contrast, the underweight and normal groups, exhibit narrower distributions of KERMA values. Nonetheless, even in these groups, a few outliers are present, indicating occasional instances of unusually high radiation exposure. The X-axis represents BMI categories, while the Y-axis represents DAP (Gy/cm²), observed patterns increase in DAP with higher BMI due to the radiation dose increases progressively as BMI moves from underweight to obesity classes. Greater variability in higher BMI categories, Obesity classes, especially II and III, exhibit a broader spread of values and more outliers (Fig. 2). The Spearman's correlation suggests a weak positive association between BSA and KERMA, but the result is non-significant (Table 4).

The strength of the association between BSA and several other variables (KERMA, DAP, kV, mA). KERMA-BSA: A weak positive linear correlation (R= 0.136, $R^2 = 0.018$) is observed. However, the Eta value (0.642, $Eta^2=0.412$) indicates a much stronger association when considering BSA as a categorical variable (perhaps due to binning or grouping). This discrepancy suggests a non-linear relationship or the presence of outliers affecting the linear correlation.

Table No.1: Frequency of male and female according to age

Age (years)	Male	Female
Under 40	3	-
40-60	32	19
Over 60	36	19

Table No.2: Mean KERMA, DAP, KV and mA across body mass index groups

BMI Groups	Mean KERMA (mGy)	Mean DAP (Gy/cm²)	KV	mA
Under weight	277.7	19.33	73	727
Normal	878.2071	65.6572	76.67	699.19
Overweight	1102.4384	66.1011	86.21	747.24
obesity I	1606.8228	112.3007	83.34	777.63
Obesity	1719.8982	92.2175	99.27	722.36
Extreme obesity	850.2857	52.0571	109.86	676.86
Total	1244.5629	80.749	86.25	739.75

Table No.3: Normality Test for KERMA and DAP radiation dose measures across BMI categories

Normality test	BMI	Shapiro-Wilk			
		Statis-tic	P-value.	Statis-tic	P-value
KERMA (mGy)	Underweight	.260			
	Normal	.248	.014	.763	.001
	Overweight	.224	.000	.687	.000
	Obesity I	.234	.000	.628	.000
	Obesity	.302	.001	.746	.001
	Extreme obesity	.269	.200	.830	.138
DAP (Gy/cm²)	Underweight	.260			
	Normal	.307	.000	.761	.001
	Overweight	.249	.000	.709	.000
	Obesity I	.211	.000	.638	.000
	Obesity	.303	.001	.758	.001
	Extreme obesity	.318	.110	.773	.048

Table No.4: Correlations coefficient between BSA and KERMA

Spearman's		KERMA (mGy)	BSA
KERMA (mGy)	Correlation-Coefficient	1.000	.182
	P-value	.	.057
	N	110	110
BSA	Correlation-Coefficient	.182	1.000
	P-value	.057	.
	N	110	110

Table No.5: Measures of association of BSA with radiation-parameters

	R	R^2	Eta	Eta^2
KERMA-BSA	.136	.018	.642	.412
DAP-BSA	.173	.030	.678	.460
KV-BSA	.470	.221	.805	.648
mA-BSA	.005	.000	.698	.487

DAP-BSA: Similar to KERMA, a weak positive linear correlation (R=0.173, R^2 = 0.030) is observed, but the Eta value (0.678, Eta^2=0.460) suggests a much stronger association when BSA is treated categorically. Again, this points to a non-linear relationship or outlier influence. KV-BSA: A moderate positive linear correlation (R=0.470, R^2=0.221) is observed, indicating that 22.1% of the variance in kV is explained by BSA. The Eta value (0.805, Eta^2=0.648) is even higher, suggesting a strong association when BSA is treated categorically. The relatively close agreement between R and Eta suggests a reasonably linear relationship. mA-BSA: A negligible linear correlation (R=0.005, R^2=0.000) is observed. However, the Eta value (0.698, Eta^2=0.487) indicates a strong association when BSA is treated categorically. This large discrepancy strongly suggests a non-linear relationship or the presence of significant outliers (Table 5). This ANOVA results investigating the relationship between a radiation parameter (KERMA, DAP) and age categories: KERMA: Age categories overall effect: There was no-significant difference in the mean KERMA between age groups (p=0.580). DAP-Age Categories Overall Effect: The mean DAP did not significantly differ among age groups (p=0.415) [Table 6].

Table No.6: Relationship between age categories and radiation-parameters

Age categories		Sum of Squares	df	Mean Square	F	P-value
KERMA (mGy)	Between Groups	4023813.972	3	1341271.324	.658	.580
	Within Groups	216129179.968	106	2038954.528		
DAP (Gy/cm^2)	Between Groups	22720.220	3	7573.407	.958	.415
	Within Groups	837758.018	106	7903.378		

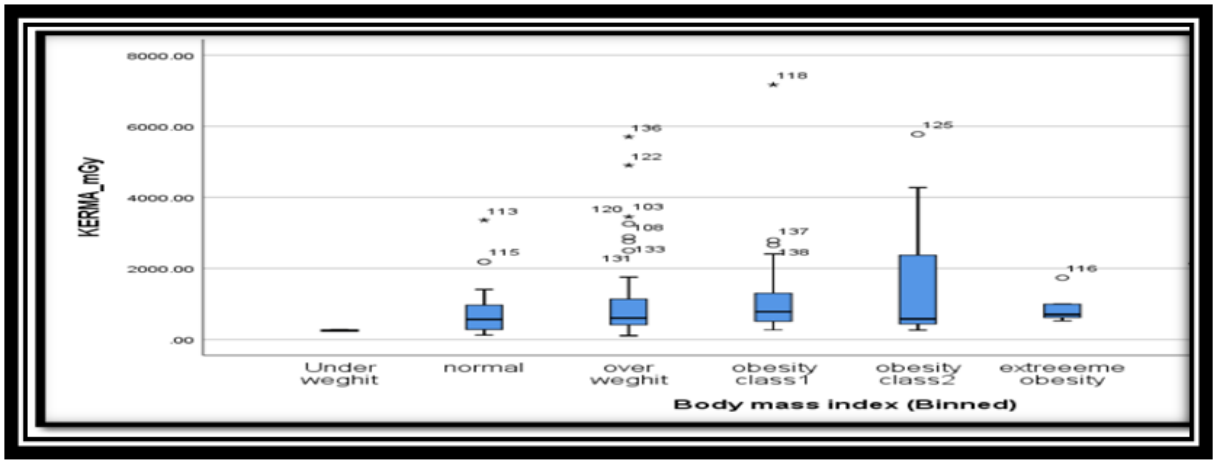

Figure No. 1: KERMA across BMI categories

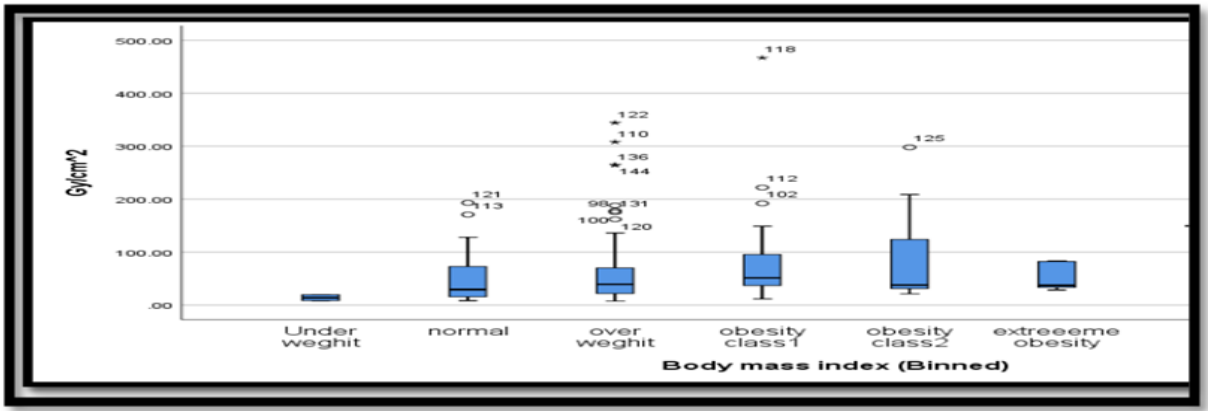

Figure No, 2: DAP (Gy/cm^2) across BMI categories

DISCUSSION

A significant relationship between body mass index (BMI) and radiation exposure, indicating that higher BMI levels are linked to increased KERMA values.[11,16]This observation prompts an exploration of the factors contributing to the wide variability in exposure levels among individuals in obesity. As BMI increase , there is an increase in the thickness of body tissues, including fat and muscle,obesity is often categorized by two types of fat distribution: visceral (around organs) and subcutaneous (under the skin). Visceral fat can lead to increased abdominal girth, while subcutaneous fat affects overall body shape and the proportion of fat that overlays vital organs.[17] The presence of significant fat around the heart (epicardia fat) cases difficulties in accurately imaging cardiac structures because fat has a lower atomic number and density compared to muscle and organ tissues, this leads to a differential attenuation of x-rays, specifically, fat will attenuate x-rays less than muscle tissue. An increased layer of fat may results in diminished visibility of vascular structures during cardiac catheterization impacting the contrast and resolution of the image obtained. Therefore, modern fluoroscopy automatic system raises the KVp subsequently more x-ray produces to obtain more resolution hence leading to greater radiation absorption.[16]

It also important to note that individuals with obesity may have a higher prevalence of chronic health conditions, such as coronary artery disease, diabetes, or respiratory disorders.[18] This association can result in an increased frequency of medical imaging and, subsequently, higher radiation exposure. Understanding these dynamics is crucial for developing tailored imaging strategies that minimize risk while maintaining diagnostic efficacy.

This study found a positive correlation between BMI and radiation doseDAP.[19,20]With higher BMI categories requiring more radiation for effective imaging . Obesity categories exhibit more variability in radiation doses, reflecting the challenges in imaging individuals with higher BMI., Uneven fat distribution may require different imaging settings, leading to dose variability and the outliers indicate significant variation in radiation doses for individuals within the same BMI category. These may result from unique anatomical characteristics, technical challenges, or inconsistent equipment calibration.

Kohet al[11] stated that beyond factors such as sex, BMI, and overall weight, BSA serves as a reliable biomarker for assessing radiation exposure and dose. Furthermore, BSA is identified as a significant anthropometric parameter that varies between sexes.While this study indicates that the linear correlation between BSA and radiation dose is relatively weak. However, a more robust association is observed when BSA is analysed in a categorical manner. In contrast, the relationship between BSA and kilovolt (kV) appears to exhibit a more pronounced and linear correlation.

There is no statistically significant evidence of an overall effect of age category on the KERMA&DAP (Table 5). This suggests that, within the age ranges considered in this study, age does not significantly influence these radiation parameters which provides strong evidence that age does not significantly influence KERMA, DAP within the age ranges and other conditions of this study.

CONCLUSION

Body mass index has been shown to be a significant factor in determining the radiation dose to both the patient and the operator, in such a way that higher BMI raises the DAP and KERMA exposure during cardiac catheterization procedures.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Marwa Abd AL-Redha Abd Al-Khaliq, Najeeb Hassan Mohammed
Drafting or Revising Critically:	Marwa Abd AL-Redha Abd Al-Khaliq, Najeeb Hassan Mohammed
Final Approval of version:	All the above authors
Agreement to accountable for all aspects of work:	All the above authors

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