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RESEARCH PAPER

Impacts of body mass index on radiation exposure of patients undergo interventional cardiology

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A B S T R A C T:
Impacts of patient body mass index (BMI) on the radiation exposure during interventional cardiology procedures have been investigated. The study included cardiac catheterization and percutaneous coronary intervention patients between January and August 2021 (89 patients: ages: 36-80 years old: male and female). Radiation exposure (x-ray) was recorded clinically, and the patient radiation exposure was established into three groups. First, the clinical data and technical factors were gathered from 29 Cardio angiography (CA); second, 30 percutaneous coronary intervention (PCI). Third, 30 double set-ups (CA/PCI) procedures; all performed using the femoral approach. Statistics is a powerful statistical software (SPSS) has been used to analysis the recorded data with a linear regression model. The results were shown a significant correlation between the body mass index (BMI) and the variables parameters; kV, mA, FT and DAP. For every value of BMI of the patients visiting the cardiology hospital, the specific and real needed value of (kV, mA, FT, and DAP) can be determined using the above models. The regression analysis method can be used in quality assurance and driving the diagnostic reference level and dose optimization.

KEY WORDS: Body mass index; cardiology; radiation exposure; radiation dose; x-ray
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1.INTRODUCTION :

Interventional cardiology (IC) procedures are increasingly used for the diagnosis and treatment in clinical practice. The most frequently reported cardiac procedures by interventional fluoroscopy are coronary angiography (CA) and percutaneous coronary intervention (PCI) (Pantos et al., 2009). From this procedure, the X-rays are taken after a radiopaque contrast agent is injected into the left or right ventricle of the heart through a catheter, leading to increased exposure to ionization radiation (Liu et al., 2020; Proietti et al., 2017). However, with the high prevalence of obesity in the general population, obesity has become more prevalent among IC patients. There is a significant relationship between obesity and body mass index, increasing body mass index (BMI) (Madder et al., 2019).

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The body mass index values are calculated by measuring the weight and height values for each case, and it is also called: Keetele index (Heymsfield and Cefalu, 2013). There was an association between patient body mass index (BMI) and absorbed radiation dose during radiation exposure approved during previous studies (Salah et al., 2018). This increase in radiation dose is attributable to the increased energy required to overcome tissue attenuation and facilitate a sufficient number of photons reaching the image intensifier to generate adequate images (Fetterly et al., 2011).
Three types of factors influence radiation dose to the patient during interventional cardiology. The first technical factor affects radiation dose (X-ray beam quality, X-ray geometry, X-ray beam limitation devices, and fluoroscopic and acquisition imaging dose rate settings. The second type is Procedure-related factors include the increase in treatment of complex lesions, such as chronic total occlusions, because of improvements

in techniques and IC equipment. Moreover, the third Group of Factors is Patient-related factors (body mass index, comorbidities, and seriousness of coronary artery disease) (Clark et al., 2000; Fetterly et al., 2011).

Concurrently, the number of diagnostic and therapeutic procedures in modern cardiology has increased the exposure to ionizing radiation. Along with using automatic exposure control (AEC) equipment, especially in interventional cardiology studies, the harmful effects of ionizing radiation have increased (Yamagata et al., 2016).

The present study was performed to estimate the association relationship between patient's BMI and radiation exposure factors for the patients undergoing IC. The investigation of the relationship is done using statistical analyzes methods regarded as linear regression methods.

2.MATERIALS AND METHODS

2.1 Data Collection

The CA, PCI and combined CA and PCI (CA/PCI) data were performed from 1 January to 31 August 2021 and collected from the Erbil Heart center, Kurdistan region-Iraq. Some important factors have been taken into account to estimate body mass index, such as; patient characteristics (age, sex, weight, and length); exposure factors kV, mA and FT, DAP and PSD. Clinical data and technical factors were gathered from 29 Cardio angiography (CA), 30 percutaneous coronary intervention (PCI), and 30 double set-ups (CA/PCI) procedures, all performed using the femoral approach. The data was gathered using a stratified random sampling method. The mentioned center has ten cardiologists, ten nurses and 10 radiology technicians. In the center, four angiography rooms were active and there is four fluoroscopy x-ray machine. In rooms 1 and 2, a Philips medical system manufactured in 2019, model: MRC 2000407, S/N (1927A4 ,191502) was set , in room 3 is geared with Philips medical system manufactured in march 2006 S/N 231 and In room 4: GE medical system by SIMENS, model : CARD AMP , manufactured in 2006 Germany S/N 1210(Innova 2100).

2.2 Statistical Analysis:

To analysis the result statistically, we used the simple linear regression model in this study. A simple linear regression model is used to model, characterize, optimize, and/or predict a continuous response as a function of independent variables. The process of performing a linear regression allows you to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other. The model has the following (basic) form:

$$Y = \beta_0 + \beta_k X_{ik} \quad \text{----------------------(1)}$$

where Y_i is the i^{th} observed response in the dataset, β_0, β_k are the model parameters we wish to estimate, X_{ik} are the k independent variables (also called factors or predictors) for the i^{th} observation (Domínguez-Almendros et al., 2011).

In this study, the observed response variable are kV, mA, FT and DAP, where the independent variable is BMI. According to this, the model to this study has the following form:

$$\begin{cases} kV = \beta_{Kv}\, BMI \\ mA = \beta_{mA} BMI \\ FT = \beta_{Kv} BMI \\ DAP = \beta_{DAP}\, BMI \end{cases} \quad \text{----------------- (2)}$$

The regression method was chosen with a free intercept. The justification for this is that the AEC compensates by keeping the quantity of radiation. T-test was used to determine the significance of the coefficients and test the goodness of fit of the model F-test using the ANOVA table. To determine the interpretation ratio of the used model, R^2 was evaluated.

3.RESULTS

The summary of 89 patients' data for three interventional cardiology process groups CA, PCI and CA/PCI, and their associated radiation dose metric with exposure factors are listed in Table 1. The normalization of BMI for the three groups is shown in Figure 1. The relation between the BMI and kV, mA, FT and DAP are shown in the scatter plot in Figure (2). Also, a boxplot for four response variables, kV, mA, FT, DAP and explanatory variable BMI, was drawn for the three groups. The result of simple linear regression to obtain the relationship between the response variables above and the explanatory variable BMI was shown in Tables 2 and 3. The simple linear regression was calculated to predict each (kV, mA, FT, and DAP) based on BMI for three groups. The first group for CA is in Table 3; a significant regression equation based on kV versus BMI was found. The F test P-Value < .000 indicates a highly significant effect, with an R^2 of 0.957 interpretation kV. The predicted model was

$$kV = 2.984\ BMI \quad \text{---------------------- (3)}$$

where the effect of BMI with a significant amount of 2.984 (t-test P-Value <0.000, as in Table 2) reflects on kV.

A significant regression equation based on mA versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.911 interpretation of mA. The predicted model was

mA = 0.508 BMI ----------------------- (4)

where the effect of BMI with a significant amount of 0.508 (t-test P-Value <0.000, as in Table 2) reflects on mA.

A significant regression equation based on FT versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.672 interpretation of FT. The predicted model was

FT = 0.127 BMI -------------------- (5)

where the effect of BMI with a significant amount of 0.27 (t-test P-Value <0.000, as in Table 2) reflects on FT.

A significant regression equation based on DAP versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.574 interpretation of DAP. The predicted model was

DAP = 1.635 BMI -------------------- (6)

where the effect of BMI with a significant amount of 1.635 (t-test P-Value <0.000, as in Table 2) reflects on DAP.

For PCI model, a significant regression equation based on kV versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.955 interpretation of kV. The predicted model was

kV = 2.788 BMI ----------------------- (7)

where the effect of BMI with a significant amount of 2.788 (t-test P-Value <0.000, as in Table 2) reflects on kV.

A significant regression equation based on mA versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.950 interpretation of mA. The predicted model was

mA = 0.559 BMI ----------------------- (8)

where the effect of BMI with a significant amount of 0.559 (t-test P-Value <0.000, as in Table 2) reflects on mA.

A significant regression equation based on FT versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.754 interpretation of FT. The predicted model was

FT = 0.361 BMI ----------------------- (9)

where the effect of BMI with a significant amount of 2.984 (t-test P-Value <0.000, as in Table 2) reflects on FT.

A significant regression equation based on DAP versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.881 interpretation of DAP . The predicted model was

DAP = 2.521 BMI ------------------- (10)

where the effect of BMI with a significant amount of 2.984 (t-test P-Value <0.000, as in Table 2) reflects on DAP .

For CA/PCI model , a significant regression equation based on kV versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.963 interpretation of kV. The predicted model was

kV = 2.872 BMI -------------------- (11)

where the effect of BMI with a significant amount of 2.872 (t-test P-Value <0.000, as in Table 2) reflects on kV.

a significant regression equation based on mA versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.920 interpretation of mA. The predicted model was

mA = 0.490 BMI --------------------- (12)

where the effect of BMI with a significant amount of 0.490 , (t-test P-Value <0.000, as in Table 2) reflects on mA.

A significant regression equation based on FT versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.743 interpretation of FT. The predicted model was

FT = 0.282 BMI ----------------------- (13)

where the effect of BMI with a significant amount of 0.282 (t-test P-Value <0.000, as in Table 2) reflects on FT.

A significant regression equation based on DAP versus BMI was found, the F test P-Value < .000 indicating a very highly significant effect, with an R^2 of 0.680 interpretation of DAP . The predicted model was

$DAP = 2.983\ BMI$ -------------------- (14)

where the effect of BMI with a significant amount of 2.983 (t-test P-Value <0.000, as in Table 2) reflects on DAP.

4.DISCUSSION

Exposure factors and radiation dose of patients have not been comprehensively studied, particularly the effect of Body Mass Index (BMI). In the present study, an evaluation of the patient's exposure factors and radiation dose during diagnostic and interventional cardiology was investigated and correlated with the patient's (BMI). According to the regression model result, all the factors studied in this research, namely kV, mA, FT and DAP, have a significant relationship with the BMI and confidently determine this result, which agrees with the published by others (Georges et al., 2017; Mercuri et al., 2009; Shah et al., 2015). However, no explanation and clarification allow the relationship between BMI and radiation exposure factors and identify the most important factors and factors that can be ignored. Therefore, this study is the first step in forming a model to indicate the relationship between kV, mA, FT, DAP and BMI, and the most influential factor. As shown in the results, all the estimated values for the coefficients of all three groups, CA, PCI, and CA/PCI, the simple linear regression models, were highly significant Table 2. Besides the very highly significant models fitting using F-test, expressing the reliable models that BMI can explain the response variables (kV, mA, FT, and DAP) as in the above equation models (3,4, 5, ... and 14). The standard probability plot of the residuals shown in figure (4) can be used to check whether the variance is usually distributed, where the resulting plot is approximately linear. We proceed by assuming that the error terms are normally distributed. Furthermore, the plot is based on the percentiles versus ordered residuals (Domínguez-Almendros et al., 2011).

Table 1: Some descriptive Statistics for patient characteristics for the groups CA, PCI, and CA/PCI, with their associated radiation dose metric and exposure factors.

	n		kV	mA	DAP/(Gy.cm^2)	FT (minutes)	BMI (kg/m^2)
CA	29	mean ± SD	80.48 ± 17.8	13.98 ± 3.36	44.27 ± 38.53	3.5 ± 2.34	26.74 ± 3.75
		(Min. - Max.)	(53-120)	(5.9-18.7)	(4.51-148)	(1.08-12)	(15.24-33.31)
PCI	30	mean ± SD	78.9 ± 16.65	15.93 ± 3.05	69.78 ± 30.26	10.18 ± 5.93	28.04 ± 3.42
		(Min. - Max.)	(45-120)	(8.6-19.5)	(4.51-148)	(2-24.8)	(15.24-34.13)
CA/ PCI	30	mean ± SD	82.47 ± 18.58	14.4 ± 3.27	86.22 ± 59.84	8.18 ± 4.82	28.65 ± 3.59
		(Min. - Max.)	(54-120)	(7-18.7)	(28.1-241.41)	(1.1-19.4)	(23.44-35.65)

Table 2: Simple linear regression coefficients for the response BMI (kg/m^2) with KV, mA, FT, and DAP predictor variables through origin.

Model	Response	Predictor	Unstandardized Coefficients		t	Sig.
			β	Std. Error		
CA	kV	BMI (kg/m2)	2.984	0.120	24.854	0.000
	mA	BMI (kg/m2)	0.508	0.030	16.935	0.000
	FT(minutes)	BMI (kg/m2)	0.127	0.017	7.582	0.000
	DAP(Gy.cm^2)	BMI (kg/m2)	1.635	0.266	6.142	0.000
PCI	kV	BMI (kg/m2)	2.788	0.113	24.693	0.000
	mA	BMI (kg/m2)	0.559	0.024	23.482	0.000
	FT(minutes)	BMI (kg/m2)	0.361	0.038	9.439	0.000
	DAP(Gy.cm^2)	BMI (kg/m2)	2.521	0.172	14.624	0.000
CA/PCI	kV	BMI (kg/m2)	2.872	0.104	27.624	0.000
	mA	BMI (kg/m2)	0.490	0.027	18.315	0.000
	FT(minutes)	BMI (kg/m2)	0.282	0.031	9.152	0.000
	DAP(Gy.cm^2)	BMI (kg/m2)	2.983	0.380	7.854	0.000

Table 3: ANOVA table for the response variables kV, mA, FT, and DAP each with BMI (kg/m^2) as predictor variable through origin for all models.

Models	Response	Source	Sum of Squares	d.f.	Mean Square	F	Sig.	R^2
CA	kV	Regression	188183.989	1	188183.989	617.719	.000	0.957
		Residual	8530.011	28	304.643			
		Total	196714.000	29				
	mA	Regression	5448.934	1	5448.934	286.799	.000	0.911
		Residual	531.976	28	18.999			
		Total	5980.910d	29				
	FT	Regression	342.186	1	342.186	57.481	.000	0.672
		Residual	166.685	28	5.953			
		Total	508.871d	29				
	DAP	Regression	56490.303	1	56490.303	37.719	.000	0.574
		Residual	41934.095	28	1497.646			
		Total	98424.398	29				
PCI	kV	Regression	185951.233	1	185951.233	609.761	.000	0.955
		Residual	8843.767	29	304.957			
		Total	194795.000	30				
	mA	Regression	7485.807	1	7485.807	551.416	.000	0.950
		Residual	393.693	29	13.576			
		Total	7879.500	30				
	FT	Regression	3116.441	1	3116.441	89.093	.000	0.754
		Residual	1014.405	29	34.979			
		Total	4130.846d	30				
	DAP	Regression	152013.669	1	152013.669	213.872	.000	0.881
		Residual	20612.289	29	710.769			
		Total	172625.958	30				
CA/PCI	kV	Regression	206191.902	1	206191.902	763.079	.000	0.963
		Residual	7836.098	29	270.210			
		Total	214028.000	30				
	mA	Regression	6010.997	1	6010.997	335.433	.000	0.920
		Residual	519.683	29	17.920			
		Total	6530.680	30				
	FT	Regression	1990.977	1	1990.977	83.764	.000	0.743
		Residual	689.300	29	23.769			
		Total	2680.277	30				
	DAP	Regression	222337.716	1	222337.716	61.678	.000	0.680
		Residual	104539.166	29	3604.799			
		Total	326876.883	30				

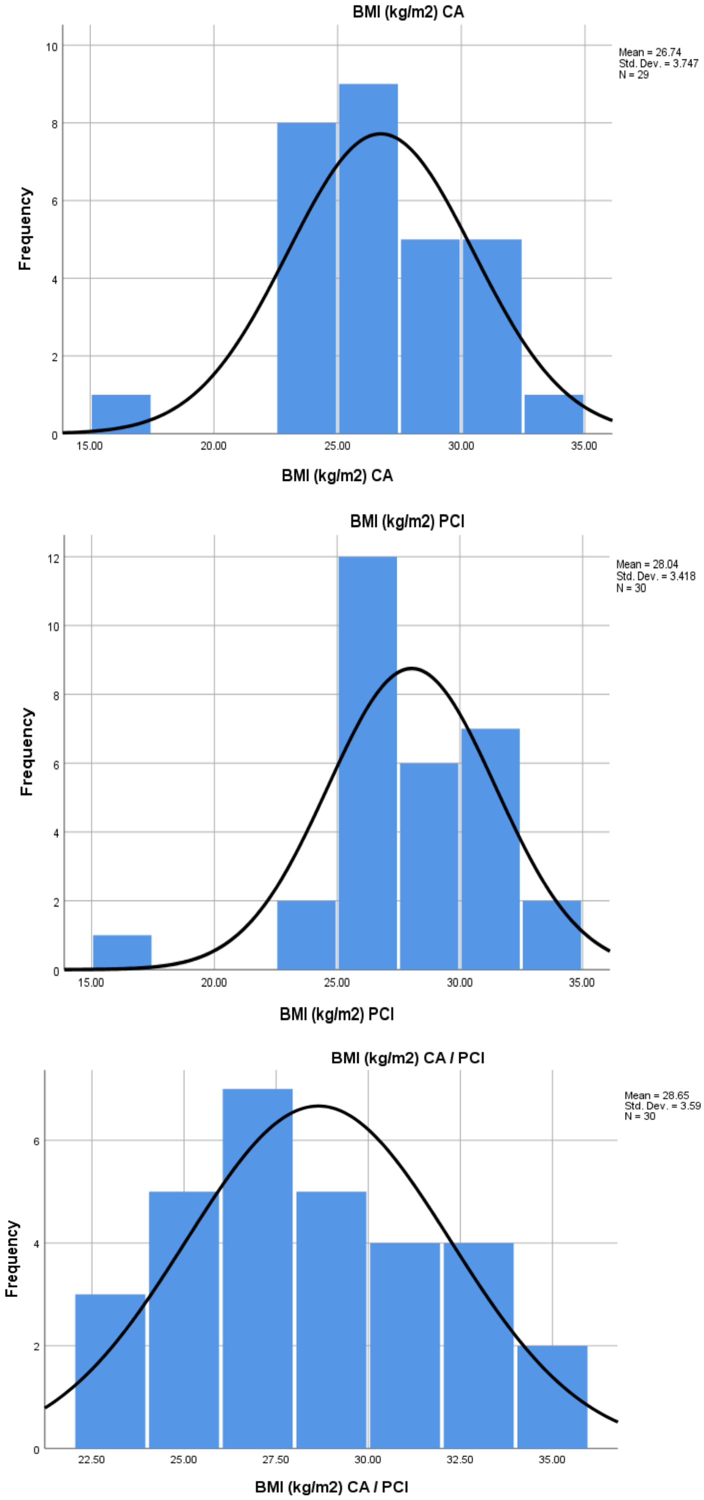

Fig 1. Normalization of BMI in CA, PCI , and CA/PCI.

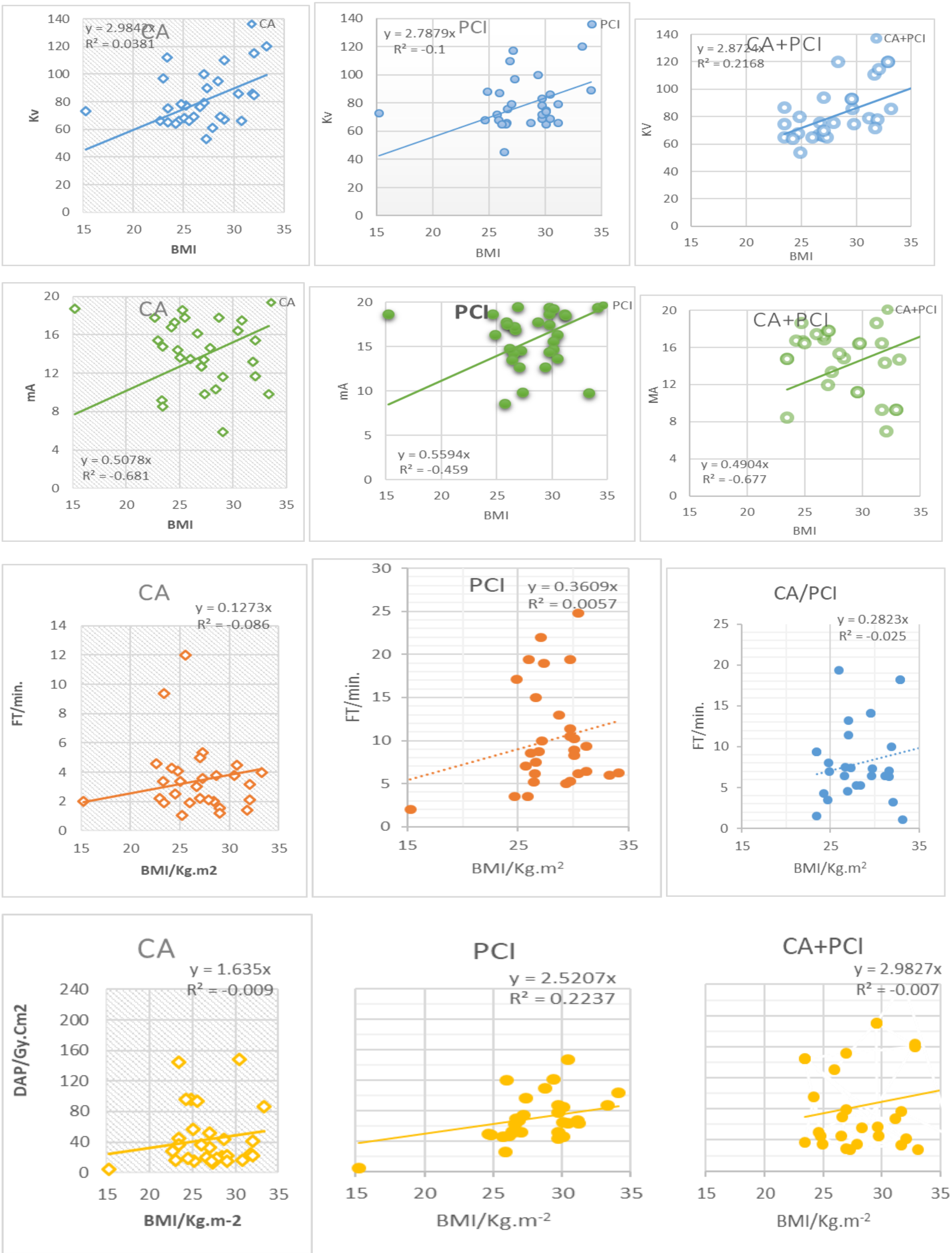

Fig 2. Scatter plots matrix showing BMI as function of Kv, mA, FT, and DAP, respectively, for CA, PCI, and CA/PCI.

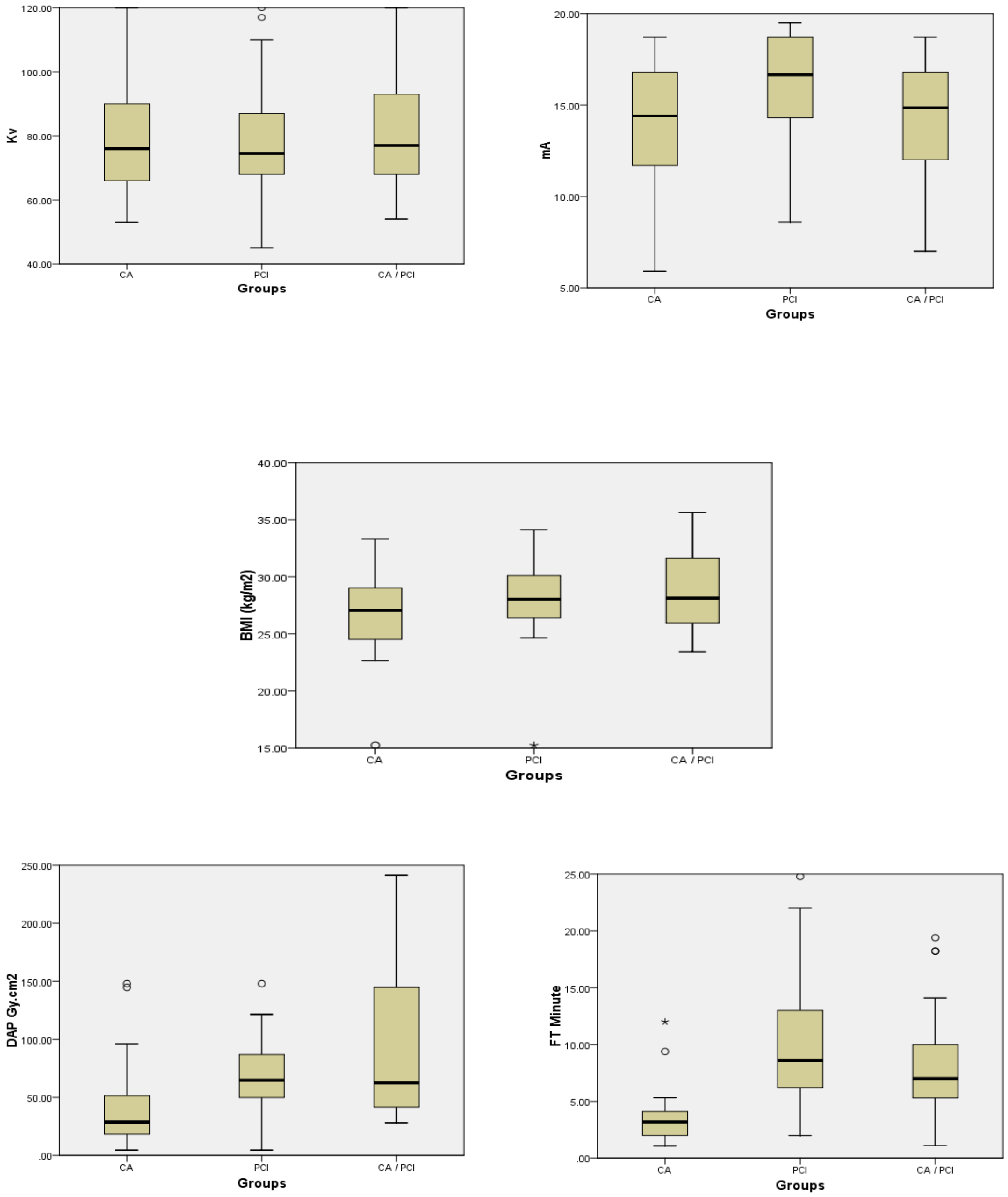

Fig3. Boxplots showing the four predicting variables Kv,mA, FT,DAP and BMI

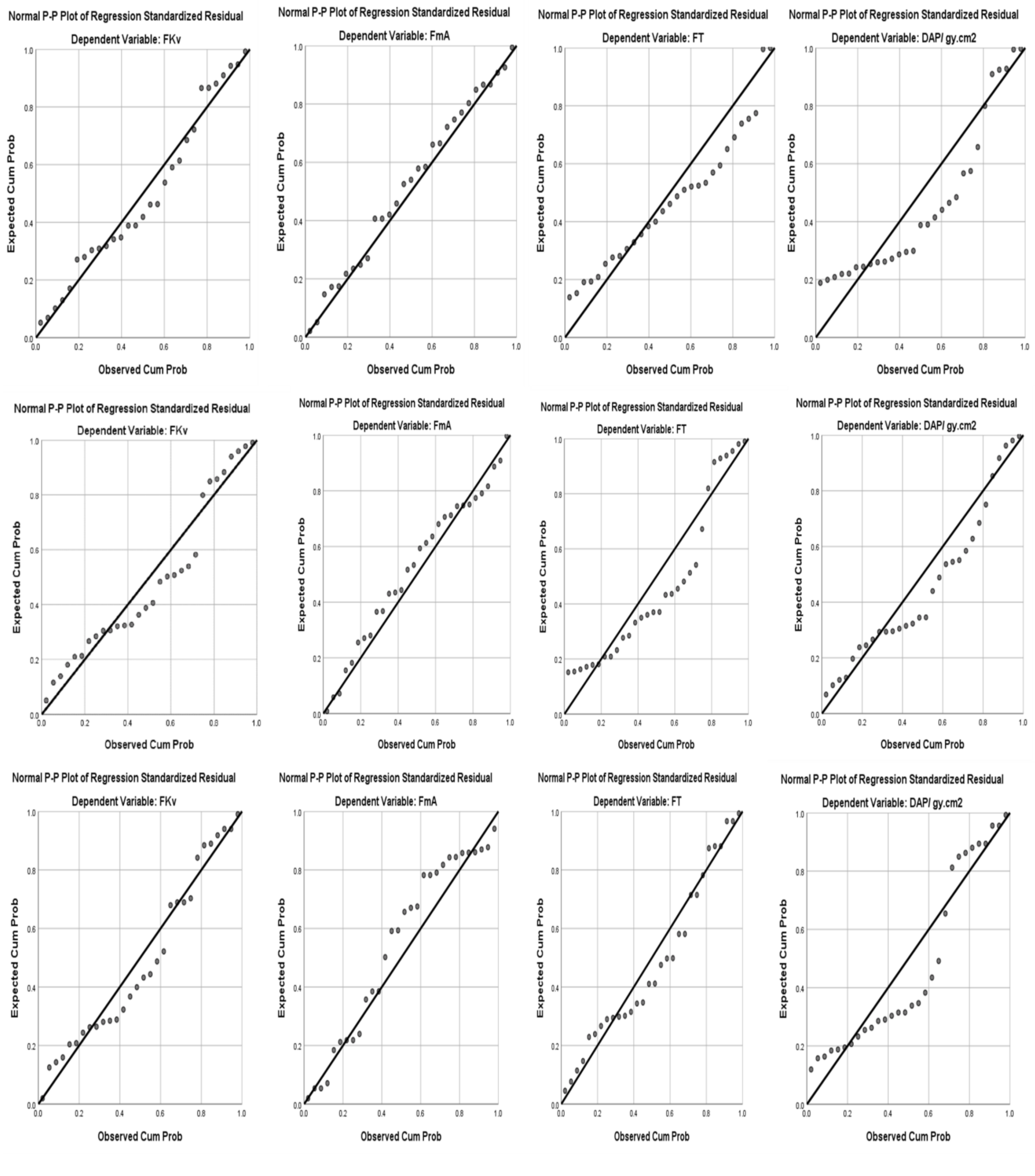

Fig4: Normal P-P plot of regression standardized residual dependent variable (kV, mA, FT and DAP) for all Three group CA, PCI and CA/PCI.

5. CONCLUSIONS

The body mass index was the main parameter that coordinated with the radiation absorption dose. Impacts of patient body mass index (BMI) on the radiation exposure during interventional cardiology procedures (ICP) were high significant impacts. The study concludes that for every value of BMI for the patients visiting the cardiology hospital, the specific and real needed value of (kV, mA, FT, and DAP) can be determined using the above models. In other words, the risk of over or undervalues for the response values will be avoided. The regression analysis method can be used in quality assurance and driving the diagnostic reference level and dose optimization.

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Conflict of Interest

The authors declare no conflict of interest

References:

Clark, A., Brennan, A., Robertson, L., McArthur, J., 2000. Factors affecting patient radiation exposure during routine coronary angiography in a tertiary referral centre. *The British journal of radiology* 73, 184-189.

Domínguez-Almendros, S., Benítez-Parejo, N., Gonzalez-Ramirez, A., 2011. Logistic regression models. *Allergologia et immunopathologia* 39, 295-305.

Fetterly, K.A., Lennon, R.J., Bell, M.R., Holmes, D.R., Rihal, C.S., 2011. Clinical determinants of radiation dose in percutaneous coronary interventional procedures: influence of patient size, procedure complexity, and performing physician. *JACC: Cardiovascular Interventions* 4, 336-343.

Georges, J.-L., Karam, N., Tafflet, M., Livarek, B., Bataille, S., Loyeau, A., Mapouata, M., Benamer, H., Caussin, C., Garot, P., 2017. Time-course reduction in patient exposure to radiation from coronary interventional procedures: the greater Paris area percutaneous coronary intervention registry. *Circulation: Cardiovascular Interventions* 10, e005268.

Heymsfield, S.B., Cefalu, W.T., 2013. Does body mass index adequately convey a patient's mortality risk? *Jama* 309, 87-88.

Liu, X., Guo, L., Xiao, K., Zhu, W., Liu, M., Wan, R., Hong, K., 2020. The obesity paradox for outcomes in atrial fibrillation: Evidence from an exposure-effect analysis of prospective studies. *Obesity Reviews* 21, e12970.

Madder, R.D., VanOosterhout, S., Mulder, A., Ten Brock, T., Clarey, A.T., Parker, J.L., Jacoby, M.E., 2019. Patient body mass index and physician radiation dose during coronary angiography: is the obesity epidemic impacting the occupational risk of physicians in the catheterization laboratory? *Circulation: Cardiovascular Interventions* 12, e006823.

Mercuri, M., Xie, C., Levy, M., Valettas, N., Natarajan, M.K., 2009. Predictors of increased radiation dose during percutaneous coronary intervention. *The American journal of cardiology* 104, 1241-1244.

Pantos, I., Patatoukas, G., Katritsis, D.G., Efstathopoulos, E., 2009. Patient radiation doses in interventional cardiology procedures. *Current cardiology reviews* 5, 1-11.

Proietti, M., Guiducci, E., Cheli, P., Lip, G.Y., 2017. Is There an Obesity Paradox for Outcomes in Atrial Fibrillation? A Systematic Review and Meta-Analysis of Non–Vitamin K Antagonist Oral Anticoagulant Trials. *Stroke* 48, 857-866.

Salah, A., Taha, A.A., Diab, H., Abdel Ghany, H., 2018. Investigation of effect of body mass index of patient radiation dose during interventional cardiac processes. *Journal of Scientific Research in Science* 35, 87-94.

Shah, A., Das, P., Subkovas, E., Buch, A.N., Rees, M., Bellamy, C., 2015. Radiation dose during coronary angiogram: relation to body mass index. *Heart, Lung and Circulation* 24, 21-25.

Yamagata, K., Aldhoon, B., Kautzner, J., 2016. Reduction of fluoroscopy time and radiation dosage during catheter ablation for atrial fibrillation. *Arrhythmia & electrophysiology review* 5, 144.