The Effect of Obesity on Medical Imaging

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Keywords: CT, Obesity, IBM, X-ray and Medical imaging.

1. Introduction:

Medical imaging encompasses various technologies used to view the human body for diagnosing, monitoring, or treating medical conditions, with each method providing unique information.[1] **Computed tomography (CT)** is a widely used imaging technique that utilizes X-rays to generate detailed three-dimensional images of internal organs through two-dimensional slices. CT scans excel in showing bone details with high clarity, unlike MRI, which is better for soft tissues. The process is non-invasive and painless.[2] CT images are cross-sectional and can be reconstructed into three-dimensional visuals using computer processing. This technology is prevalent, with 80 million procedures annually in the U.S. and 50 million in Japan. However, excessive use raises concerns about potential cancer risks.[3]. Beyond medicine, CT is also employed in archaeology to study artifacts like ancient coffins. CT scanners offer quick, accurate, and detailed imaging of areas difficult to capture with standard X-rays.[4]

2. The aim of study:

The global rise in overweight and obese populations has created challenges in radiography, particularly for imaging obese patients. These challenges include increased radiation doses and reduced image quality (IQ). Research has focused on examining the impact of obesity on radiation dose and image quality in adult abdominal imaging.

Literature Review:

The foundation of tomography dates back to the early 19th century, when a scientist proposed that an object could be reconstructed using multiple geometric projections. Later, a Polish scientist developed a method for approximating solutions to numerous linear algebraic equations, which became crucial in the development of the first tomography machine. In 1959, the concept of using X-rays to scan the head and calculate the radial mass of a flat surface was introduced. This idea led to the creation of the first tomography machine in England, with the first successful scan conducted in London in 1971, taking approximately two and a half hours. Over the past decade, advances in computed tomography (CT) technology have significantly improved the efficiency and ease of CT scanning for both children and adults, as noted by Robinson and Terry E [5]. Advancements in scanning protocols have enabled comprehensive evaluations of cystic fibrosis (CF) lung disease with reduced radiation exposure. These new techniques offer greater flexibility in designing CT protocols tailored for early and advanced stages of the disease, incorporating CF scoring systems and quantitative measures of CT findings. Mayo and John R. demonstrated that helical multi-detector array CT scanners can produce contiguous high-resolution chest images, facilitating accurate, noninvasive diagnoses of various metastatic lung diseases while maintaining acceptable radiation exposure levels. Optimizing the benefit-risk ratio requires careful justification of diagnostic and follow-up scans and the implementation of all available dose reduction tools. Given the complexity of modern CT acquisition protocols, dose optimization is most effective through collaboration among radiologists, medical physicists, and radiology technologists [6]. Common CT dose indicators include the volume CT dose index (CTDI vol) and the dose-length product, which are also utilized in establishing national diagnostic reference levels (DRLs). However, CTDI vol represents the radiation output measured using a reference phantom and does not account for patient size, making it an indirect measure of actual patient dose. To address this limitation, the American Association of Physicists in Medicine (AAPM) Task Groups 204 and 220 proposed the size-specific dose estimate (SSDE). This method estimates patient dose by applying conversion coefficients to CTDI vol, adjusted for the patient's size, providing a more accurate assessment of radiation exposure [7-8].

3.1 Patient and Methodology

3.1.1 Patient

This study was done at the Kadhimiya-hospital, Diagnostic radiology department (CT scan). The age of patient from 18-65 years old, female and male sex. The imaging area was abdominal. The patient enters the imaging room, before examination was fill the questioner and calculate the patient's weight and height. Then, patient was taking the CT-imaging with duration of filming ranges from 3 to 7 minutes.

3.1.2 Equation BMI Body Mass

Index is a simple calculation using a person's height and weight. The formula is (**$BMI = kg/m^2$**) Where kg is a person's weight in kilograms and m2 is their height in meters squared.

A **BMI** of 25.0 or more is overweight, while the healthy range is 18.5 to 24.9. BMI applies to most adults 18-65 years [9].

3.1.3 Statically Calculation

Patients' models were calculated statistically, comparing Kv. and MaS with patient BMI.

Then the relationship between patients' weight and Kv was calculated to determine the behavior effect.

4.1 Result

4.1.1 Patient Information

Table (4-1): The patient information include age, BMI, Kv and MaS for all cases before and after CT- image.

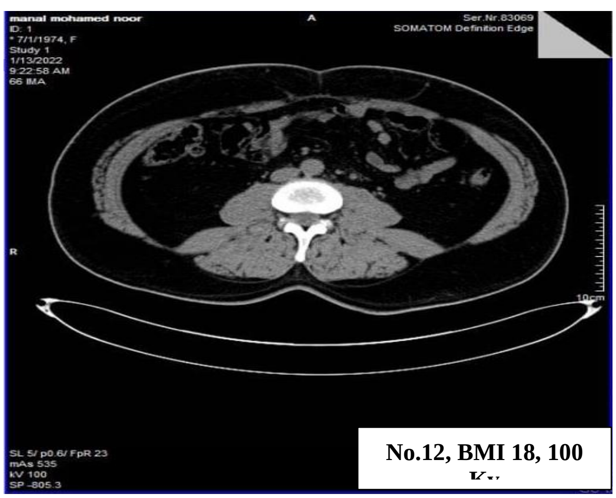
No.	Patient no.	Age	Sex	Weight	Height	BMI	Kv	mAs	Co.
1	**Patient 1**	58	M	60	165	18	100	152	38.4

2	**Patient 2**	45	F	90	160	27.3	120	131	19.2
3	**Patient 3**	52	F	120	170	41	140	420	19.2
4	**Patient 4**	45	F	65	163	25	100	238	38.4
5	**Patient 5**	60	F	100	166	39	140	584	38.4
6	**Patient 6**	25	M	61	169	19	100	135	38.4
7	**Patient 7**	30	F	80	166	29.2	120	233	38.4
8	**Patient 8**	52	M	85	173	29.3	100	360	38.4
9	**Patient 9**	45	F	110	167	39.5	140	360	38.4
10	**Patient 10**	30	F	88	183	25.6	120	360	38.4
11	**Patient 11**	60	M	95	177	30.6	120	229	36
12	**Patient 12**	45	F	70	166	16.5	100	527	38.4
13	**Patient 13**	50	M	88	179	27.5	120	263	36
14	**Patient 14**	48	F	110	165	40.7	140	138	38.4
15	**Patient 15**	33	F	84	167	30.2	120	226	19.2
16	**Patient 16**	65	F	90	168	32	120	210	38.4
17	**Patient 17**	48	F	98	170	33.9	120	451	19.2
18	**Patient 18**	60	F	100	168	35.7	140	135	38.4

Table (4-1), shows the patient's weight and height were taken before CT image to calculate body mass index for adults. Also, the sex and age for each patient taken into account with age group ranged from 18-65 years old. The abdominal cavity was chosen for all cases because higher accumulates for fat. The results show discrepancies between potential tube (kVp), tube current time (mAs) with weight factor [10].

4.2 Computed Tomography Image

CT –scan image have been selected to compare with the table and to clarify the effect of obesity in the region on the amount of dose. Where three CT- image for patient with different weights were selected.



No.12, BMI 18, 100 Kv

No.10, BMI 25.6, 120 Kv

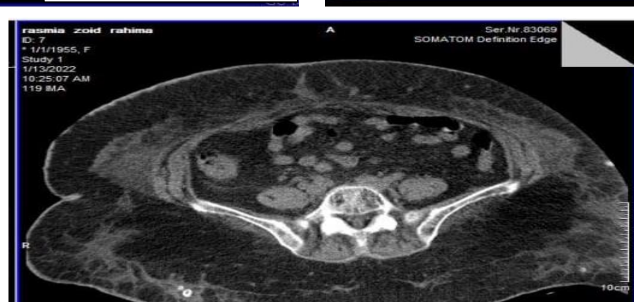


Figure (4-1): Axial contrast-enhanced computed tomography (CT) image of upper abdomen shows excessive intra-abdominal fat deposition for patient No (12, 10 and 18).

Through the image above, notice the difference in fat distribution and concentration in abdomen area. This contrast in soft tissue density lead to change in dose, as shown in No.10 compared with No 12 increase abdomen fat contributed to increase the dose. At No. 18 kilo voltage tube was 140 because fat density filled all the region.

Statistics				
		BMI	KV	mAs
N	Valid	17	17	17
	Missing	0	0	0
Mean		30.6706	114.1176	260.5294
Std. Deviation		7.53623	13.71989	117.26525
Skewness		-.335	.456	.845
Std. Error of Skewness		.550	.550	.550
Kurtosis		-.609	-.611	.131
Std. Error of Kurtosis		1.063	1.063	1.063

4.3 Statically & Analysis data

CT images of patients in Al- Kadhimiya Hospital after filling the details in the table above were taken. For the analyze the data we used (SPSS) program for the same. First of all, we have to test the normality of the data. Table (2) below shows the descriptive statistics (mean, standard deviation) of the three variables (BMI, KV, & mAs). In the main time the table shows normal distribution of the three variables by the measurements (Skewness & Kurtosis), which their values are greater than (0.05), means that (BMI, KV, & mAs) are normally distributed. Also, the normality distributions shown by the bar charts of the three figures below.

Table (4-2): Descriptive Statistics

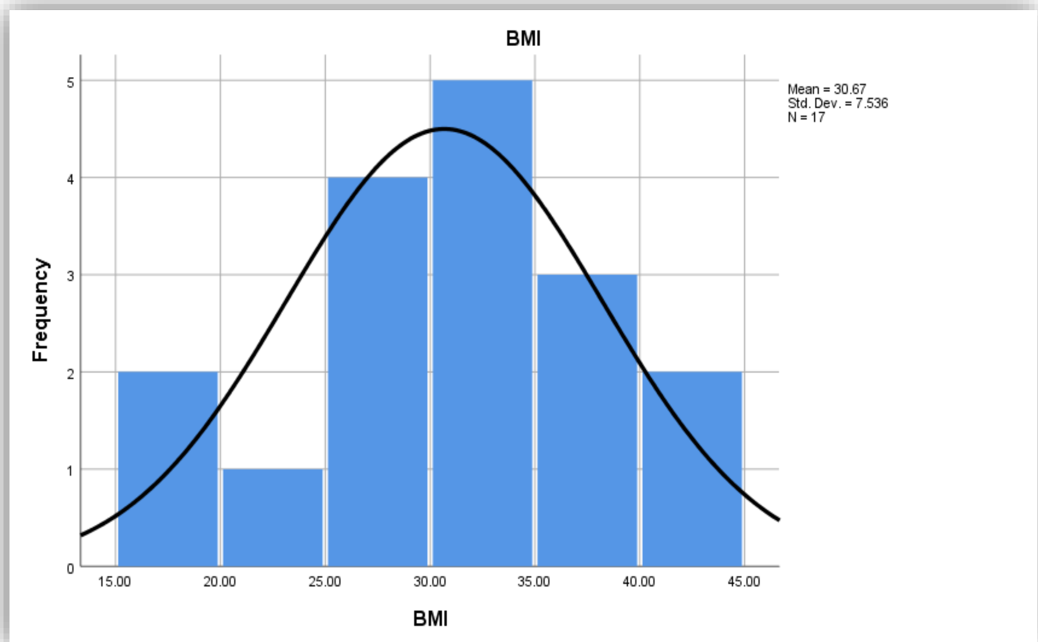


Figure (4-2): BMI normal distribution bar chart

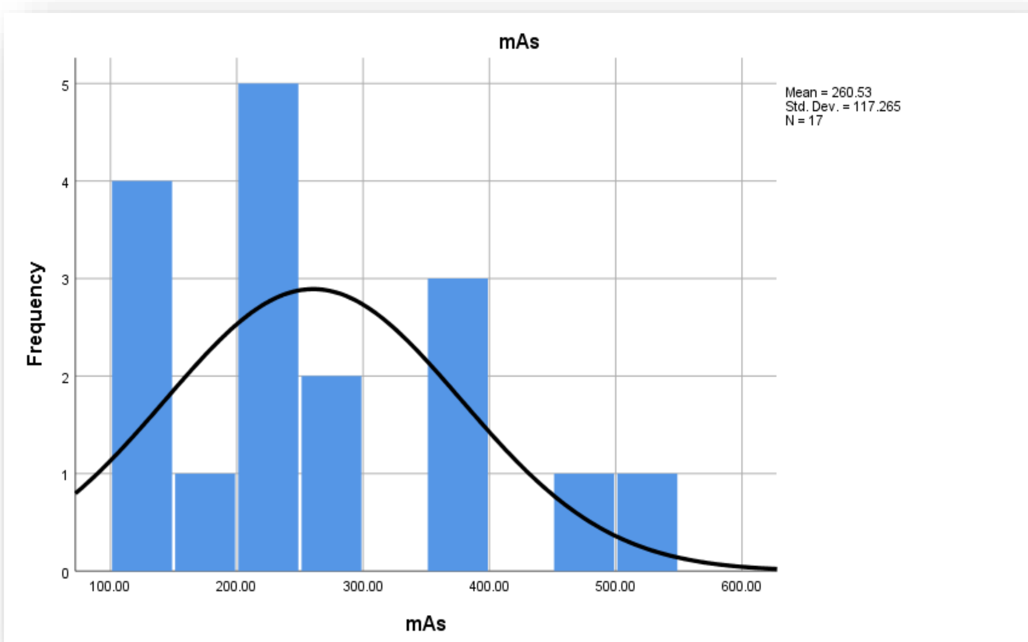


Figure (4-3): KV normal distribution bar chart

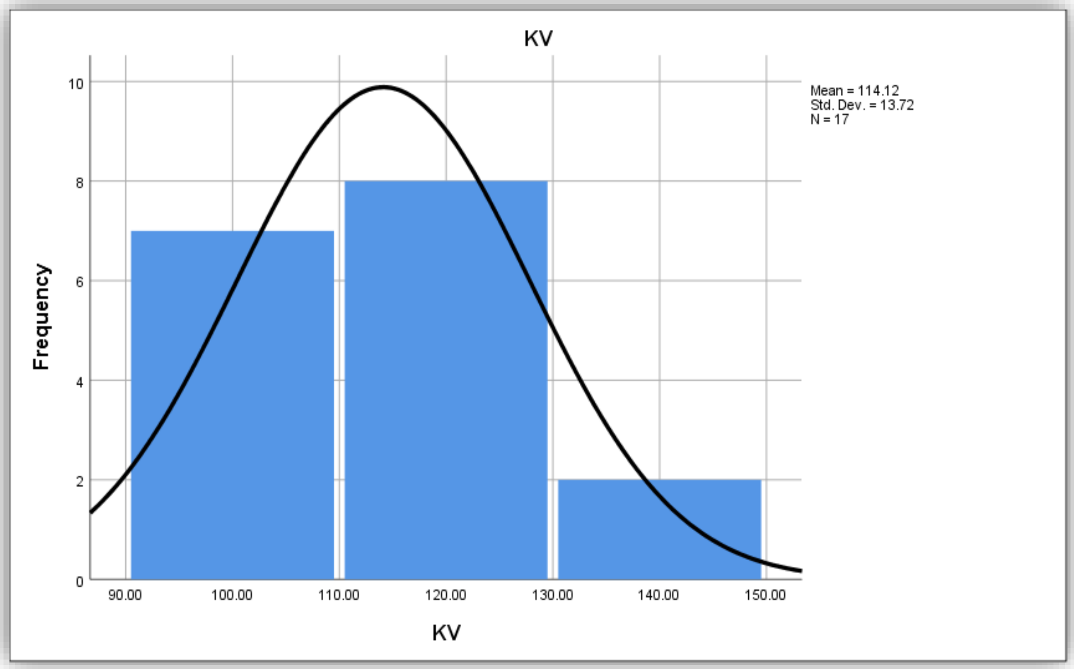


Figure (4-4): mAs normal Distribution bar chart.

We consider (BMI) as the dependent variable with (KV & mAs) as independent variables to test the effectiveness of the independent variables on the dependent variable, the analyze as follows;

Table (4-3) below shows the correlation matrix between the three variables which seems that the correlation is very weak.

Table (4-3): Correlation Matrix

Correlations				
		BMI	KV	mAs
Pearson Correlation	BMI	1.000	.460	-.080
	KV	.460	1.000	-.374
	mAs	-.080	-.374	1.000
Sig. (1-tailed)	BMI	.	.032	.380
	KV	.032	.	.070
	mAs	.380	.070	.
N	BMI	17	17	17

	KV	17	17	17
	mAs	17	17	17

Table (4-4): Coefficients

Coefficients[a]											
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-2.467	18.052		-.137	.893					
	KV	.275	.140	.500	1.967	.069	.460	.465	.464	.860	1.163
	mAs	.007	.016	.107	.421	.680	-.080	.112	.099	.860	1.163
a. Dependent Variable: BMI											

From table (4-4) we get;

- The estimated linear regression equation is;

$$\widehat{BMI} = -2.467 + 0.275\ KV + 0.007\ mAs$$

Means that increasing in KV by one point gives increasing in BMI by (0.275). in the mean time increasing in mAs by one point will give increasing in BMI by (0.007).

- t – test for the independent variables shows that KV – t – test with acceptable significance (0.069), while mAs was weak significance (0.68).
- Part & Partial Correlation between the independent variables & the dependent variable are also weak; [KV (0.465, 0.464), mAs (0.112, 0.009)].
- There is no multicollinearity in the data as shown by (VIF), which are less than (3).

Table (4-5): Model Summary

Model Summary[b]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.471[a]	.221	.110	7.10858	.221	1.991	2	14	.173	1.534
a. Predictors: (Constant), mAs, KV										
b. Dependent Variable: BMI										

From table (4-5), we can conclude that the correlation coefficient of the multiple model is weak (0.471) which gives determination coefficient also weak (0.221). Durbin – Watson value (1.534) which greater than (1.3), means there is no autocorrelation of in the model.

The value of (F – test) of the model shows that the model in non – significance (0.173), with value (F = 1.991), table (5) below gives the details.

Table (4-6): Analysis of Variance (ANOVA)

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	201.268	2	100.634	1.991	.173[b]
	Residual	707.447	14	50.532		
	Total	908.715	16			

a. Dependent Variable: BMI

b. Predictors: (Constant), mAs, KV

5.1 Conclusion

- Clinically, obesity is classified by body mass index, which accounts for both height and weight and defined as kg m^{-2}. Although body mass index has been clinically useful to quantify the degree of obesity and classify patients into categories for diagnosis and treatment for the purposes of medical imaging, the most important factors to obtain diagnostic quality imaging include patient weight, patient girth, and distribution of the adipose tissue.

- If a patient can fit on a CT scanner (weight and girth), image quality is generally adequate. Details of small structures are visible even in the most obese patients. However, there are some limitations, including increased noise due to inadequate beam penetration.
- The energy (kVp) and quantity (mAs) of X-ray beams significantly influence image quality in computed tomography (CT). For larger patients with increased soft tissue, standard settings (80-120 kVp and fixed mAs) may result in noisy, poor-quality images due to insufficient X-ray penetration. Adjusting the kVp to 140 increases beam energy, improving tissue penetration and reducing noise, while setting the mAs to "automatic" optimizes photon delivery for better image quality. However, these adjustments come with trade-offs: higher kVp reduces image contrast, and increased mAs raises radiation dose. Advances such as iterative reconstruction techniques and dual-source CT systems help minimize radiation dose while maintaining or enhancing image quality, particularly in obese patients.

5.2 Recommendation

- Our study recommends conducting further research to explore additional benefits of calculating BMI for patients to optimize high-resolution computed tomography techniques.
- Patient size not only impacts the clarity of X-ray images in computed tomography but also affects other radiological modalities, such as fluoroscopy and ultrasound, which should also be carefully considered in clinical practice.

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