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Assessment of Digital X-Ray Machine Image Quality Using Quantitative Analysis

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Abstract
Introduction*: This study includes the significant increase of image quality and the new potential for dose reduction. It intends to assess digital x-ray machine image quality using quantitative analysis for five organs; Feet exam, breast exam, Pelvic exam, Spinal exam and chest exam in police Hospital in Sudan in Khartoum State.*
Statement of the problem*: The evaluation of x-ray using quality mostly done subjectively, using visual perception which gives unreliable result these true of quantitative methods were applied more accurate results can be obtained and hence correlation of problem will be most accurate.*
Purpose: *this study aimed to assessment of digital x-ray machine image quality using quantitative analysis.*
Material and method: *A total of 100 patients from both male and female were randomly selected from whom exposed their Feet, breast, pelvic, spinal or chest to digital X-ray machine, from Neusoft in Police Hospital in Khartoum State. Region of interest (ROI) were selected from the image using 3×3 pixels in the high intensity and low intensity region on the same image then data were extracted from these region as signal, noise, signal to noise ratio, contrast before and after image enhancement using histogram equalization function; The Interactive Data Language (IDL), Statistical Package for the Social Sciences(SPSS) and Microsoft Excel programs were used.*
Results: *signal in high intensity region before and after enhancement, was 1409.66±532.08 and 1859.09±614.52; at p = 0.05 using t-test where p was <0.0001 and t = 19.2. While noise before and after enhancement did not show an increase in the high intensity area but barley it deceases it was 43.94±104.53 and 42.08±9.42 at p =0.05 where p = 0.8 and t = 0.254 also Signal to noise ratio showed and improvement before enhancement since noises were not increases and the signal arbitrary were increased after enhancement as follows: 36.99±10.30 and 42.08±9.42. linear increased by 0.95 units per each units before the enhancement starting at 7.2 This increased were significance using t-test with t = 9.717 and p <0.0001. The values of the signal and noise in low intensity areas before enhancement were 677.83±517.26 and, 41.01±142.41while after enhancement the signal and noise were 1104.65±71345 and 24.51±8.84; it increased by 0.99 unit per each unit before the enhancement starting at 6.7 units at p <0.0001 and t = 13.057 Noise also follows the same pattern where it shown direct linear relationship it increased by 0.97 units per each units before enhancement starting at 6.9 at t = 1.652 and p =0.1. Therefore signal to noise in low intensity region before enhancement was 24.51±8.84 and increase as a result of enhancement to 31.05±11.89 using t-test with t = 11.6 and p <0.0001. Similarly contrast was increased as a result of enhancement because contrast represent the differences between high and low intensity areas where enhancement increases the signal in the high intensity areas relative to the low intensity area; therefore contrast before enhancement was 0.57±0.14 and after enhancement was 0.94±0.1 in average using t-test with t = 1.041 and p = 0.299.*
Key words: *high and low intensity regions , image quality , enhancement, signal, noise, contrast, digital X-ray*

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I. Introduction

Digital radiography (DR) systems are replacing analog systems in many clinical applications. Broadly speaking, DR can be defined as projection x-ray imaging in which the image data are sampled into discrete elements in the spatial and intensity dimensions. Initially, image data captured by the x-ray capture element of the detector, in a process similar to that used by analog (ie, screen-film) radiographic systems. The captured analog signal then transformed into digital form through the processes of sampling and quantization. The digital image data finally transferred to a computer and processed for display and distribution. DR detectors vary dramatically with respect to the technologies on which they based. However, these detectors all share three distinct components: the x-ray capture element, the coupling element, and the collection element. The performance of digital detectors and the quality of their acquired images directly related to various physical processes that take place in these elements during image formation.[1]

Digital radiographic systems are gaining widespread use in many clinical applications. Digital radiographic detectors vary dramatically with respect to the technologies that they use and the particular implementation. Their performance thus varies from system to system. It is often necessary to characterize the performance of a digital radiographic or mammographic detector for optimization, design, comparison, or quality assurance purposes. To do so, it is most useful to measure the performance of the detector in terms of common performance metrics, so that meaningful comparisons. The performance of a digital radiographic detector described in terms of a number of performance factors. Among them, sharpness and noise are two key characteristics that describe the intrinsic image quality performance of digital radiographic systems. Together, these two, along with an associated characteristic, the signal-to-noise ratio (SNR), define the intrinsic ability of an imaging system represent the anatomic features of the body part imaged. The quantification of sharpness, noise, and SNR in radiographic systems in terms of common performance metrics of the modulation transfer function (MTF), the noise power spectrum (NPS), and the detective quantum efficiency (DQE).[1]

II. Material And Method

In the present study, digital X-ray machine, from Neusoft which made in china in June 2015 manufacture was used assess digital x-ray machine image quality using quantitative analysis. A total of 100 patients from both male and female were randomly selected from whom exposed their Feet, breast, pelvic, spinal or chest in Police Hospital in Khartoum State. Region of interest (ROI) were selected from the image using 3×3 pixels in the high intensity and low intensity region on the same image then data were extracted from these region as signal, noise, signal to noise ratio, contrast before and after image enhancement using histogram equalization function; where distribution of image intensity histogram were redistributed for better image quality in respect to visual perception. In X- ray imaging the exposure parameters used are selected according to patient weight and organ size. The Standard (FFD) of 100 cm was used for all routine examination and the chest X- rays FFD of 180 cm are used for geometrical reason. The Interactive Data Language (IDL), SPSS (Statistical Package for the Social Sciences) and Microsoft Excel programs.

III. Results

Table (1) the mean and stander deviation of the variables calculated from high and low intensity region before and after enhancement.

Signal	Mean ± Std.	
	Before E	After E
S high I R	1409.7±532.1	1859.1±614.5
N high I R	43.9±104.5	42.08±9.4
S to N high I R	36.9±10.3	42.08±9.4
S low intensity R	677.8±517.3	1104.7±713.5
N low I R	41.01±142.4	24.5±8.8
S N low I R	24.5±8.8	31.05±11.9
Contrast Before	0.57±0.1	0.94±0.1

Where:
E is Enhancement **S** is signal, **IR** is intensity region, and **N** is noise.

Table (2) Paired Samples Correlations

Paired samples	Correlation	Sig.
S W & S W E	0.844	.000
Noise W & Noise W E	0.105	.141
S N W & S N W Enhancement	0.722	.000

Signal Black & Signal Before	0.763	.000
Noise Black & Noise Before	0.154	.029
S N Black & Signal Noise Before	0.741	.000
Contrast Before & Contrast After	0.111	.117

Where: w is white and **E** is enhancement

Table 3 Paired Samples t-test for significance differences of the signal before and after enhancement

Paired Samples Test (before and after E)	t	Sig. (2-tailed)
S High intensity	19.241	.000
N high intensity	.254	.800
S to N Ratio high intensity	9.717	.000
Signal low intensity	13.057	.000
Noise low intensity	1.652	.100
S to N Ratio low intensity	11.585	.000
Contrast	1.041	.299

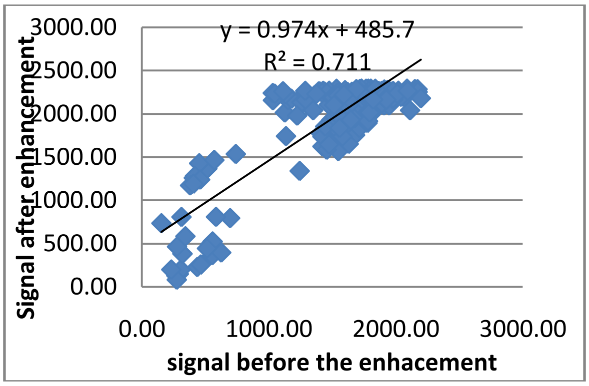

Figure 1 scatter plot show a direct linear relationship of Signal in high intensity region before and after enhancement.

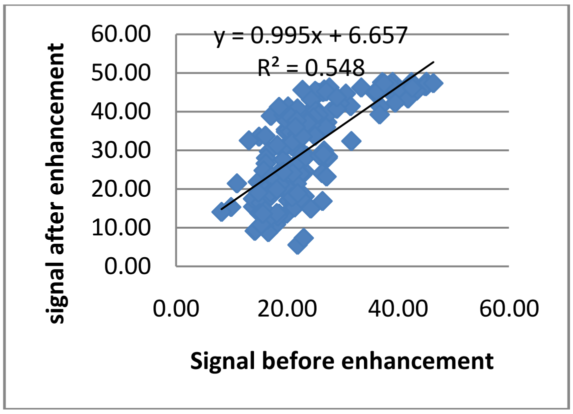

Figure 2 scatter plot show a direct linear relationship of Signal in low intensity region before and after enhancement.

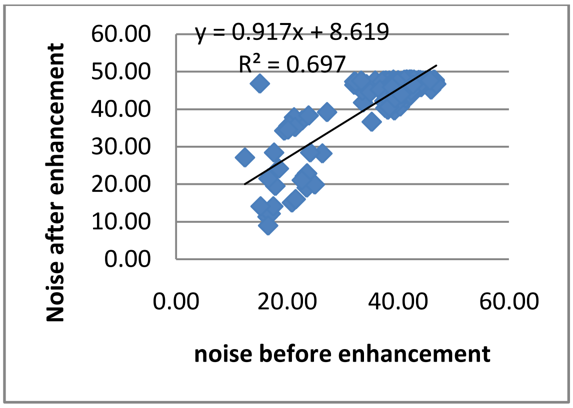

Figure 3 scatter plot show a direct linear relationship of Noise in high intensity region before and after enhancement.

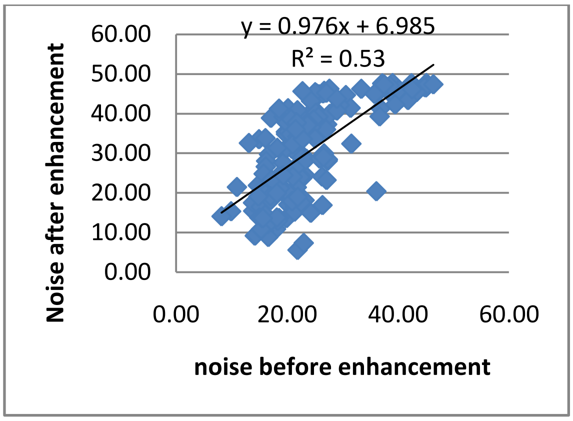

Figure 4 scatter plot show a direct linear relationship of noise in low intensity region before and after enhancement

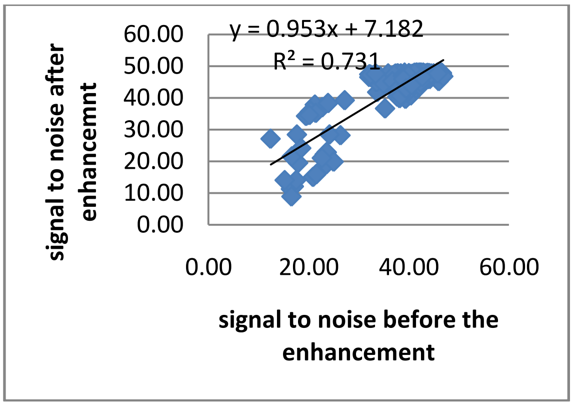

Figure 5 scatter plot show a direct linear relationship of Signal to Noise in high intensity region before and after enhancement

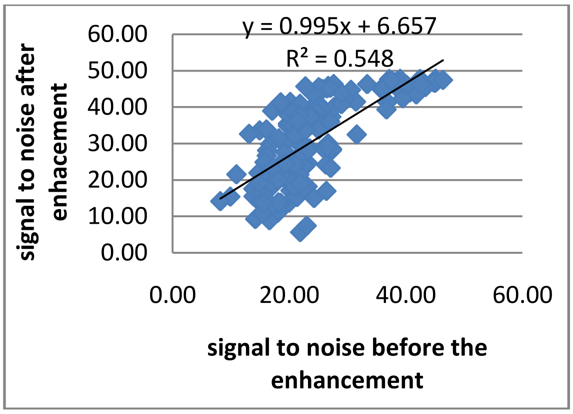

Figure 6 scatter plot show a direct linear relationship of Signal to Noise in low intensity region before and after enhancement.

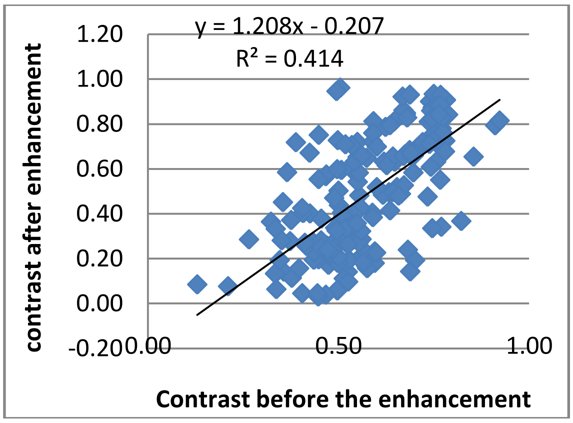

Figure 7 scatter plot show a direct linear relationship of contrast before and after enhancement.

IV. Discussion

The physicians and radiography specialist are concern to image quality that reveals the pathology and hence the proper management of the patient condition and be satisfied; this situation mostly lead to high dose given to the patient where if the image quality was not suitable so repetition of the imaging process is mandatory. This study includes the significant increase of image quality and the new potential for dose reduction. It intends to assess digital x-ray machine image quality using quantitative analysis for five organs; Feet exam, breast exam, Pelvic exam, Spinal exam and chest exam in police Hospital in Sudan in Khartoum State.

A total of 100 adults patients were exposed to DR device their images were used to study signal, noise and contrast before and after in high and low intensity regions. The mean and standard deviation for the variable above and the linear relationships between them were shown in Tables (1), (2) and (3) .

A comparative status were shown in Table (1) using mean ± standard deviation for the signal in high intensity region before and after enhancement, it was 1409.66±532.08 and 1859.09±614.52; which indicate and increases of signal after enhancement. The signal was increased linearly as a result of enhancement by 0.9742 per each unit before the enhancement starting at 486 units (Figure 1); this increases and differences between the two form of the intensity was significance at p = 0.05 using t-test where p was <0.0001 and t = 19.2 (table (3).

While noise before and after enhancement did not show an increase in the high intensity area but barley it deceases it was 43.94±104.53 and 42.08±9.42 (Table 1). As shown in (Figure 3) there is a direct linear relationship between the noise values before and after enhancement where it increase relatively by 0.92 units versus each units before enhancement starting at 9 units this increases were inconclusive using t-test at p =0.05 where p = 0.8 and t = 0.254 (Table 3)

Signal to noise ratio showed and improvement after enhancement since noises were not increases and the signal arbitrary were increased after enhancement as follows: 36.99±10.30 and 42.08±9.42. This increase was direct linear increase by 0.95 units per each units before the enhancement starting at 7.2 (Figure 5). This increased were significance using t-test with t = 9.717 and p <0.0001 (Table 3).

The values of the signal and noise in low intensity areas before enhancement were 677.83±517.26 and, 41.01±142.41while after enhancement the signal and noise were 1104.65±71345 and 24.51±8.84; this result also show that the signal in the low intensity areas were increased as a result of histogram equalization which broaden the high intensity in the low intensity area as well noise were decreased as a result of the increases of the image signal adaptively. The increases of signal were linearly i.e. it increase by 0.99 unit per each unit before the enhancement starting at 6.7 units this increases were significance at p <0.0001 and t = 13.057 (Table 3). Noise also follows the same pattern where it shows a direct linear relationship it increases by 0.97 units per each units before enhancement starting at 6.9 (Figure4) this results were inconclusive using t-test with t = 1.652 and p =0.1 (Table 3).

Therefore signal to noise in low intensity region before enhancement was 24.51±8.84 and increase as a result of enhancement to 31.05±11.89. This result supported by a direct linear relationship where the SNR increases by 0.99 units for each unit before the enhancement starting at 6.7 units (Figure 6), this increase were significance using t-test with t = 11.6 and p <0.0001 (Table 3). Similarly contrast was increased as a result of enhancement because contrast represent the differences between high and low intensity areas where enhancement increases the signal in the high intensity areas relative to the low intensity area; therefore contrast before enhancement was 0.57±0.14 and after enhancement was 0.94±0.1 in average. The contrast were increased linearly by 1.21 per each unit before enhancement and start at 0.2078 unit (Figure 6). But this increase were inconclusive using t-test with t = 1.041 and p = 0.299 (Table 3).

V. Conclusions

This study intended to assessment of digital x-ray machine image quality using quantitative analysis. It was done in police hospital in Khartoum state from September 2016 till September 2019 for five organs; Feet exam, breast exam, Pelvic exam, Spinal exam and chest exam ; it aimed to measure the signal, noise, signal to noise ratio and contrast; in high and low intensity regions for to minimize the dose to patients, wrong diagnostic, rejections images and repeat images.

The signal was increased linearly as a result of enhancement by 0.9742 per each unit before the enhancement starting at 486 units; this increases and differences between the two form of the intensity was significance at p = 0.05 using t-test where p was <0.0001 and t = 19.2 While in noise before and after enhancement there is a direct linear relationship between the noise values before and after enhancement where it increase relatively by 0.92 units versus each units before enhancement starting at 9 units this increases were inconclusive using t-test at p =0.05 where p = 0.8 and t = 0.254 Signal to noise ratio showed direct linear increase by 0.95 units per each units before the enhancement starting at 7.2 . This increased were significance using t-test with t = 9.717 and p <0.0001. The result of the signal and noise in low intensity areas before enhancement showed that the signal in the low intensity areas were increased as a result of histogram equalization which broaden the high intensity in the low intensity area as well noise were decreased as a result of the increases of the image signal adaptively. The increases of signal were linearly i.e. it increase by 0.99 unit per each unit before the enhancement starting at 6.7 units this increases were significance at p <0.0001 and t = 13.057 . Noise also follows the same pattern where it shows a direct linear relationship it increases by 0.97 units per each units before enhancement starting at 6.9 this results were inconclusive using t-test with t = 1.652 and p =0.1. Therefore signal to noise in low intensity region before enhancement was supported by a direct linear relationship where the SNR increases by 0.99 units for each unit before the enhancement starting at 6.7 units , this increase were significance using t-test with t = 11.6 and p <0.0001 (Table 4-3). Similarly the contrast were increased linearly by 1.21 per each unit before enhancement and start at 0.2078 unit. But this increase were inconclusive using t-test with t = 1.041 and p = 0.299 .

It concluded that the quantitative analysis is a valuable tool for digital X- Ray image estimation.

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