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Assessment of Image Quality for Digital Radiography Units using Prototype Phantom

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ABSTRACT:- The main objective of this study to measure the x-ray machines resolution using Modulation Transfer Function MTF which gives a full description of the machine resolution. this study introduced the a more reliable method of measuring the resolution which is modulation transfer function (MTF) which gives a complete description of the resolution instead of using full width at half maximum (FWHM) or the visibility method which is more qualitative where MTF is a real quantitative method, by designed a prototype phantom consisted of five wires with different thickness and kV for five x-ray units.
with three object spatial frequency 0.333, 0.298 and 0.216 cycle/mm, imaging the designed phantoms the thickness from wire showed the best results of 0.333 cycle/mm from all hospitals was 92% for 44 kV at ALS hospital, and for 0.298 cycle/mm the best resolution from all hospitals was 97% for 40 kV at Sudan University hospital, the frequency 0.216 cycle/mm the best resolution was 100% at RO with kV 40, ALS at 44 kV and SHN and ALS at 46 kV. Also, the results showed that as the object spatial frequency increased (thickness of the wire decreased) the resolution values decreased as the results of the Kv increases. This is mainly due to the penetration of the radiation as well as the limitation of the x-ray resolution in picking up finer details where the intensifying screen and the film capabilities limit the infant of the resolution.

Keywords: using Modulation Transfer Function, Image Quality, Spatial Resolution, Spatial Frequency

I. INTRODUCTION:

The image quality of any scanning system is one of the most important metrics, which must be characterized and understood in order to achieve optimal results. The best descriptor of quality is spatial resolution, which is most commonly described by the modulation transfer function (MTF). Several methods exist to test the MTF of conventional transmission radiography systems, but these cannot be directly applied to backscatter radiography due to the inherent differences in how their images are formed.

Recently, digital radiography systems are quickly replacing the conventional film–screen systems in many radiology departments around the world. Digital radiography systems have advantages including a wide dynamic range, flexibility in image display, possibility in changing image quality parameters, digital image management by using Picture Archiving and Communication System (PACS) and then reduction of costs associated with processing, managing, and storing films [1]. However, in the digital radiography systems, large amounts of exposure can be compensated by detector-computer system and then it is relatively easy to unknowingly overexpose the patient and increase the risk of effects induced by ionizing radiation [2]. There is a trade-off between the radiation exposure to the patient and image quality especially in digital radiographies. Based on the principle of “as low as reasonably achievable” (ALARA), digital radiographies should provide image quality adequate to enable an accurate diagnosis with the lowest achievable radiation dose [3]. Detectors with higher detection quantum efficiency can create better images with lower radiation exposure [4].

Several studies have compared images obtained with DR or computed radiography (CR) with conventional screen film radiographs [4-8], but few studies compared different models of DR systems [9].
The characterization of the key magnitudes of an optical system, such as the transfer function or the depth of field (DOF) [10], is a key process both to perform the appropriate processing on the experimental images and to, ultimately, understand the limits of the so obtained results.

Several methods to measure the MTF can be found in the literature. One of the best known techniques is the so-called knife-edge method, where a straight-edged test plate is imaged in the microscope. The measured 1D intensity profile normal to the edge is the edge spread function (ESF). From this profile the most common method to obtain the MTF is the analysis of the line spread function through the differentiation of the ESF [11,12]. However, the use of discrete approximations of the derivative function introduces a bandpass filter, an effect that can be minimized by analyzing directly the ESF [13-15]. Moreover, the application of this approach to SXT requires the very accurate fabrication of a microscopically straight-edged test plate, a process that has not proven to be easy. This study aims to assessment of Image quality for digital radiography units using Prototype Phantom in Order to find the optimum exposure factor that preserve x-ray machine resolution

II. MODULATION TRANSFER FUNCTION:

The modulation transfer function (MTF) of an imaging system is the most complete description of the spatial resolution properties for that device. The MTF is the magnitude response to sinusoids of different spatial frequencies, and it provides a quantitative description of the degradation of contrast with increasing spatial frequencies. In practice, the MTF is usually determined along one dimension from the line spread function (LSF), as shown by Equation 1

$$MTF(f) = \frac{\left|\int_{-\infty}^{\infty} LSF(x) e^{-i2\pi f x} dx\right|}{\left|\int_{-\infty}^{\infty} LSF(x) dx\right|}$$

The LSF can be determined by the detector response to either a slit or gradient over the response to a sharp edge. The difficulty in aligning the narrow slit with the x-ray beam is often the deterrent in using this method, and the edge response is used instead.

III. MATERIAL AND METHODS:

The X-ray machines resolution has been assessed using designed phantom which was consisted of five wires, embedded in a 6 x 9.5 x 1 cm wood holder, each wire is 1 cm away from the adjacent wire with thickness of 1.4mm, 0.8mm, 0.6mm, 0.5mm and 0.4mm. The radiographic measurements were performed in five conventional X-ray machines in five hospitals. The X-ray was manufactured by: Royal Care International Hospital with Toshiba, Ahmed Gasem hospital with Shimadzu, East Nile hospital with Philips, Nawagez Medical Center with x ray Philips machine, Dar alsalam Medical Center with Shimadzu.

Method of data collection

Determination of the spatial resolution is essential in order to find the optimum KV relative to machine type, the phantom is placed on the detector surface, and a uniform source of radiation is placed above the bar phantom that was the focus-to-film distance was 1m. An image is acquired, the units was set at 2mAs and 40kVp value. An X-ray exposure was made. This step was repeated at same constant mAs and different Kvp settings (40, 44 and 46kVp) and that was repeated for the five models of the x-ray machines. The choice of x-ray tube voltage (kV) affected the image contrast and is one of the adjustable factors of x-ray equipment and in different x-ray units the images were obtained by applying the same parameter setting. The images of the phantom were scanned to a computer, and using Interactive Data Language IDL for generate a profile throw the lines in ordered to drown a curve and obtain the resolution, modulation transfer function and frequency of the lines with different Kv and thickness, Then calculation of the Fourier transform of the LTF to obtain the MTF an alternative is to use the Modulation Transfer Function (MTF) in order to describe the ability of the system to maintain the amplitudes of spatial frequencies passing through it and MTF is a plot of resolution, measured in percent, against spatial frequency measured in lp/mm.

IV. RESULTS AND DISCUSSIONS:

This is a descriptive study intended to assesses the diagnostic x-ray machine resolution using Modulation Transfer Function as an objective method of evaluation; in order to find the optimum kV relative to machine type, by designing a prototype phantom consisted of three wires with different thickness (0.333 mm, 0.298 mm and 0.216 mm) and obtained images with differences Kv (40, 44 and 46) and computed the MTF using line transfer function (LTF) by having the absolute values of Fast Fourier Transform (FFT) for the LTF. The radiographic measurements were performed in five conventional X-ray units in five hospitals the results of their performance were discussed.

Table 1. show the resolution versus spatial frequency for all hospitals for 40 kV from all x ray machines:

Spatial frequency	SU	Ah	SH	RO	ALS
	40 Kv	40 Kv	40 Kv	40 Kv	40 Kv
0.333	0.83	0.77	0.84	0.781	0.89
0.298	0.97	0.95	0.9	0.7829	0.9
0.216	0.98	0.98	0.93	1	0.95

Using different x-ray machines the 40 kV with different spatial frequencies imaging the designed phantoms showed the best results with spatial frequency 0.333 was 89% , and for frequency 0.298 was 97% and the spatial frequency 0.216 give a resolution reach up to 100% , that means with decrease the wire thickness the resolution gets better as shown in table 1. And fig 1. This is mainly due to the penetration of the radiation as well as the limitation of the x-ray resolution in picking up finer details where the intensifying screen and the film capabilities limit the infant of the resolution Fig 1.

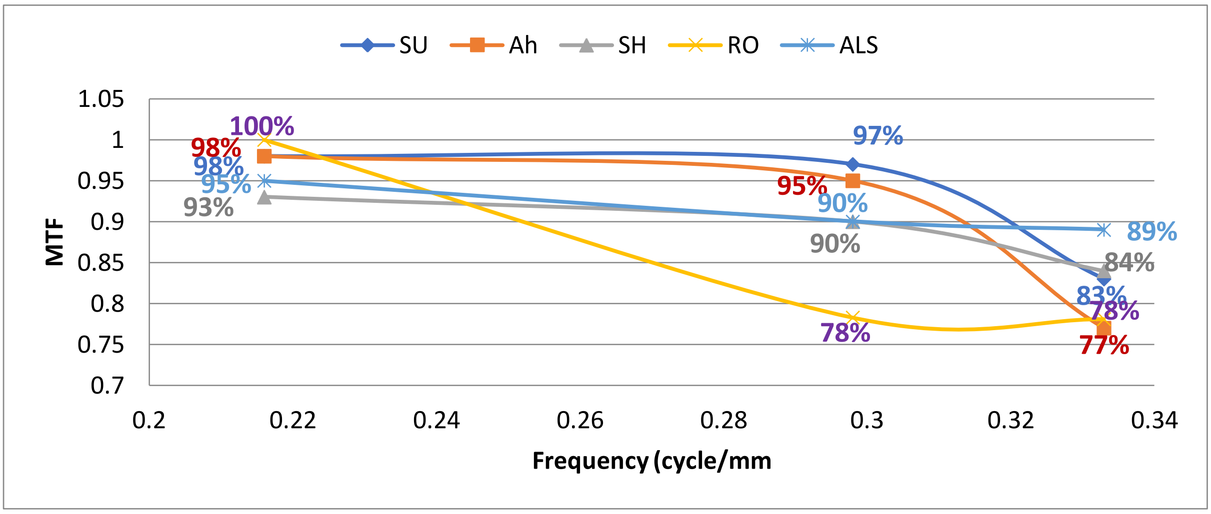

Fig 1. show line graph for resolution versus spatial frequency in percentage for all hospitals from 40 kV for different x ray machines

Table 2. show the resolution versus spatial frequency for all hospitals for 44 kV from all x ray machines:

Spatial frequency	SU	AH	SHN	ROS	ALS
	44 Kv	44Kv	44 Kv	44 Kv	44 Kv
0.333	0.68	0.73	0.885	0.5967	0.92
0.298	0.83	0.87	0.91	0.7444	0.98
0.216	0.93	0.98	0.9	0.7643	1

Also the results showed that as the object spatial frequency increased (thickness of the wire decreased), at 44 kV for the spatial frequency 0.333 the best resolution was 92% at ALS hospital, for 0.298 was better at 98% and when the spatial frequency was 0.216 the resolution at ALS reach up to 100 % as shown in table 2. And fig 2.

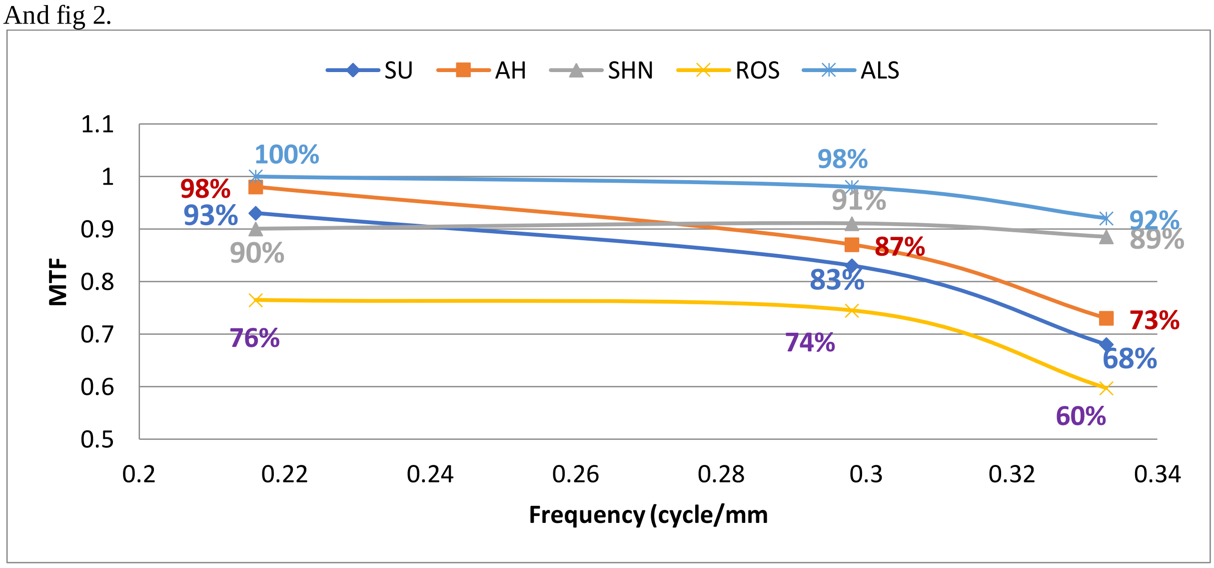

Fig 2. show line graph for resolution versus spatial frequency in percentage for all hospitals from 44 kV for different x ray machines

Table 3. show the resolution versus spatial frequency for all hospitals for 46 kV from all x ray machines:

Spatial frequency	SU	AH	SHN	RO	ALS
	46 kV	46Kv	46 kV	46 kV	46 kV
0.333	0.77	0.53	0.808	0.5774	0.89
0.298	0.9	0.58	0.94	0.6596	0.96
0.216	0.91	0.94	1	0.7033	1

Using different spatial frequencies at 46 kV the resolution be a better with reduce the thickness of wire, for spatial frequency 0.333 the best resolution was 89% at ALS hospital, for 0.298 give 96% also at ALS hospital while the frequency 0.216 give a full resolution at SHN and ALS with 100%, this means with decrease the wire thickness the resolution gets better as shown in table 3. And fig 3.

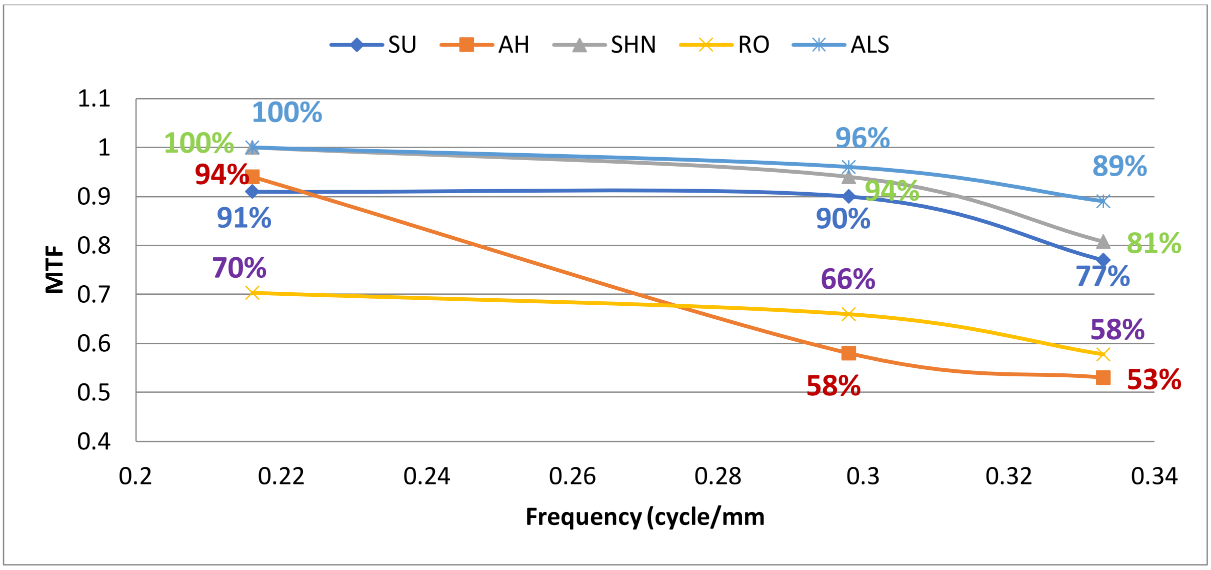

Fig 3. show line graph for resolution versus spatial frequency in percentage for all hospitals from 46 kV for different x ray machines

for all hospital x-ray machines the resolution for 40, 44 and 46 kV, while the scatter plot shown in figures 1, 2 and 3 versus spatial frequency for 40, 44 and 46 Kv denoted decreases of the resoultion as the result of increase of spatial frequency i.e. as the object get thinner

V. CONCLUSION:

This is a descriptive study intended to assesses the diagnostic x-ray machine resolution using Modulation Transfer Function as an objective method of evaluation; in order to find the optimum kV relative to machine type, by designing a prototype phantom consisted of three wires with different thickness (0.333 mm, 0.298 mm and 0.216 mm) and obtained images with differences Kv (40, 44 and 46) and computed the MTF using line transfer function (LTF) by having the absolute values of Fast Fourier Transform (FFT) for the LTF. The radiographic measurements were performed in five X-ray units in five hospitals the results of their performance were investigated using wire phantom designed by the researcher which consisted of variable thicknesses used to test variable exposure factors with three object spatial frequency 0.333, 0.298 and 0.216 cycle/mm, imaging the designed phantoms the thickness from wire showed the best results of 0.333 cycle/mm from all hospitals was 92% for 44 kV at ALS hospital, and for 0.298 cycle/mm the best resolution from all hospitals was 97% for 40 kV at Sudan University hospital, the frequency 0.216 cycle/mm the best resolution was 100% at RO with kV 40, ALS at 44 kV and SHN and ALS at 46 kV. Also, the results showed that as the object spatial frequency increased (thickness of the wire decreased) the resolution values decreased as the results of the Kv increases. This is mainly due to the penetration of the radiation as well as the limitation of the x-ray resolution in picking up finer details where the intensifying screen and the film capabilities limit the infant of the resolution.

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