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Assessment of Image Quality Parameters for Computed Tomography in Sudan

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Abstract

X-ray-computed tomography (CT) has become one of the most important investigation procedures worldwide. The study aimed to assess image quality parameters, mainly noise, and radiation doses during abdominal examination. This study examined the diagnostic parameters (kilo voltage, tube current time product, slice thickness, and pitch) and their effects on image quality as well as the radiation doses received from computed tomography scanners using phantom. The study carried out in four CT centers in Sudan. The study applied prospective and experimental methods. The study demonstrated there was a linear correlation between diagnostic parameters and image noise. The reduction in milli-ampere second and peak kilo voltage increased the image noise. Moreover increasing the pitch led to an increase in the image noise, whereas increasing the slice thickness, reduced the image noise. There was also a linear relationship between kilo voltage and radiation dose at Elnileen diagnostic center characterized by an increase kilo voltages values which led to an increase in the radiation dose by 92% and a reduction in the image noise by 83%. However, at Antalya medical center, increasing in kilo voltage values led to an increase in the radiation dose by 35% and a reduction in the image noise by 26%. Also increasing in milli-ampere second values led to an increase in the radiation dose by 49% and a reduction in the image noise by 46% in a phantom compared with an increase in radiation dose by 82% and a reduction in the image noise by 51% in patients .The study found that an optimal protocol for adult abdominal scan at Antalya medical center was 4.22HU for image noise and 10.45 mGy for radiation dose when using 120 kVp, 300 mAs, 5 mm slice thickness and pitch of 0.8. At Elnileen diagnostic center, however, the optimal protocol was 5.4 HU for image noise and 5.4 mGy for radiation dose using 130 kVp, 50 mAs, 10 mm slice thickness and pitch of 2. In addition, the quality control tests for image quality parameters carried out at the two centers were performed by using the Chat Phan phantom and all the tests were within the acceptable limits, according to Sudan Atomic Energy Commission (SAEC) Standardizations. The study concludes with a number of recommendations, such as; the necessity for an extensive collaboration among manufacturers, radiologists, technologists and physicists to find a plan to decrease patient radiation dose (ALARA Principle) from computed tomography scanner.

Keywords

CT, Image Quality, Patient Dose

1. Introduction

X-ray-computed tomography (CT) has rapidly evolved in terms of both technical performance and clinical use. It has become one of the most important of all x-ray procedures worldwide [1]. The CT technique has been introduced into many medical applications and it is accepted as a useful method in diagnostic imaging owing to the fact that it provides three-dimensional image reconstructions with low contrast detectability, fast volume coverage, easy hardware implementation and considerable spatial resolution [2] [3] [4] [5].

The components of CT image quality are noise, slice thickness (Z-axis resolution), low contrast resolution and high contrast resolution. While image quality has always been a concern for the physics community, clinically-relevant image quality has become important to get clear diagnostic findings for early detection of serious diseases. Image quality can be defined in terms of image noise, which limits low contrast resolution, and spatial resolution.

To optimize image quality, patient dose and relevant issues such as CT dosimetry should not be ignored as obtaining high quality images is always associated with high patient doses.

In Sudan, as far as the authors' knowledge, few studies regarding CT image quality and patient doses have been published locally and worldwide. This study, therefore, would have a good contribution to the existing literature.

The main purpose of this study is to assess image quality parameters and patient dose parameters, in order to optimize imaging procedure.

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2. Materials and Methods

This prospective, analytical and experimental study deals with diagnostic parameters of the computed tomography scan to evaluate the image quality in CT images. The study was carried out in Sudan at Khrtoum State in the CT departments of Antalya medical center, Elnileen diagnostic center and Al Amal diagnostic center. The data was collected from June 2014 to Augest 2016. A special data collection sheet was designed by the authors after was approved by the research ethics committee at each center. The inclusion criteria of the study variables that were measured are, the diagnostic parameters (kVp, mAs, slice thickness and pitch), and the radiation dose [CT dose indices volume (CTDIvol) and dose length product (DLP) and image noise (SD)]. The authors concentrated on image noise as a image quality parameter because it is a key parameter in assessing CT image quality according to previous studies [2] [3] [4] [7] [9] [13] [17] [18] [20].

Before data collection, extensive quality control (QC) tests were performed in all the CT departments in our study. The QC tests used both Catphan 600 and-Catphan 500/600 (The Phantom Laboratory, Salem NY, USA) phantoms. Catphan 500/600 is a CT quality assurance phantom suitable to test low contrast detectability, spatial resolution, noise, slice thickness and homogeneity. It is specially designed to evaluate image quality for CT. Different tests can be performed, evaluating the homogeneity, the noise level, the modulation transfer function and the visibility of low contrast details (Laboratory 2006). The evaluation method of interest in this study was measuring the noise level along with routine quality control tests performed by local quality control (QC) committee, the QC tests for this study was carried out by Sudan Atomic Energy Commission (SAEC) and all departments have successfully passed the extensive tests.

The $CTDI_{vol}$ and DLP based on the manufacturer's data were used for estimation the radiation dose in axial images of the rando-phantom.

The corresponding $CTDI_{vol}$ and DLP of each acquisition condition indicated on the monitor screen were recorded. The $CTDI_{vol}$ and DLP obtained by the standard protocol were compared with that obtained by other protocols.

In order to perform the experiments with doses and noise levels representative of routine phantom values, thirteen clinical data of normal liver examinations performed by the same CT department and scanning parameters were recorded. The radiation dose and the level of the noise were chosen as they are the most important quality parameters and have a direct effect on the quality of the image.

Seven additional abnormal examinations including liver metastases (hyper vascular) were performed. For each patient, one region of interest (ROI) was chosen from one liver metastasis and another ROI from a homogeneous normal area adjacent to the liver. The mean CT number and SD then recorded to calculate contrast to noise ratio (CNR) as follows: CNR = (CTL − CTM)/SDM, where CTL is the mean CT number of the normal liver and CTM is the mean CT number of the metastasis and SDM is the SD of the metastasis liver.

So the contrast-to-noise ratio was defined as the difference between the mean CT attenuation values of the right lobe of the liver and the background references divided by image noise [9].

The statistical analysis was performed using the software statistical package for the social science (SPSS) version 18.0. The relationship between SD and tube current-time product settings and the relationship between CNR and $CTDI_{vol}$ were investigated using the linear regression analysis and Pearson correlation coefficient (r). To optimize the technical factors (kVp, mAs, ST and pitch) as a function of $CTDI_{vol}$ and SD, tagutchi setting was used.

3. Results and Discussion

3.1. Results

The results show in Table 1 and Table 2, Figures 1-9.

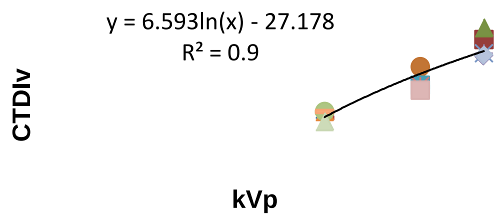

Figure 1. Correlation of kVp with $CTDI_{vol}$ in Elnileen center.

Table 1. Noise evaluation from three centers.

Parameters	Low resolution (large slice thickness ≥ 5 mm)			High resolution (low slice thickness ≤ 5 mm)		
ROI/Hospital	NILE	ANT	ALAMAL	NILE	ANT	ALAMAL
Iso center	4.59	2.3	2.2	26.56	1.2	2.5
0 degree	3.57	1.9	3.2	19.8	1.2	1.3
90 degree	3.83	1.8	2.9	19.1	1.1	1.9
180 degree	4.13	1.7	3.4	19.6	1.9	2.5
270 degree	4.37	2.3	2.5	20.9	1.4	2.2
Standard devotion	4.098	2	2.84	21.192	1.36	2.08

Table 2. Unit's specifications.

Center	manufacturer	Installation date	Max No of slices	No of tube exposures	Max kV	Max mA
NIL	Siemens	2008	16	16423	130	450
ANT	GE	2011	16	9653	140	300
ALAMAL	Toshiba	2010	64	11794	140	500

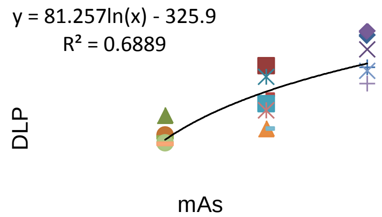

Figure 2. Correlation of mAs and DLP.

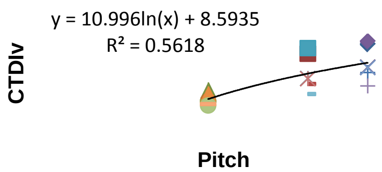

Figure 3. Correlation of Pitch and $CTDI_{vol}$.

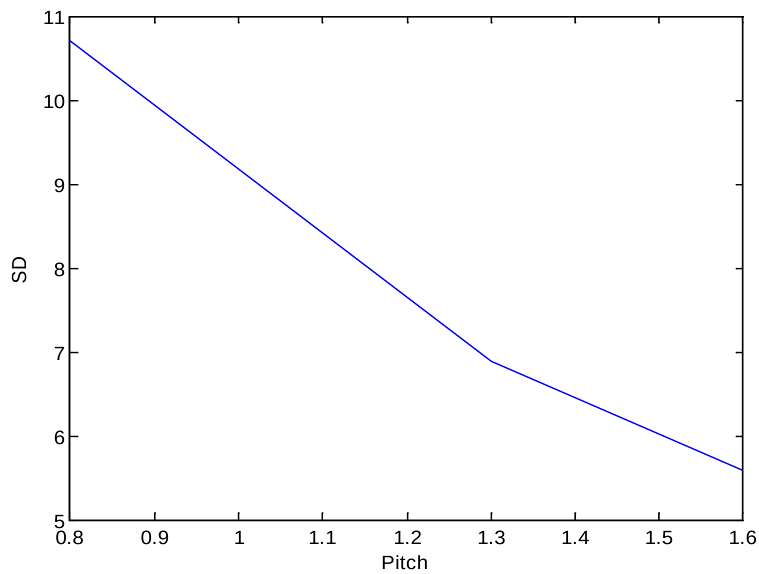

Figure 4. General correlation between noise and pitch.

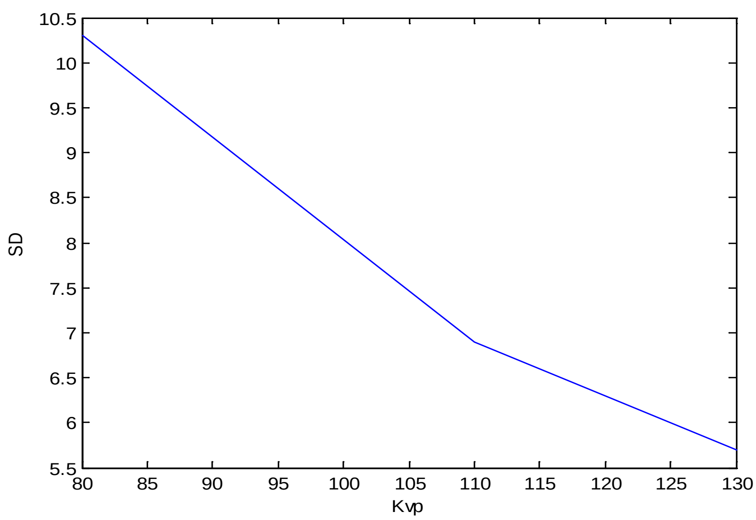

Figure 5. General correlation of kV_p and Noise (SD).

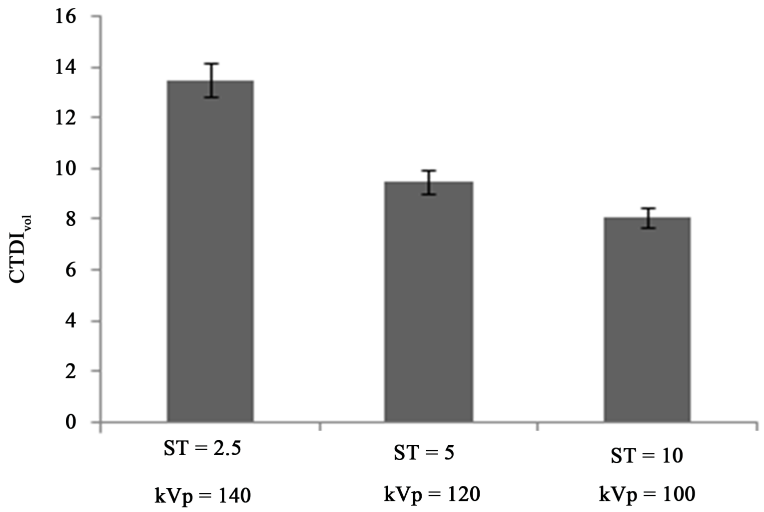

Figure 6. The adjusted factor of (ST) and kilo voltage kV_p versus $CTDI_{vol}$ (GE scanner).

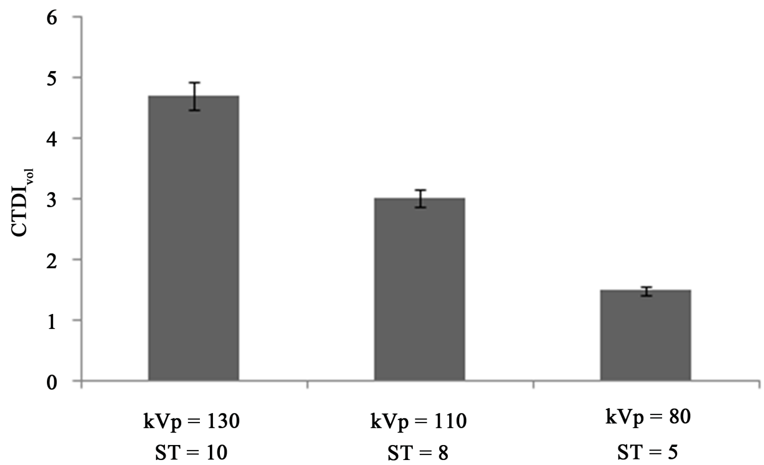

Figure 7. The adjusted factor slice thickness (ST) and kV_p versus $CTDI_{vol}$ (Siemens Scanner).

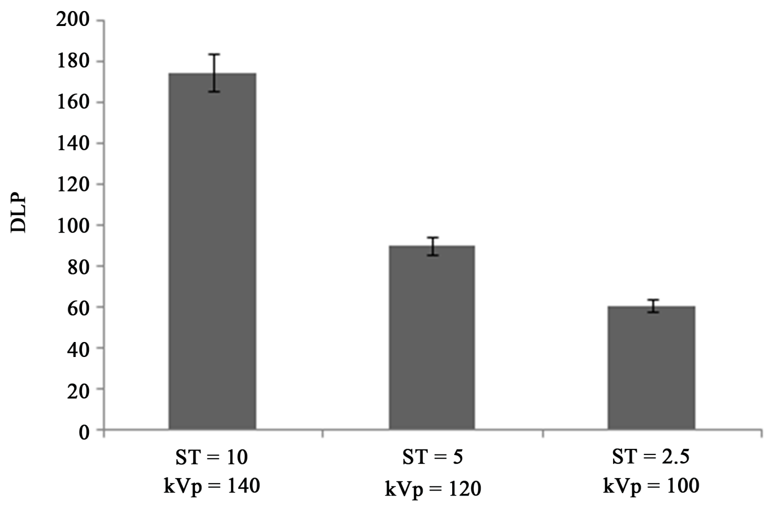

Figure 8. The adjusted factor slice thickness (ST) and kilo voltage kV_p versus DLP (GE scanner).

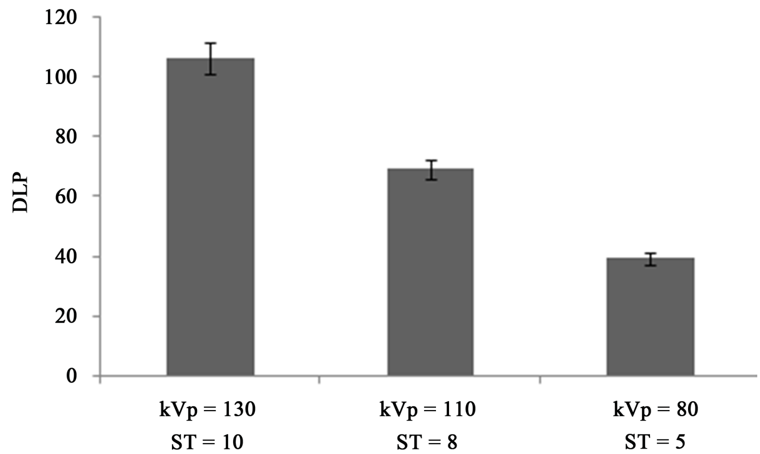

Figure 9. The adjusted factor slice thickness (ST) and kV_p versus DLP (Siemens scanner).

3.2. Discussion

The low contrast detectability is dependent on how much noise is present in the image. One way of quantifying the contrast in an image is to determine the contrast-to-noise ratio, which provides a value describing the quality of an image. In this study, the noise was determined by measuring noise at Region of interest ROIs at the centers and peripheries, as shown in table one for slices less and more than 5 mm (Table 1). This is considered to be acceptable according to SAEC standardizations that were obtained from the international atomic energy agency IAEA.

Two diagnostic parameters were evaluated to obtain a minimum image noise or an optimal radiation dose. The best minimum image noise was obtained by having a slice thickness of 5 mm and kV_p of 120 at Antalya center (GE scanner) (Table 2). However, at Elnileen diagnostic center (Siemens scanner) the minimum image noise was obtained by having a slice thickness of 10 mm and kV_p of 130 at Antalya center (GE scanner). The different values are due to differences in multi detector scanner types between the two centers. In addition, at Antalya center, the optimum CTDIvol (9.76 mGy) was obtained with 120 kV_p and slice thicknesses of 5 mm. At Elnileen diagnostic center, however, the optimum $CTDI_{vol}$ (3.17 mGy) was obtained with 110 kV_p and slice thicknesses of 8 mm. Finally (Figure 1 and Figure 2), at Antalya medical center, the optimum dose length product DLP (88 mGy·cm) was obtained when 120 kV_p was used with 5 mm slice thickness. However, at Elnileen Diagnostic center, the optimum DLP (67 mGy·cm) was obtained with 110 kV_p and 8 mm slice thickness.

Other adjustment factors were (pitch & kilo voltage). At Antalya Medical center, the minimum image noise was obtained by using the pitch of 1.3 with 120 kV_p, However, at Elnileen diagnostic center, 130 kV_p and pitch of 2 provided the minimum image noise.

Moreover, at Antalya medical center, the optimum $CTDI_{vol}$ (10.45 mGy) was obtained with 120 kV_p and pitch of 1.3. However, at Elnileen diagnostic center, 110 kV_p and pitch of 1.5 provided the optimal $CTDI_{vol}$ (3.66 mGy). Finally, the optimal DLP (88 mGy·cm) at Antalya medical center (Figure 8 and Figure 9), was obtained with 120 kV_p and pitch of 1.3). At Elnileen diagnostic center, however, 110 kVp and pitch of 1.5 were used to obtain the optimal DLP (69 mGy·cm).

The relationship between tube current-time product (mAs), tube kilo voltage (kVp) and image noise (SD) were evaluated. It showed that a reduction in mAs and kV_p increases the image noise. This is consistent with studies done by Seung-Wan 2010 and Reid et al 2010; they found that doses increased linearly with an increase in mAs and by the power function of kV_p for increases in kV_p. They also found that the image noise decreases as a function of kV_p and mAs and increases as a function of the phantom diameter.

Also the relation between slice thickness (ST) (**Figure 7** and **Figure 8**), pitch (P) and image noise showed that as pitch increases (**Figures 3-5**), the image noise decreases, and approximately inversely nonlinear relationship between slice thickness and image noise, *i.e.* increasing slice thickness decreases the image noise. For some manufacturers of multi detector scanners, the slice thickness is independent of the table speed based on the interpolation algorithm used. This is in line with a study done by Brochure. 2001 who showed that an increase in slice thickness leads to an improvement in the noise level and a reduction in the spatial resolution. He also found that decreasing the pitch decreases the duration of the patient exposure to radiation, and hence the patient dose per slice and image noise increase. This agrees with previous studies done by Yu-Chun Lin, Rehani *et al.* and Reid et al 2010. They found that increasing the pitch increases the doses to the patients.

4. Recommendations

This study recommends the following:

First of all, further studies are required to optimize protocols in different CT examination in multi-detector CT. Secondly, further studies are required to look at the effect of the patient age (pediatric and adult). Finally, developing a CT training program in quality assurance program, targeted for technologists, radiologist, physicists and CT scanner manufacturer. It is necessary for manufacturers, radiologists, technologists and physicists to work side by side to find a plan to decrease patient radiation dose (ALARA Principle) from CT scanner.

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