Assessment of Radiation Dose Reduction when using AEC of MSCT in Sudan

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Abstract: ***Objective**: This study aimed to compare the radiation dose of patients undergoing abdominal CT exams when using AEC and when using the daily routine manual protocol, in different hospitals equipped with multi detector CT scanners (MSCT) **Methods**: The acquired data was from arterials phase and vinous phase of contract materials injected during abdominal CT examination in the same patient. For the arterial phase the scan was performed with the routine manual scan factors, but for the vinous phase the AEC dose reduction techniques was applied. Scan and dose related factors were registered during both phases, this includes: KVp, mAs, scan length, scan time, number of slices, slice thickness, collimator, CTDI, and DLPs. **Results**: The lower CTDI and DLP values were the direct results of the decreased values of the mAs which applied by the SUREDOSE during the vinous phase. The average mAs was less by 56.6%, 61.6% and 56.6%. CTDI was less by 54.2%, 63.9% and 64.6% in hospital 1, 2, and 3 respectively during the SUREDOSE phase than the routine manual phase. For DLP it was also less by 57.1%, 62.8% and 57.7% in hospital 1, 2, and 3 respectively. For hospital 4 the mAs, CTDI and DLP increased by 47.7%, 54.3% and 42.8%% respectively and this highlighted the risk of not applying the AEC correctly. Conclusion: The proper installed AEC with optimum work of CT equipment's parts decease the patient radiation dose which indicated by the decreasing in the values of CTDI and DLPs.*

Keywords: AEC, MSCT, CT abdomen, CTDI and DLPs

1. Introduction

Computed tomography is a medical procedure that uses specialized X-ray equipment to produce a cross-sectional image representing a slice of the person being imaged (FDA, 2010). There has been a remarkable increase in use of CT since its inception in the early 1970s. 43% of the collective dose due to medical exposures arose from CT examinations, the contribution of the CT scanning to the total collective dose due to diagnostic medical examinations is approximately 47% (1). The computed tomography dose index (CTDI) is the primary metric used in CT to describe the radiation output from a scanner, it is a measure of the amount of radiation delivered from a series of contiguous irradiations to a pair of standardized acrylic phantoms. It is measured from one axial CT scan. The CTDI was defined in the early days of CT, when dose assessments were made using thermo luminescent dosimeters and have several disadvantages. To better represent the overall energy delivered by a given scan protocol, the $CTDI_{vol}$ can be integrated along the scan length to compute the dose-length product (DLP), (2) where the DLP (in mGy-cm) is equal to $CTDI_{vol}$ (in mGy) times scan length (in cm). The DLP reflects the integrated radiation output (and thus the potential biologic effect) attributable to the complete scan acquisition. General Principles of ''as Low as Reasonably Achievable'' The guiding principles for radiation protection in medicine are: Justification: The examination must be medically indicated. Optimization: The examination must be performed using doses that are as low as reasonably achievable (ALARA), consistent with the diagnostic task. Limitation: Although dose levels to occupationally exposed individuals are limited to levels recommended by consensus organizations, limits are not typical for medically necessary examinations or procedures. As the growth in CT use increased, particularly in pediatric patients, and concern over the population dose from CT was expressed in the scientific literature and lay press (3) and (4) it became clear that the responsible use of CT required adjustment of technique factors based on patient size (attenuation characteristics) (5) and (6). All dose-reduction strategies are predicated on the assumption that the CT scanners radiation dose levels and image quality fall within manufacturer specifications and other general quality criteria. It is technologically possible for CT systems to adjust the x-ray tube current in real time in response to variations in x-ray intensity at the detector (7), much as fluoroscopic x-ray systems adjust exposure automatically. The modulation may be fully preprogrammed, occur in near–real time by using a feedback mechanism, or incorporate preprogramming and a feedback loop. These methods of adapting the tube current to patient attenuation, known generically as AEC, are analogous to photo timing in general radiography and have demonstrated reductions in dose of about 20% to 40% when image quality is appropriately specified. AEC is a broad term that encompasses not only tube current modulation (to adapt to changes in patient attenuation) but also determining and delivering the right dose for any patient (infant to obese) to achieve the diagnostic task. Concurrently, new technologies, such as automatic exposure control (AEC), were in development, and were eventually made commercially available for all current CT systems. The use of AEC greatly enhances and simplifies efforts to decrease patient dose. Automatic exposure control systems are designed to adjust the kilovoltage (Kv), milliamperage, or exposure time of a test in order to obtain an image of diagnostic quality. Such systems detect the amount of radiation immediately in front of the image receptor and adjust the dose or dose rate to the patient in order to assure sufficient photons are reaching the image receptor (IAEA, annual report 2008). Automatic exposure control techniques are available on most CT scanners from major vendors (8). AEC is used to adjust the mA automatically according to the thickness of the body in the z-direction and scan plane the X-ray. Image quality selection paradigms for automatic exposure control systems each manufacturer of CT systems uses a different method of defining the image quality in the user interface. GE uses a concept known as the Noise Index. The noise index is referenced to the standard deviation of pixel values in a specific size water phantom and is compared with patient attenuation measured from the CT radiograph (scout) to maintain image noise. Toshiba allows two ways to prescribe image quality in their Sure Exposure AEC algorithm: Standard Deviation and Image Quality Level. Like GE's Noise Index, Sure Exposure also compares the patient's CT radiograph (Scanogram) data to the standard deviation of a specific-attenuation water phantom. Philips uses a Reference Image from a satisfactory patient examination (Reference Case) stored in the system with which image quality for future examinations is to be matched. Siemens uses quality reference mAs to define the effective mAs (5 mAs/ pitch) required to produce a specific image quality in an 80-kg patient (20 kg for pediatric cases) for a given protocol.

2. Materials and Methods

The equipment's used in this study was a multi detector CT scanners which are four TOSHIBA Acquilon 64, from Japan and one New Soft machine from china. The AEC in the Toshiba machine, SUREDOSE is based upon two ways to prescribe image quality in its Sure Exposure AEC algorithm: Standard Deviation and Image Quality Level. The technique is called the Noise Index, which is referenced to the standard deviation of pixel values in a specific size water phantom and compared with patient attenuation measured from the CT radiograph (scout) to maintain image noise. Abdominal CT exam was selected for this study. Normally the procedure was performed in five phases for every patient includes scout view, image without contrast, arterial phase contrast, vinous phase contrast, and washout phase. The data in this study was acquired during the arterials phase and vinous phase of contract materials injected during abdominal CT examination in the same patient. For the arterial phase the scan was performed with the routine manual scan factors, but for the vinous phase the SUREDOSE AEC dose reduction techniques was applied. Scan and dose related factors were registered during both phases, this includes: KVp, mAs, scan length, scan time, number of slices, slice thickness, collimator, CTDI, and DLPs. The arterials phase and vinous phase were selected for comparison because the scan is done for the same area with the same scan length, this will make the comparison of CTDI and DLP between the different scan techniques to be a reasonable one.

3. Observations, Results and Discussion

Table 1 and figure 1 represents statistical summary of the exposure factors during the arterial manual selected phase in the Toshiba scanner (4 instruments). It was observed that the mAs and kVp was settled to 150 and 120 respectively for all the patients regardless the age, sex, and weight of patients. Table 1 and figure 1 showed the exposure and the dose indicator factors during the vinous phase while applying the SUREDOSE software. The mAs was considerably less in this phase than in the arterial phase for all machine with exceptional to the machine in hospital number 4 where the mAs values were increased. The mAs also showed wide variations during vinous phase, this was indicated by the calculated standard deviations the mAs, which were19.6, 27.3 and 24.05 in hospitals 1, 2 and 3 respectively. There were no variations between the two phases in the other exposure factors (kVp, pitch, slice thickness, scan length), which indicate that the software is mainly changing the mAs values. Also a Large variations were observed in both CTDI and DLP between the two phases. The lower CTDI and DLP values were the direct results of the decreased values of the mAs which applied by the SUREDOSE during the vinous phase. The average mAs was less by 56.6%, 61.6% and 56.6%. CTDI was less by 54.2%, 63.9% and 64.6% in hospital 1, 2, and 3 respectively during the SUREDOSE phase than the routine manual phase which represented in Table 2 and Figure 2. For DLP which showed in Table 3 and Figure 3 it was also less by 57.1%, 62.8% and 57.7% in hospital 1, 2, and 3 respectively. In hospital 4 one raw of the CT detectors was not functioning, this has disturbed the SUREDOSE software, leading to increase of the mAs values and hence the patient radiation dose. mAs, CTDI and DLP in this hospital increased by 47.7%, 54.3% and 42.8%% respectively. This highlighted the risk of not applying the AEC correctly.

The increased probability of the stochastic radiation hazard from CT exams is directly proportional to the DLP. In this survey the application of the AEC remarkably decreased the DLP (up to 62%), which means large reduction was achieved during only one phase. Applying the AEC through in the five abdomen phases will considerably decrease the total dose to the patients. It should be mentioned also that the image quality was satisfactory for the radiologist during the vinous phase with AEC applied and the mAs reduction did not affected the quality of the image.

When compared the result of this study to recent study by Adam N. et.al. 2015 we found that the proper use of AEC will decrease the radiation dose to the patient by reducing the mAs values and hence the CTDI and DLPs values. The study performed by Adam N. et.al. 2015 showed that the mAs values were lowered by 40% and the CTDI reduced by 39% while the DLPs mean values were lowering by 42% in the imaging of cerebrospinal fluid with CT using contrast material.

Table 1: showed the variations in mAs values during the arterial phase and vinous phase in the all hospitals

	mAs mean ± STDV (min – max)	
	Routine manual protocol	SUREDOSE protocol
1	150 ± 0 (150 – 150)	84.9 ± 19.6 (56 – 139)
2	150 ± 0 (150 – 150)	92.4 ± 27.3 (50 – 148)
3	150 ± 0 (150 – 150)	84.78 ± 24.05 (41 – 123)
4	150 ± 0 (150 – 150)	314.2 ± 59.08 (210 – 419)

Table 2: Showed the variations in CTDI values during the arterial phase and vinous phase in the all hospitals

	CTDI Mean ± STDV (min – max)	
Hospitals	Routine manual protocol	SUREDOSE protocol
1	26.87 ± 10.01884	14.6 ± 4.3
	(20.70 – 78.60)	(9.19 – 32)
2	23.50 ± 2.40	14.8 ± 4.5
	(15.80 -29.70)	(6.9 – 22.5)
3	24.13 ± 1.88	15.6 ± 4.4
	(20.70 - 28.70)	(6.23 – 28.7)
4	21.40 ± 1.40	39.4 ± 5.06
	(19.80 - 23.90)	(30.8 – 46.7)

Table 3: showed the variations in DLP values during the arterial phase and vinous phase in the all hospitals

	DLP Mean ± STDV (min – max)	
Hospitals	Routine manual protocol	SUREDOSE protocol
1	1313.521 ± 109.3959 (1112.9 – 1607)	750.3 ± 156.2 (512.2 - 1136.9)
2	1333.03 ± 93.5 (1212 - 1591.7)	838.2 ± 200.04 (447.2 - 1283.8)
3	1327.23 ± 115.99 (1078.3 - 1512.7)	763.4 ± 184.6 (348.5 – 1160)
4	1292.3 ± 176.5 (918.7 - 1560.8)	3013.08 ± 315.4 (2610.1 - 4012.7)

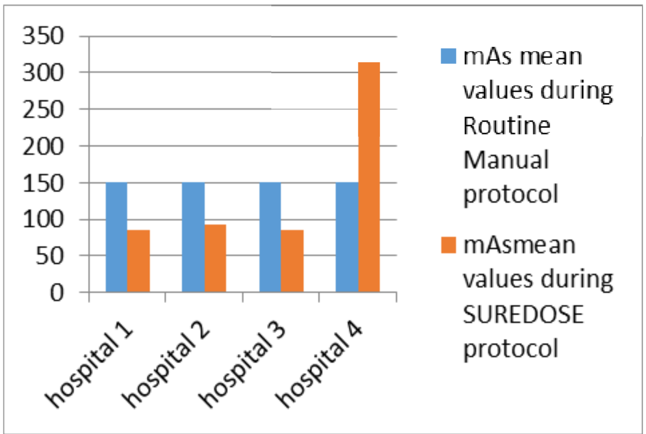

Figure 1: mAs mean values during SUREDOSE and the Routine Manual Protocols

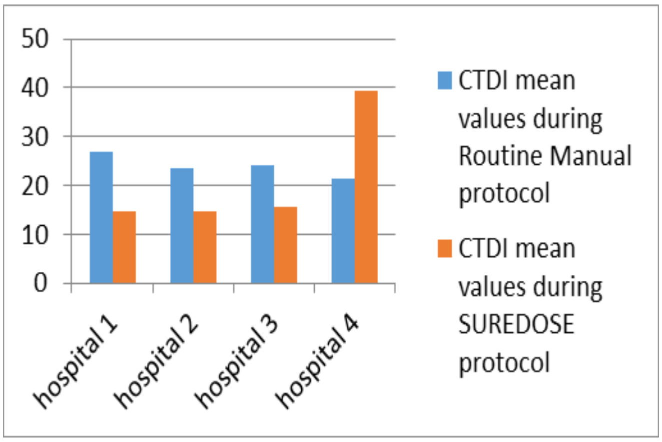

Figure 2: The CTDI mean values of the SUREDOSE and the Routine Manual Protocols

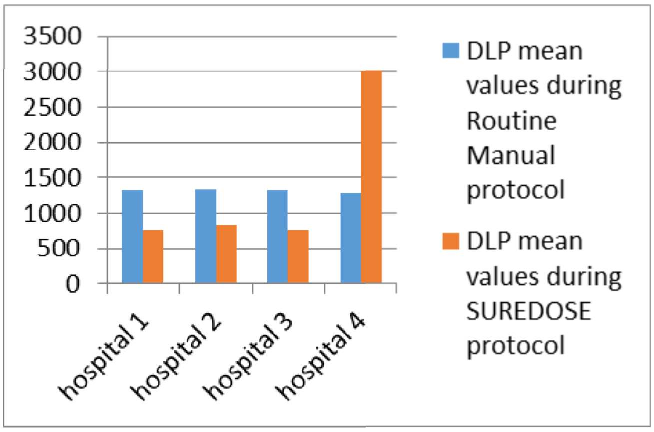

Figure 3: The DLPs mean values of the SUREDOSE and the Routine Manual Protocols

4. Conclusion

The aim of this study was to evaluate the efficiency of using AEC software in lowering the radiation dose to the patients while maintaining a diagnosable image quality. The radiations dose to the patients was measured during abdominal CT examination in four Toshiba machines and one New Soft machine which were not applying AEC during their CT scans in any exam. Patient radiation dose received during normal daily arterials phase was measured and compared to the dose of the same patient when applying the AEC during vinous phase of abdominals CT exam. The proper installed AEC with optimum work of CT equipment's parts decease the patient radiation dose which indicated by the decreasing the values of CTDI and DLPs. The CTDI was less by 54.2%, 63.9% 64.6% and 54.8% in hospital 1, 2, 3 and 4, respectively during the SUREDOSE phase than the routine manual phase. For DLP it was also less by 57.1%, 62.8% and 57.5% and increased to 42.8% in hospital1, 2, 3 and 4, respectively between the two phases. If there was equipment's problem or the software was not properly installed (E.g. hospital 4) and the operator selected AEC the values of CTDI and DLPs were increased. The non-application of this software was only due to lake of knowledge about both how to use it and the benefits of dose reduction associated with it. Application of this software is very useful and operator should be trained to use it in all CT exams. In Sudan the non-application of this software was only due to lake of knowledge on how to use it and the associated benefits of dose reduction associated with it. Application of this technique is very useful and operator should be trained to use it in all CT exams.

References

[1] United Nations Scientific Committee on the Effects of Atomic Radiation. Sources
[2] US Food and Drug Administration (FDA), Nov. 2001.
[3] Jessen KA, Shrimpton PC, Geleijns J, et al. Dosimetry for optimisation of patient protection in computed tomography. Appl Radiat Isot 1999;50:165–72.
[4] Haaga JR. Radiation dose management: weighing risk versus benefit. AJR Am J Roentgenol 2001; 177(2):289–91.
[5] Nickoloff EL, Alderson PO. Radiation exposures to patients from CT: reality, public perception, and policy. AJR Am J Roentgenol 2001;177(2):285–7.
[6] Wilting JE, Zwartkruis A, van Leeuwen MS, et al. A rational approach to dose reduction in CT: individualized scan protocols. Eur Radiol 2001; 11(12):2627–32.
[7] Boone JM, Geraghty EM, Seibert JA, et al. Dose reduction in pediatric CT: a rational approach. Radiology 2003;228(2):352–60.
[8] Gies M, KalenderWA,Wolf H, et al. Dose reduction in CT by anatomically adapted tube current modulation: simulation studies. Med Phys 1999;26(11):2235–47.
[9] Sigal-Cinqualbre AB, Hennequin R, Abada HT, Chen X, Paul JF. Low-kilovoltage multi-detector row chest CT in adults: feasibility and effect on image quality and iodine dose. Radiology 2004;231:169–174.

Author Profile

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