Evaluation of Radiation Dose and Image Quality for Patients Undergoing Computed Tomography (CT) Examinations

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ABSTRACT

Computed tomography (CT), is an X-ray procedure that generates high quality cross-sectional images of the body, and by comparison to other radiological diagnosis, CT is responsible for higher doses to patients.
The aim of this work is to study the CT practice in some CT units in different hospitals in Egypt, in order to investigate the radiation doses imparted to patients during CT examinations and image quality.
Dose measurements were performed for the most common applied CT examinations covering radiation sensitive organs in the head and trunk regions. Selected CT examinations are; routine head, routine chest, routine abdomen and routine pelvis.

Computed Tomography Dose Index $(CTDI)_w$ was calculated for each scanner from an average of three measurements in the head phantom and another three measurements in the body phantom. DLP values were estimated for each type of examination. Mean values of CTDIw had a range of 36.0-69.0 mGy for head and 11.0-30.0 mGy for chest, abdomen and pelvis examinations.
Organ dose and hence effective dose, calculated using Monte Carlo simulation technique. The effects of selecting tube KV and mAs on both spatial resolution and low contrast detectability were examined for two groups of KV values (90 and 120), the mAs values were degraded from 100 to 300 mAs in 100 mAs interval in first case, and from 50 to 300mAs, in 50mAs interval in second case.

INTRODUCTION

Many somatic effects of radiation became evident a few months after use of the X-ray in diagnostic medical applications. The radiation doses delivered to patients during medical examinations as well as workers are of interest from a radiation protection point of view, owing to the highly non-uniform nature of dose distribution and well recognized variation in the radiosensitivity of different organs and tissues. An assessment of the radiation risk may based on one or two specific organs doses, or may be based on the effective dose, which requires knowledge of the doses to 12 organs with specific weighting factors and to 10 remainder organs, as recommended by the International Commission for Radiological Protection (ICRP) [1].

However, as radiation-related diagnosis and treatment techniques become more sophisticated, a patient is more likely to be subject to radiation exposure that is too risky to ignore. While not overriding the benefits gained from the procedures, it is highly desirable to develop techniques to reduce patient dose without impacting the quality of care.

One of the most diagnostic tools that can cause high radiation doses is computed tomography (CT), which is an X-ray procedure that generates high quality cross-sectional images of the body, and by comparison to other radiological diagnosis, CT is responsible for higher doses to patients.
According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), worldwide, CT constitutes approximately 6% of all medical X-ray examinations, its contribution to the resultant collective dose was about 41% in 1999-2000 [2] . Due to increase of CT units being in use and added applications, the CT contribution to collective dose is growing during this decade. For instance, in the UK, CT contributions has more doubled over 10 years to about 47% [3], while representing in 2003-2004 about 9% of all X-ray examinations [4] , and in the USA, CT admitted to be comprised up to 15% of the examinations and 70% of the collective dose in some medical centers in 2002 [5] .
The aim of this work is to study the CT practice in some CT units in different hospitals in Egypt, in order to investigate the radiation doses imparted to patients during CT examinations and image quality.

MATERIALS AND METHODS

Dosimetry

The most common CT dosimetry approaches are;

- CTDI measurements free-in-air and in quality control (QC) phantom using ion chamber, and hence DLP calculations.
- Monte Carlo technique utilizing CTDI measurements to calculate organ and effective doses.
- Direct approach using TLD and Rando phantom to measure organ doses.

Since dosimetry using ion chamber is a direct method and time saving, therefore, in all the study, the first and second approaches were followed.
Dose measurements were performed for the most common applied CT examinations covering radiation sensitive organs in the head and trunk regions.
Selected CT examinations are; routine head, routine chest, routine abdomen and routine pelvis. Dose measurements were achieved using, Victoreen 6000-100 CT probe and Victoreen 4000 electrometer. Doses were measured both in air and in standard QC dosimetry phantoms.

There are a number of dosimetric quantities that are employed routinely under various circumstances to characterize exposure from CT scanners, the main frequently used quantities are; computed tomography dose index (CTDI) for single slice, dose length product (DLP) for complete examination and, organ doses and effective dose.
CTDI is the most practical quantity concerns measure of dose related to computed tomography[6]. This quantity is simple and can easily be determined on the axis of rotation of the

scanner. This approach has formed the basis for national surveys of CT practices in many countries

The software (CTDOSE) [7]. has been used to assess patient organ doses and effective dose values resulting from different CT examinations, for different CT scanners investigated in the study. The CTDOSE computer program incorporates the (NRPB) Monte Carlo datasets resulting from simulations of x-ray interactions in a mathematical phantom represents an average adult patient [8]. To run the program, Computed Tomography Dose Index in air in the rotation axis of the CT scanner normalized to mAs ($nCTDI_{air}$) measurements adapted to dose to muscle for different CT examinations has been conducted for all scanners of the study, all together with collected physical parameters, related to such examinations needed as input quantities. (KV, mAs, slice thickness,…etc). For newer CT scanners not covered by the NRPB datasets, the matching data supplied by the (IMPACT) [9] has been used to compensate for current models.

Quality Control (QC)

The goal of a QC program is to ensure that every image created by the CT scanner is a quality image. High quality images provide the radiologist maximum information, improve the chances for correct diagnosis, and ultimately contribute to quality patient care. There are many tests including in QC programs described in the literature, but in this study, emphasis was given to those tests regarding the relationship between radiation dose and image quality. The most important test in this context is resolution.

Resolution has two components, spatial resolution (high contrast resolution), and contrast resolution (low contrast resolution or detectability).
Spatial resolution of a CT scanner is its ability to display, as a separate images, two objects that are very close to each other.

Contrast resolution of a CT scanner is the ability to display, as a distinct images, areas that differ in density by a small amount.
Contrast and spatial resolution are intimately related to each other and to the radiation dose absorbed by the detector, and attempts to improve spatial resolution may cause increased noise levels that decrease contrast resolution. [10]

The QC phantoms supplied by the manufacturers of the CT scanners were used to perform the QC tests. Computed tomography phantoms are usually cylindrical, and accommodate both head and body scanning.

A high contrast bead, wire or edge is used to measure spatial resolution, which can also be visualized by regular arrays of high contrast inserts of diminishing size. Low contrast detectability and CT number linearity can be assessed by scanning the insert containing samples of different materials of known CT numbers for given x-ray energies. [11]

RESULTS AND DISCUSSION

Dose quantities measurements and calculations.

The dose measurements were carried out in 7 hospitals for 8 CT scanners; Two of the scanners (A and B) are conventional single slice (SS) third generation mode. Only one scanner (B), is multi slice (MS) spiral mode, the rest of the scanners are single slice spiral mode.

Scanner	Type	Hospital
A	**GE**, Sytec3000plus	Ainshams specialized
B	**Philips**, MX 8000	Ainshams specialized
C	**Toshiba**, Xvision	Naser institute
D	**GE**, Prospeed S	Benha university
E	**Siemens**, Somatom4	Cancer national institute
F	**Toshiba**, Asteion	Alhayat medical center
G	**Siemens**, Somatom Balance	Suez Canal university
H	**Toshiba**, Asteion	Almansoura university

Table-1 shows the average standard parameters used to perform different examinations for each CT scanner investigated in the study. Those parameters were used by the operators (technicians) for average weight adult patients. For most scanners, the head are examined by means of the conventional (axial) technique, using 120 kVp, except for scanner E, used 140 kVp and scanner G with 130 kVp. Only one machine uses 8 mm slice thickness for the whole examination of the head, where the other machines uses slices of 5 mm for the skull base and 10 mm for the brain. 10 mm slices are used for trunk exams (chest, abdomen and pelvis) for the whole scanners. The variable parameter between scanners was the mAs setting, which were ranging between 150-360 mAs for head exams, and 150-400 mAs for the trunk exams.

In general, the selection of physical factors, such as KVp, mAs and slice thickness, have a direct influence on patient radiation dose. However those factors affect image quality. Increasing exposure increases low contrast resolution by reducing noise but also increases patient dose. Image quality consistent with the clinical indications should be achieved with the lowest possible dose to the patient.

Regarding the kilovoltage (KV) selection, in general the range is between 80-140 KV and 120KV is the preferred in most cases. All modern CT scanners operate at 120 or 140 KV for routine standard imaging because these kilovoltage settings result in good image quality without excessive tube load. The scanning parameters recommended by CT manufacturers are designed for adult patients with average weights, and the adjustment of parameters-especially that of radiation for individual patients- is left up to the user of the scanning equipment. Recently, with use of computer and phantom simulations, it was established that using 80 or 90 KV instead of 120 KV can result in the radiation dose used in pediatric contrast examinations being reduced by 50% without affecting image quality [12]

Table-1 Scanning parameters for different CT units used in 4 common examinations. (Adults)

CT scanner	Examination	kVp	mAs	No. of slices	Slice thick. (mm)
A	Head Chest, abdomen, pelvis	120 120	180 234	10,10 38,40,22	3, 10 10
B	Head Chest, abdomen, pelvis	120 120	250 300	10,10 30,38,20	5, 10 10
C	Head Chest, abdomen, pelvis	120 120	360 400	10,10 26,28,22	5, 10 10
D	Head Chest, abdomen, pelvis	120 120	260 320	10,10 28.24,22	5, 10 10
E	Head Chest, abdomen, pelvis	130 130	260 150	18 25,22,20	8 10
F	Head Chest, abdomen, pelvis	120 120	300 250	10,10 38,34,30	5, 10 10
G	Head Chest, abdomen, pelvis	130 130	260 180	10,10 28,24,22	5,10 10
H	Head Chest, abdomen, pelvis	120 120	200 200	14 34,32,28	10 10

Reducing the kilovoltage from 120 to 80 KV leads to a 65% decrease in radiation dose at a constant mAs setting because the dose varies with the square of the kilovoltage. This reduction correlates with increased image noise and potentially with decreased image quality. Thus, this voltage reduction should be compensated by increasing the tube current[13]. When all technical parameters are held constant and the KV is increased, the dose value is also increased for both the head and body dosimetry phantoms. When the kilovolt peak was increased from 120 to 140 on a GE CT/I scanner, the CTDIw increase was 37.5% for the head phantom and 39% for the body phantom.[65]. For scanner B the reduction of radiation dose could be reached to more than 100% when KVp reduced from 120 to 90 KVp. (table-2)

The radiation dose is linear with the mAs when all other factors are held constant (table-2). So if the mAs value is reduced by 50%, the radiation dose will be reduced by the same amount. However, this reduction will increase image noise by ($1/\sqrt{mAs}$), which means that a 50% reduction in the mAs value will results in a noise increase of 41%. Depending on the requirements of the clinical application, this reduction may readily accepted ; in other cases, this type of reduction in mAs may compromise the diagnostic quality of the imaging examination. For example, detection of high-contrast objects in the lung may not require a low-noise imaging protocol and the reduction in mAs may be well tolerated. On the other hand, imaging low-contrast lesions in the liver does require a low-noise imaging protocol and the reduction in mAs may limit the ability to detect these lesions[14].

$CTDI_w$ was calculated for each scanner from an average of three measurements in the head phantom and another three measurements in the body phantom. DLP was estimated for each type of examination. Mean values of CTDIw had a range of 36.0-69.0 mGy for head and 11.0-30.0 mGy for chest, abdomen and pelvis examinations.

The weighted CTDI values determined in this study are listed in table-2 for both, head and body phantoms, along with the proposed EC reference levels. Results show that the hospitals meet the EC RDLs for abdomen and pelvis examinations, in terms of radiation dose and examination technique. For general head cases, the CTDIw values for the scanners C, F, and G, are slightly exceeding the EC reference doses. As far as chest examination is concerned, although CTDIw of each scanner is within proposed values, the scanners A, and B produce doses relatively close or equal to the reference level of the chest cases where in the scanners C, F, and G, the values are slightly exceeding the EC reference doses. Mean DLP values had a range of 518-990 mGy.cm for head , 275-1140 mGy.cm for chest, 242-1200 mGy.cm for abdomen and 220-750 mGy.cm for pelvis examinations.

Table-2 shows the DLP values for different examinations along with the EC reference levels. There are no head scan values above the EC reference levels. However for abdomen, scanners A,B,C and F have mean values exceeding the reference level, although the CTDI values were within the level. Also for chest exams most values are exceeding the reference except two scanners D and E . For pelvis exams values, half of the scanners are exceeding reference level. It is anticipated that a reduction of number of slices or length of scanned volume or tube-current product (mAs), or their combination, will reduce DLP value. Monitoring of DLP provides control on the volume of irradiation and overall exposure for an examination. The volume of investigation defined by the beginning and end of the region imaged. It should cover only the region of possible disease. The extent of the volume of investigation depends on the clinical needs and the greater its value the higher the integral dose to the patient, unless an increased inter-slice distance or pitch factor is used.

Pitch is the couch increment per rotation to the slice thickness at the axis of rotation. In clinical practice the inter-slice distance generally; lies in the range between 0-10 mm, and the pitch factor between 1 and 2. Using inter-slice distance in axial mode scanning could be resulted in losing some information of those non scanned gaps. But in helical scanning mode since there are no gaps resulted, the higher the pitch factor the lower resulting dose. Increasing pitch from 1.0 to 1.5 leads to a 33% decrease in dose and a 50% reduction is achieved by changing pitch from 1.0 to 2.0. Pediatric CT exams performed at a pitch of 1.5 did not result in diagnostic accuracy when compared with those performed at a pitch of 1.0. [15]. In most of the spiral CT scanners investigated in this study the trunk region (chest, abdomen and pelvis) are scanned using pitch factors range of 1-1.5 with average value of 1.25. Using pitch of 1.25 could maintain dose reduction up to 20%. This reduction is related to the time that the x-ray beam is required to scan the area. If the pitch is increased, the amount of time needed to cover the anatomic area of interest and the resultant dose to the patient are decreased.

Table-2 : Measurements of CTDI and DLP for scanners and the EC reference values (adults)

Scanner	Examination	Slice thick. (mm)	CTDIw (mGy)	DLP (mGy.cm)
A	Head Chest, Abdomen, Pelvis	5, 10 10	55/50 30	715 1140,1200,660
B	Head Chest, Abdomen, Pelvis	5, 10 10	56/55 27	975 810,1026,540
C	Head Chest, Abdomen, Pelvis	5, 10 10	69/65 29	955 754,812,638
D	Head Chest, Abdomen, Pelvis	5, 10 10	48/45 18	705 504,432,396
E	Head Chest, Abdomen, Pelvis	8 10	36 11	518 275,242,220
F	Head Chest, Abdomen, Pelvis	5, 10 10	64/60 25	920 950,850,750
G	Head Chest, Abdomen, Pelvis	5, 10 10	66/66 23	990 644,552,506
H	Head Chest, Abdomen, Pelvis	10 10	54 24	756 816,768,672
EC Reference Dose	**Head, Chest Abdomen, Pelvis**		**60 30 35 35**	**1050 650 800 600**

CTDI and DLP are indicators of the local dose in the irradiated slice and the total radiation exposure to the patient, respectively. They are used in order to evaluate exposure parameters and compare performance against reference criteria. However these quantities do not allow any comparison with dose values reported for conventional projection radiography, nor allow an estimation of the radiological risk. For a comparison of radiation hazards of CT scanning with alternative diagnostic radiological procedures, the effective dose is used. Effective dose (E) is a dosimetry quantity that takes into account the dose to all organs irradiated during a radiological examination, as well as the radiosensitivity of each irradiated organ or tissue. The effective dose is the best available predictor of the stochastic risk of a given radiological examination. Estimation of effective dose necessitated measure or calculate the dose of organs. In this study the effective dose values for average adult has been calculated using Monte Carlo software, for the selected exams performed by each CT scanner utilizing the measured CTDI values. Table-3 shows the values of effective dose for different examinations performed by different scanners, calculated by MonteCarlo software. For head, values were ranging between (1.14-2.74 mSv). For chest exams, the range was (4.65-18.35 mSv). For abdomen, values showed the highest figure (3.86-32.53 mSv). For the pelvis the range was (4.08-18.10 mSv). Unfortunately there are no reference dose levels for effective dose issued by the organizations deal with radiation levels . Instead, some organization and researcher has reported typical (mean) effective dose values resulted from different scales studies. In table-4 a comparison between values of effective dose of this study and values given by some institutions and researches.

Table-3 : Effective dose values calculated using MonteCarlo technique (adults)

Scanner	Examination			
	Head	Chest	abdomen	Pelvis
A	1.25	15.60	16.30	9.89
B	1.75	24.45	32.53	18.10
C	2.74	17.11	17.02	15.25
D	1.14	7.08	5.69	6.22
E	1.33	4.65	3.86	4.08
F	2.07	18.35	16.42	13.50
G	2.44	13.50	10.92	11.46
H	1.40	13.87	13.78	11.18

Table-4 : Comparison of effective dose values between this study and literature. ***(average values in brackets)***

Study	Head	Chest	Abdomen	Pelvis
				-
Yeh et al.[17]	0.93-1.78	5.39-13	7.37-10.19	-
Goddard and Alfarsi.[18]	0.3-8.2 (2.4)	0.3-10.8 (3.4)	1.4-31.2 (9.5)	2.7-13.8 (6.0)
Wade etal.[19]	0.6-1.6 (1.0)	1.1-15.3 (5.2)	-	1.86-12.60 (8.4)
Clark et al.[20]	0.98-2.11 (1.9)	3.84-14.58 (8.9)	3.8-13.35 (10.6)	1.13-24.8 (7.12)
NRPB- standards.[21]	0.46-4.94 (1.78)	1.05-22.5 (7.8)	1.58-22.6 (7.58)	(10.0)
RCR- standards.[22]	(2.0)	(8.0)	(10.0)	4.08-18.10 (11.21)
This study	1.14-2.74 (1.76)	4.65-24.45 (14.56)	3.86-32.53 (14.56)	

Considering only the average values of effective doses found in this study, it is obviously that values for the trunk regions are higher than the average values reported in the literature. Whereas average value of head exams are comparable to data in literature. The effective dose for the head scan is considerably less than that for the trunk scans, even though the CTDI values for head scan are much higher. This is because fewer of the radiosensitive organs are irradiated. Actually, the effective dose value is a reflection of the overall factors that determine the radiation exposure produced by the machine. Those factors are including design characteristics for each scanner, (for example the focus-to-axis distance and flat and shaped filters), and the physical factors selected for each exam, such as the KV, mAs, slice thickness and number of slices. It was observed in this study that in general the effective dose values are correlated to the corresponding dose length product (DLP) values, i.e. low DLP values leads to low effective dose values. Owing to

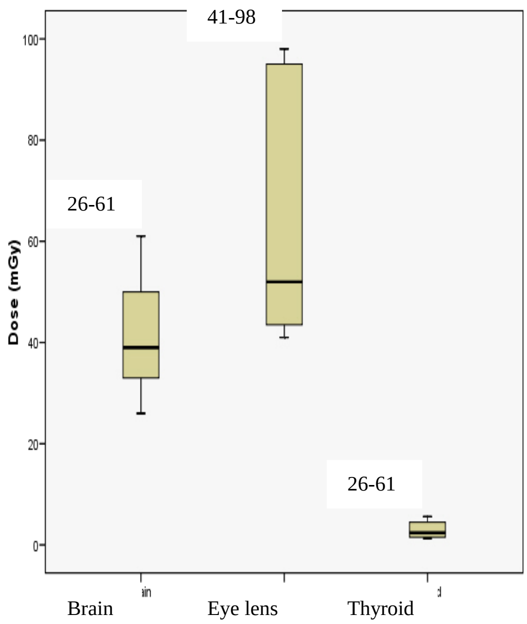


Fig-1 Organ doses range resulted for Head examinations

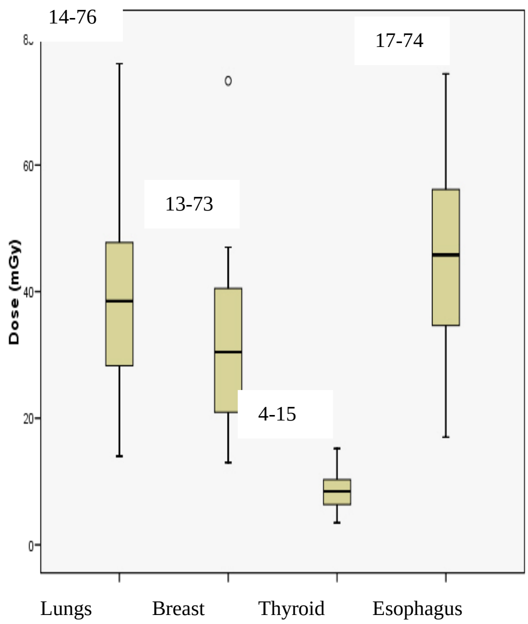


Fig-2 Organ doses range resulted for Chest examinations

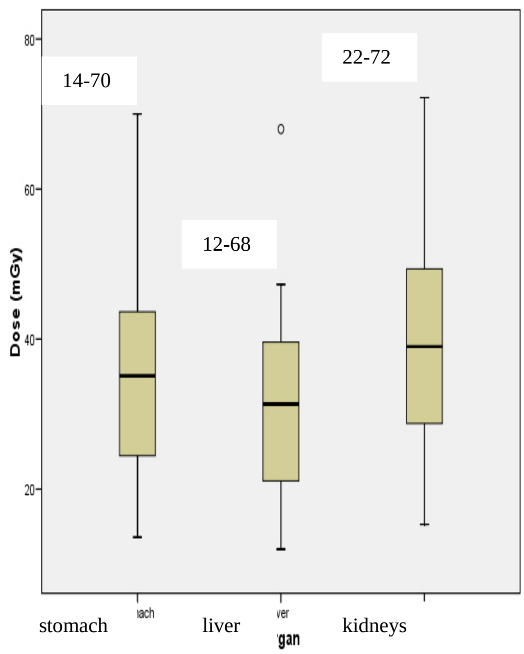


Fig-3 Organ doses range resulted for Abdomen Examinations

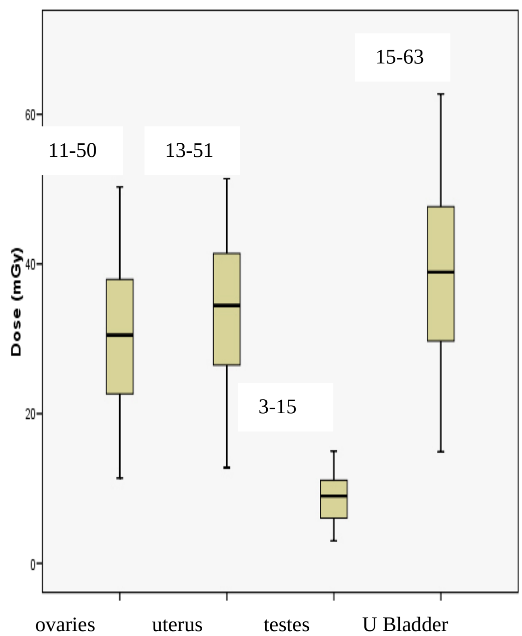


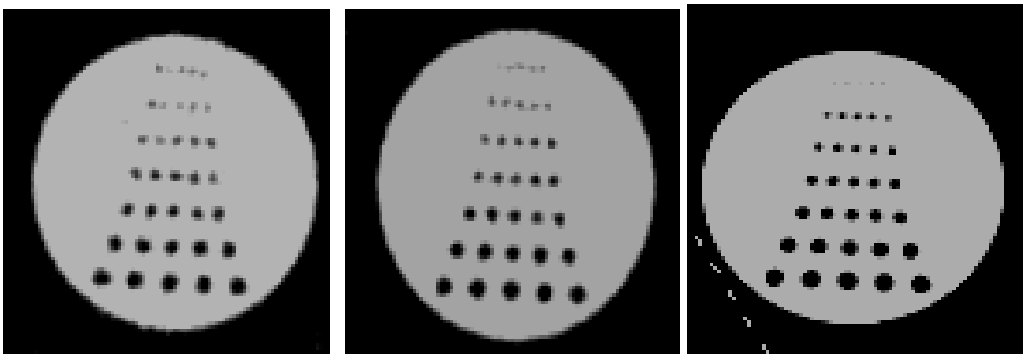
Fig-4 Organ doses range resulted for Pelvis examinations

the distribution of the radiosensitive organs in the body, effective doses for CT examinations of the head are usually much lower than those for the trunk examinations. Therefore the correlation between DLP and effective dose must be separated into two parts, one correlation for CT examinations of the head and one for CT examinations of the trunk. In order to assess risk associated with medical diagnosis in comprehensive manner, it is advantageous to consider doses to different organs for each CT procedure, rather than evaluate the effective dose resulted only (figures 1,2,3 and 4). It is noticeable that effective dose values for head exam are lower than effective dose values for trunk exams. But this fact should not obscure that dose received by some organs are very high such that doses to brain and eye lens. The dose range to brain in head exams for different scanners was (25.8-61 mGy), and for eye lens the range was (40.5-97.9 mGy). For chest exams, somatic risk is due to the doses to the lung, breast and esophagus which lying in direct x-ray beam. Considerable scattered radiation doe is to the thyroid, liver and stomach. Genetic risk is minimal due to large distance from gonads to the radiation field. Range of radiation dose resulted from chest exams was 14.00-75.94 mGy for lungs, 12.98-73.26 mGy for breast, 17.19-74.37 mGy for esophagus and thymus and 3.49-15.22 for thyroid. For abdomen exams, doses to stomach, liver, pancreas, kidneys and spleen where the highest, the range was 13.64-69.72 mGy for stomach, 12.09-67.87 mGy for liver and 21.72-72.00 mGy for kidney. For pelvis exams, genetic risk is due to high dose to gonads (ovaries and testes). Ovaries are subjected to direct x-ray beam. Testes, in general cases are subjected to scattered radiation. Uterus dose is used to assess conceptus dose in case when a pregnant patient was subjected to abdomen-pelvis examination. In case of pelvis exams the organ dose range was 11.36-50.30 mGy for ovaries, 12.77-51.43 mGy for uterus, and 3.14-15.10 mGy for testes. The U Bladder dose showed high values and the range was 14.93-62.72 mGy.

Quality control and image quality

The most important part of the quality control procedures is determination of high and low resolution of the CT image. Spatial resolution (high contrast resolution) describes the degree of blurring in an image. For a CT scanner, spatial resolution is a measure of the ability to discriminate objects of varying density a small distance apart against a uniform background. The Low contrast detectability (low contrast resolution) is the ability of the CT scanner to demonstrate small changes in tissue contrast. CT can detect density differences from 0.25% to 0.5% depending on the scanner. In figure-5 and figure-6, images of scanning the spatial resolution and low contrast inserts of quality control phantom supplied for scanner B. The spatial resolution insert is a Perspex with seven rows of holes of different diameters. The low contrast insert is Nylon (Aculon) body with six smaller lexan pins of 3,4,5,6,7 and 8mm. The Nylon CT number is 100±10 and the CT number for Lexan is 120±10.

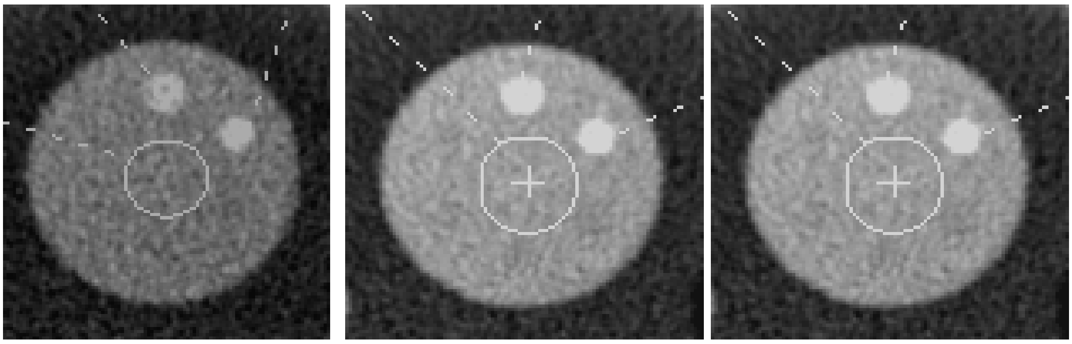
The effect of selecting tube KV and mAs on both spatial resolution and low contrast were examined for two groups of KV values (90 and 120), the mAs values were degraded from 100 to 300 mAs in 100 mAs interval in first case, and from 50 to 300mAs, in 50mAs interval in second case.



90KV, 200 mAs **90KV, 300 mAs** **120KV, 300 mAs**

Figure-5: Spatial resolution insert images at different KV and mAs settings

In ideal situation, all low contrast pins and spatial resolution pins must be clearly resolved in optimum mAs and KV settings (120 KV and 250 mAs or higher). In this study, up to the 2nd smallest row of spatial resolution holes could be resolved in most cases, this corresponding to 3.5 Lp/cm , 1st row also were resolved in higher dose cases. For the low contrast, the finest seen low contrast diameter was 7 mm in all cases. The CTDI and noise were measured for each case. Table-5 shows the spatial resolution scores, noise and dose at each image. If the images produced by (90 KV,100 mAs), and (120 KV, 50 mAs) are excluded due to high noise, the rest of the images are all in accepted level of spatial resolution. For low contrast detectability, pin of 7mm diameter were the smallest visible detail in all cases at different noise levels. As seen in images this score does not show finer visibility with higher parameters, probably due to deficiency in scanner detectors calibration. For similar version of this machine, In two separate evaluations, using (Impact Catphan) and (Philips Catphan) phantoms, scores were (5mm and 4mm) for smallest visible detail of low contrast [16]. Apart from KV and mAs selections which affect both image quality and patient radiation dose, the spatial resolution and low contrast, can be enhanced by reconstruction algorithm selection (software filter) and display matrix or the FOV (field of view) which determine the diameter of the reconstructed image, smaller FOV will reduce the pixel size and hence will improve spatial resolution. The filter parameter is used to set the mathematical algorithm which determines the sharpness or smoothness of the image. The noise in the image increase as the sharpness of the image increases, and vice versa. . In general, the low contrast decreases as the spatial resolution and noise increases. There are a wide selections of filters in modern CT scanners, can give wide range of image contrast and resolution. A standard resolution filter should be used for upper brain scans, with optimal homogeneity correction, improved bone-brain interface (edge enhancement filter). Normal filter for body and base of skull scans, which adapted to relatively low resolution images, acquired in relatively noisy conditions like large patients, thin slices and low mAs. Sharp filter for high resolution used for bone imaging when the soft tissue image quality is also important, and for that, high mAs settings are required. A sharp high resolution body scans filter, optimized for thin slice lung imaging. There are another filters assigned to medium sharp low resolution and high resolution for different parts of the body.



90KV, 200 mAs 120KV, 150 mAs 120KV, 250 mAs

Figure-6 : Low contrast insert images at different KV and mAs settings

Table-5 : Spatial resolution and low contrast scores for different parameters

parameters	Spatial resolution score	Low contrast	Noise (SD)	CTDIair (mGy)
90 KV, 100 mAs	2nd row – 3.5 lp/cm	7mm	11.7	8.8
90 KV, 200 mAs	1st row – 4.0 lp/cm	7mm	8.9	18.4
90 KV, 300 mAs	1st row – 4.0 lp/cm	7mm	7.4	29.6
120 KV, 50 mAs	2nd row – 3.5 lp/cm	7mm	12.8	11.5
120 KV, 100 mAs	2nd row – 3.5 lp/cm	7mm	7.8	23.4
120 KV, 150 mAs	2nd row – 3.5 lp/cm	7mm	6.2	35.2
120 KV, 200 mAs	1st row – 4.0 lp/cm	7mm	5.5	47.4
120 KV, 250 mAs	1st row – 4.0 lp/cm	7mm	4.9	59
120 KV, 300 mAs	1st row – 4.0 lp/cm	7mm	4.6	71.6

These results of spatial resolution and low contrast evaluation of this study and previous studies in literature are encouraging to select lower parameters for general cases where ultra high resolution images are not intended. A careful minimization in scanning factors (KV and mAs), especially for children and thinner adult patients, should be achieved in CT units in order to attain optimum degree of image quality and radiation dose saving. Sohaib et al. [23], studied the effect of reducing mAs on the diagnostic quality of images

and the radiation dose to the orbits in patients undergoing sinus CT. No significant difference in image quality was shown when gradual decrease from 200 mAs to 50 mAs was achieved. Mean radiation dose was reduced by 77%. Livingston et al [16] performed brain exams for adult patients using 100 mAs for initial non-contrast part of the exam and then 80 mAs for the contrast part of the exam, with tube voltage of 110 KV in both cases. They deduced that using 80 mAs for a contrast exam yielded necessary image information as those obtained using 100 mAs for non-contrast exam. Tsapaki et al [24] used 160 mAs for thinner adult patients undergoing abdomen/pelvis exams and 200 mAs for heavier patients. The FOV ranged from 33 cm to 50 cm according to patient dimensions. Image quality evaluation did not differ significantly between two groups. Shah et al. [25] confirmed that mAs can be reduced significantly in pediatric CT. mAs could be reduced by nearly 60% of previously used settings. They confirmed that, for cranial exam, mAs could be reduced to a range of 90-130 mAs, and to a range of 76-90 for chest, abdomen and pelvis exams without any effect on image quality in the level of detail available to reach a diagnosis. Although there were no significant differences even at 60-75 mAs in abdomen or pelvis exams, there was a trend towards lower structural resolution in this group. Frush et al. [26] assessed the effect of reduction in mAs settings on structural resolution in abdominal pediatric CT. In their study, reduced detection in low-visibility structures was evident at a level less than or equal to 80 mAs, Where the detection of high visibility structures remained unchanged at lower settings. Lucaya et al. [27] suggested that thoracic pediatric CT could be performed at lower settings (34-50 mAs) with acceptable image quality. Kamel et al. [28] reported that anatomical details, image quality and reader confidence to reach a diagnosis were not different when compared at 80 mAs and 240 mAs. Al-Haj et al. [29] used standard scan protocol for three groups in pediatric chest and abdomen/pelvis procedures at 120 KVp. They suggested that for children weight range of (0-9 kg), chest and abdomen/pelvis could be examined with 50 mAs and 70 mAs respectively. For (9-18 Kg), chest and abdomen coulde visualized with 60 mAs and 80 mAs respectively. For (18-27 Kg), 70 and 90 mAs are enough to examined chest and abdomen. Donelly et al[30] suggested use of 100-120 KV and 30-40 mAs for average child patient, for chest CT exams, and 100-120 KV and 50-70 mAs for abdomen exams.

Determination of imaging parameters is a responsibility of medical staff at each CT unit, according to machine performance and diagnosis requirements. From results obtained at this study and previous studies in literature. It believed that lower values of tube potentials (KV) and tube current-time (mAs) are enough to produce acceptable level of image quality and leads to adequate diagnosis.

In order to assure these image quality results obtained by QC phantom imaging, and since it was not possible to perform image quality experiments on real patient. The available head Rando phantom, which essentially manufactured for dosimetry applications using TLD dosimetry method, was used to achieve quality checks in head scans (fig.7). The phantom representing an average sized human head. The phantom has almost the same densities of the human head components of bone and soft tissue materials. The head phantom scanned with different settings of KV, mAs and window levels. Fiqures (8 and 9) shows the figures of selected axial scans of the skull. The images were reconstructed, first with bone window, and then by soft tissue window. For bone window cases, the quality remained unchanged at lower settings. For soft tissue window, although quality increases at higher settings, images at lower settings are at acceptable level of quality.

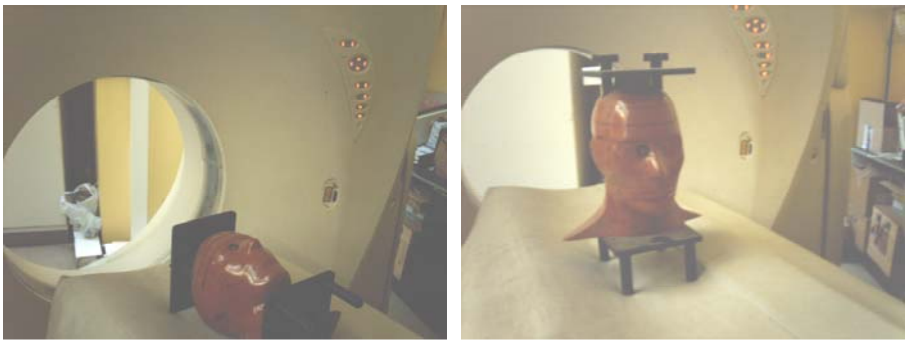


Figure 7 : Rando head phantom used to investigate image quality.

On the basis of this study, the radiology departments must adopt extended studies, and by cooperation of the radiologists, technicians and medical physicists to investigate all factors which affect patient radiation dose and image quality, in order to ensure optimum level of radiological diagnosis. The practice of CT imaging should ensure that patient doses are kept as low as reasonably achievable.

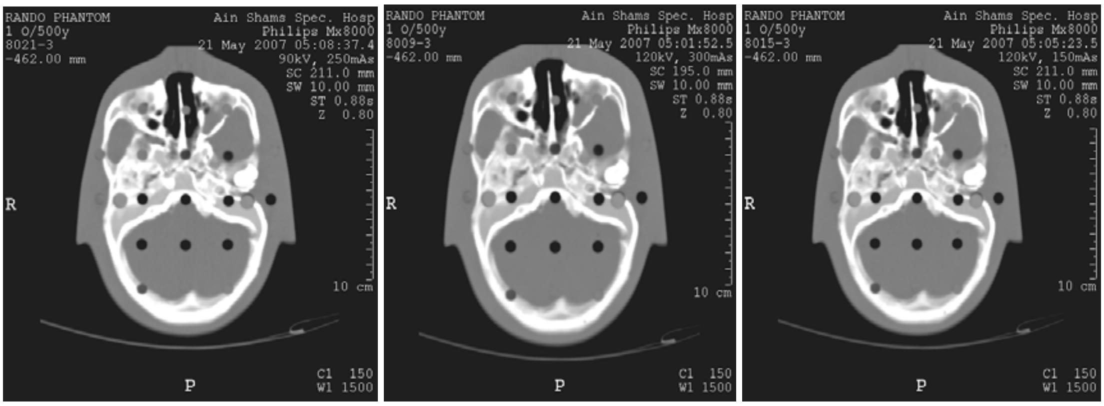


Figure 8 : Images of the skull using bone window at different settings

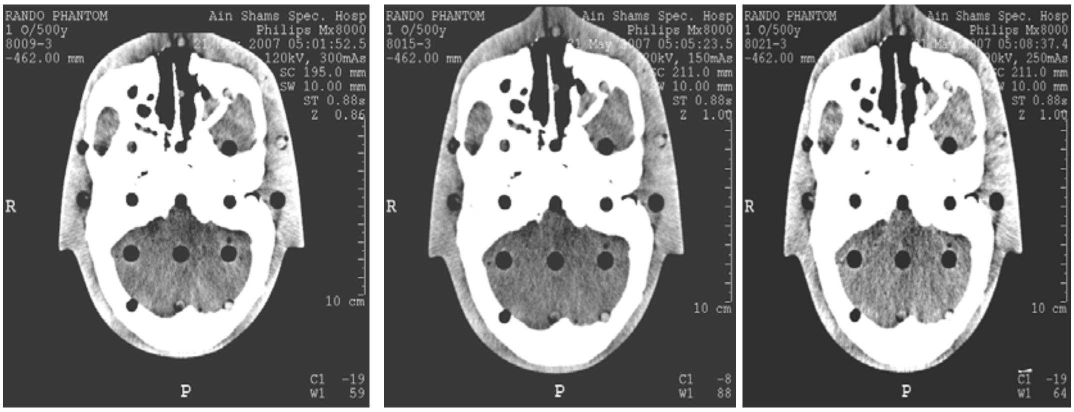


Figure 9 : Images of the skull using soft tissue window

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