Radiation Dose Reduction of Head CT scan with a Low–Tube Voltage.

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الخلاصة

ان تعرض المرضى للاشعاع بواسطة جهاز المفراس (CT- Scan) يتعلق بعلم الآشعة و الفيزياء الطبية. والهدف من هذا البحث هو دراسة تقليل جرعة الاشعاعية لمنطقة الرأس بواسطة جهاز المفراس واستخدام 90kv الطاقة الفولتية بدلا من 120 kv.لقياس الجرعة الاشعاعية يستخدم جهاز الشبح مع 16 Detectors للمفراس والطاقة الفولتية kv(120 و 90) و Tube Current ما بين mAs (560-100).الجرعة المؤثرة والجرعة المركبة الطويلة DLP قيست لمنطقة الراس , بصورة عامة فقد وجد بانه كلما كان طول المسافة المفحوصة طويلة فان الجرعة الاشعاعية المركبة اكبر بالنسبة للاشخاص المفحوصين لمسافة اقصر.استخدام KV 90 بدلا من KV 120 قد ادى الى تقليل الجرعة الاشعاعية بمقدار % 35 بدون ان يقلل من مقدار وضوحية الصورة.

Abstract

The increasing radiation exposure to patient from CT has been of concern to radiologists, medical physicists. The aim of this study is to reduce radiation dose from head computed tomography (CT) by using a technique with low tube voltage (90 Kv) instead of (120 Kv).

A phantom for measurement of the radiation dose and a phantom containing low-contrast objects were scanned with a 16–detector row CT scanner at 120 kV and 90 kV. The tube current–time product settings were 100–560 mAs, and the doses at the center and periphery of the phantom were measured.The effective dose and the DLP were estimated for patients who are undertaking head for CT examinations-By using phantom. From these results it is found that the longer scan series imparts a higher DLP to the patient compared to that of a shorter scan series. A reduction from 120 kV to 90 kV led to as much as a 35% reduction in the radiation dose, without of low-contrast detectability, at CT.

Introduction

Designing experiments to determine the relationship between diagnostic accuracy and radiation dose is challenging because additional radiation exposure is undesirable. Although the radiation dose delivered at CT can be modified by changing the tube current (in milliamperes), tube voltage (in peak voltage), scanning time, pitch, or scanner geometry, the most commonly manipulated parameter is the tube current (1). The dose and radiation exposure at CT are linearly related to the tube current if all other parameters are held constant.

Multisection computed tomography (CT) offers greater diagnostic advantages than does single-section CT and can be used in a variety of clinical settings. Because of the routine use of thinner sections, extended acquisition volumes, and multiple-phase acquisitions, patients may experience higher radiation exposure (2-5).

Although the radiation dose can be reduced by decreasing the tube current–time product settings (6-8), this alteration also reduces the contrast-to-noise ratio (CNR). Sigal- Cinqualbre et al (9) reported a weight-adapted contrastenhanced head CT technique with low tube voltage that allowed reduction of the radiation dose, as well as reduction of the contrast material dose.

Materials and Methods

Phantom: The phantom which is used frequently in CT dose measurement is two cylinder of Perspex; one with 16cm diameter and called head phantom and the other with 32cm called body phantom and the material is polymethylmethacrylate (PMMA). Holes with matching PMMA plugs are available in the phantoms for inserting a pencil ionization champers with an active length of 100 mm at the center and equally spaced peripheral positions

CT scanner: We used a 16–detector row CT scanner (IDT16; Philips Medical Systems). The scanning parameters were as follows: detector configuration, 1.5 mm (detector collimation) _ 16 (detectors); section thickness, 5.0 mm; section interval, 5.0 mm; rotation time, 0.75 second; pitch, 0.659; scan field of view, 50.0 cm; and display field of view, 35.0 cm. Scanning was performed at the standard tube voltage of 120 kV (effective energy, 64 keV) and at the low tube voltage of 90 kV (effective energy, 54 keV). In measurements of the radiation dose at 120 and 90 kV, the tube current–time product settings were 100, 150, 200, 250, 300, 350, 400, and 450 mAs and 100, 150, 200, 250, 300, 350, 400, 450, 500, and 560 mAs, respectively.We did not measure the radiation dose at 500 and 560 mAs and 120 kV.

CT Dose: The CT DOSE software requires the following input parameters: scanned volume (in terms of baseline in the phantom and number of slices), slice width, couch increment (axials), effective mAs and CT dose index per mAs (CTDI). CTDI is a measure of the total dose from a single slice irradiation. The European working document gives the following formula for CTDI [10]:

$$CTDI = \frac{1}{T} \int_{-\infty}^{\infty} D(Z)\, dz$$

Where Z is the integral along a line parallel to the axis of rotation, D is the dose profile of a single slice, and T is the normal slice thickness. The quantity dose–length product (DLP) was then derived for all scan protocols using the methods described in the European working document, for comparison against the four proposed diagnostic reference levels relating to head [10]. The quantity DLP uses a weighted CTDI, ($CTDI_w$ (mGy)). $CTDI_w$ is an approximation to the average dose over a single slice and is derived from a combination of measurements at the surface and centre of a defined set of Perspex phantoms, according to the equation:

$$CTDIw = 1/3\ CTDIc + 2/3\ CTDIp$$

Where $CTDI_c$ is the CTDI measured at the centre of the phantom and $CTDI_p$ is the CTDI measured at the periphery of the phantom.

The European working document gives the following formulae for DLP:

$$CTDI_{VOL} = \frac{CTDI_W}{Pitch}$$

Where pitch is defined as table distance traveled in one 360° rotation / total collimated width of the x-ray beam .The definition of DLP is :

$$DLP = CTDI_{vol} \times Scan\ Length$$

Therefore, DLP increases with an increase in total scan length or with the variable affects $CTDI_w$ (e.g. tube voltage or tube current) or the pitch .Because scan length is expressed in centimeters, the SI unit for DLP is (mGy .cm).

The effective dose reflects the non uniform radiation absorption of partial body exposure relative to a whole body radiation dose and allows comparisons of risk among different CT examination protocols. A reasonable approximation of the effective dose can be obtained using the equation:

$$E = E_{DLP} . \ DLP$$

Where E is the effective dose and E_{DLP} is a conversion factor ($mSv.mGy^{-1}.cm^{-1}$) that varies dependent on the body region that is imaged

Results

Radiation doses: Radiation doses obtained in the center and in the periphery of the phantom are shown in Tables (1) and (2), respectively; weighted CT dose index for those doses provided by the manufacturer are shown in Table (3). With assignment of a value of 100% to the radiation dose obtained in the center of the phantom at 120 kV and 300 mAs, the relative doses obtained in the center at 90 kV were 35% at 250 mAs, 43% at 300 mAs, 50% at 350 mAs, 59% at 400 mAs, 65% at 450 mAs, 73% at 500 mAs, and 79% at 560 mAs (Table 1). When we assigned a value of 100% to the dose obtained in the periphery of the phantom at 120 kV and 300 mAs, the relative doses obtained in the periphery at 90 kV were 46% at 250 mAs, 53% at 300 mAs, 60% at 350 mAs, 79% at 400 mAs, 87% at 450 mAs, and 96% at 500 mAs (Table 2). The relative dose obtained in the periphery was higher than was the dose obtained in the center.

Table 1: Radiation Doses in Center of Phantom.

Tube Current- Time product (mAs)	Dose (mGy)	
	90 kV	120 kV
100	1.90	4.71
150	2.95	7.18
200	4.06	9.53
250	5.15	12.11
300	6.34	14.66
350	7.32	17.76
400	8.64	18.32
450	9.49	22.38
500	10.73	…………..
560	11.51	……………

Table2: Radiation Doses in periphery of Phantom.

Tube Current- Time product (mAs)	Dose (mGy)	
	90 kV	120 kV
100	4.37	8.88
150	6.54	14.93
200	9.87	18.17
250	11.70	24.85
300	13.55	25.26
350	15.20	30.90
400	19.98	41.02
450	22.03	47.87
500	24.20	……..
560	28.64	……..

Table 3: Relationship between Tube current-Time product and Weighted CT Dose Index Value at 90 and 120 Kv.

Tube Current- Time product (mAs)	Weighted CT Dose Index Value (mGy)	
	90 kV	120 kV
100	19	44
150	28	62
200	38	63
250	47	70
300	50	71.3
350	51	72.3
400	52	72.8
450	52.3	75.4
500	52.5	……………..
560	52.7	……………….

Effective dose and Dose-Length-Product result: In this study the Phantom is used to estimating effective dose for 20 patients undergoing (head) CT exam. As well as the Dose Length Product (DLP), which is another dose descriptor related to CTDI estimated, and is commonly

reported on CT scanners. The range of effective dose for patients head at ranges between (1.1-1.4) mSv with mean value (1.215±0.0625) mSv, The DLP average between (233-843) mGy.cm and mean value (454±39.347) mGy.cm show Table (4).

Table 4: DLP and Effective Dose for head CT exam.

Sex.	No. of Patients	MAs	kVp.	CTDI w / mGy	DLP/mGy.cm	Effective Dose / mSv.
M	1	250	90	51.30	816	1.3
M	2	250	90	51.30	843	1.3
M	3	250	90	51.30	754	1.3
M	4	250	90	51.30	744	1.3
F	5	250	90	51.30	775	1.4
F	6	250	90	51.30	795	1.3
F	7	250	90	51.30	729	1.4
F	8	250	90	51.30	627	1.3
F	9	250	90	51.30	749	1.3
M	10	250	90	51.30	770	1.3
M	11	250	90	51.30	734	1.2
M	12	250	90	51.30	841	1.2
M	13	250	90	51.30	708	1.2
M	14	250	90	51.30	662	1.2
M	15	250	90	51.30	795	1.3
M	16	250	90	51.30	775	1.3
F	17	250	90	51.30	728	1.3
F	18	250	90	51.30	580	1.4
F	19	250	90	51.30	233	1.4
F	20	250	90	51.30	759	1.2

Discussion

The effective dose is a radiation descriptor that may be used to charecterize radiation exposures to patients undergoing CT examinations. The magnitude of the effective dose is related to the stochastic radiation risks of cancer induction and the production of genetic effects. In this study the effective dose was estimated by using Phantom, from the result one notes the significant differences ($p<0.05$) of effective dose between the male and female patients for different types of examinations. The difference between men and women from the specificity of their organs and in general the weight of female is less than that for male so the male dose is less. [11], this result shows good agreement with that published byLemke et al. [12], and Shrimpton et al. [13]. See Table (5).

Table 5: The effective dose/ (mSv) in this study and another studies.

CT exam	Effective dose/(mSv)					
	This study	Gray et al [16]	Shrimpton et al.[15]	Lemke et al[14]	Tsapaki et al.[17]	EC [12]
Head	1.215±0.0625 M* 1.310±0.0418F*	0.6M 0.6F	1.65M 1.78F	1.95M 1.98F	1.4± 0.3	2.2

In estimates of attributable risks in developed countries, the risk of cancer from diagnostic x-rays reportedly ranged from 0.6% to 3.0% [16]. On the basis of these considerations, we postulate that a 35% reduction in the radiation dose can be achieved when scanning is performed at 90 kV rather than at 120 kV. We did not evaluate low-contrast detect ability at values higher than 90 kV and 560 mAs because our CT scanner did not allow us to set the tube current–time product at a value higher than 560 mAs.

A disadvantage of the CT technique with low tube voltage is the increase innoise. Boone et al [17] found a relationship between image noise and the tube voltage and the tube current–time product setting in CT. They show that noise increased at lower tube current–time product settings and lower tube voltage.

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