Effect of CT Bore size on Radiation Dose during Head CT Acquisition.

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Abstract: With the development of technology, the use of CT extended beyond the diagnostic purposes and made a room for complex radiotherapy treatment planning. As the traditional diagnostic CT scanners have small bore-size (typically 65–70 cm) and curved patient couch which is not suitable for virtual simulation with immobilised devices. Therefore wide-bore CT scanners with increased bore size (80-100 cm) were introduced for radiotherapy treatment planning. These virtual simulation CT scanners are further equipped with an external patient positioning laser system, flat patient couch and specialized visualization software. Due to the unavailability of traditional CT scanner, theses wide (or large)-bore CT simulators are used for routine diagnostic procedures. The main purpose of this study was to compare the patient doses delivered by a wide (LB) and a small-bore (AQ1) CT scanners to ensure the safe use of wide-bore simulator for diagnostic purpose. A standard head CT phantom (16 cm diameter and 15 cm length) made out of Polymethyl methacrylate (PMMA) was positioned at the iso-centre and 100 cm pencil ionizing chamber was positioned at the centre and periphery of the phantom. The phantom was scanned under different combinations of tube voltages (80, 100, 120, 135 kVp) and tube currents (100,150, 200, 300, 400 mA) and the Dose Length Product (DLP) in cGy were measured for each location of the ion chamber using an electrometer. The pitch and scan lengths (0.813, 15 cm) were kept constant for each measurement. Our study confirmed that the wide-bore is delivering considerably more dose than observed in AQ1 for head CT with the same exposure parameters. This increasement is more pronounced in exposures above 200 mA and 120 kVp. Therefore, the use of wide-bore simulator for routine diagnostic CT examinations is safer for lower kVp and mA but not encouraged for all the routine diagnostic purpose without further study.

Keywords: Computed Tomography, Wide bore CT, CT dose, CT simulator, Gantry size.

Introduction:

The gantry or the ring-shaped part of the computed tomography (CT) scanner houses major components necessary to generate the CT image. It is considered as the most important part of the scanner and vary in total size as well as in the diameter of the opening, or aperture. The range of aperture size is typically 70 to 90 cm [3]. Traditional diagnostic CT units provide a maximum scan field-of-view (SFOV) diameter of 50 cm and a limited bore size of approximately 70 cm, which cannot accommodate a larger patients or an extended simulation setup in radiation therapy (RT) [1]. Therefore until the late 1990s, imaging prior to radiotherapy treatment planning was satisfied with an acquisition of a routine CT study [4]. However, to meet the needs of radiotherapy wide-bore CT scanners with increased bore size were developed. Moreover, these dedicated units should provide high-quality images to be used for target delineation in the treatment planning process. It is believed that high quality images should not trade off for increased radiation dose. However, based on a comparison study done in USA it was found that the head and body doses for the large bore scanner was slightly higher (1–2 cGy) compared to those for the 70-cm-type units [2]. This was the first and only study found in literature related to the above concept and however it is with several limitations. These limitations were carefully addressed in the present study and near perfect comparison of radiation dose was done among two CT units with different bore sizes for head CT.

Methodology:

Dosimetric measurements were made on a 90 cm wide bore CT simulator (LB) and a standard 78 cm diagnostic CT (AQ1) for routine head CT protocol. The pitch (0.18) and scan length (15 cm) were fixed for both occasions. However, Exposures were made at five mA stations (100,150, 200, 300, 400 mA) and for each tube current (mA) station given combination of tube voltage (kVp) were used (80, 100, 120, 135 kVp). The actual dose measurements were done using standard polymethylmethacrylate (PMMA) dosimetric phantom. With the aid of pencil shape ionizing chamber the CTDI values were recorded at the centre and periphery of the PMMA phantom. The 1/3 of the CTDI at centre and 2/3 of the CTDI at periphery were summed and multiplied by the 1/pitch to obtain the $CTDI_{vol}$ values as given in the below equation.

$$\mathbf{CTDI_w} = 2/3\ CTDI_{100}\ (periphery) + 1/3\ CTDI_{100}\ (center)\quad \mathbf{CTDI_{vol}} = CTDI_w\ /pitch$$

Where, the pitch is defined as the ratio of the table feed (in mm) per 360^0 gantry rotation (Bed Index-BI) to the nominal collimated beam width (Slice width-SW)

$$\mathbf{Pitch} = BI/SW$$

To determine the dose for a single scan, the DLP is used. It is the product of dose per slice ($CTDI_{vol}$) and total scan length and is given in the below equation.

$$\mathbf{DLP}\ (mGy*cm) = CTDI_{vol}\ x\ scan\ length$$

Finally, the measured DLP values were compared for LB and AQ1 at different kVp and mA combinations.

Results and Discussion:

The obtained DLP values measured in mGy.cm were tabulated for AQ1 and LB against different combinations of mA and kVp as given in the table 1. Moreover, the plot of data on above variables demonstrates a noticeable variation of measured DLP between AQ1 and LB. According to the figure 1, there is a considerable increment in the dose generated by the LB beyond 200 mA. This elevation is more pronounced in the 200 mA and 120 kVp combinations.

Table 1: Measured DLP (mGy.cm) for LB and AQ1 for different tube current (mA) and tube voltage (kVp) combinations.

	CT equipment	DLP (mGy.cm)				
		100 mA	150 mA	200 mA	300 mA	400 mA
80 kVp	LB	57.19	117.90	159.23	248.56	296.22
	AQ1	56.86	113.78	135.30	205.97	278.38
100 kVp	LB	123.50	217.88	265.54	448.56	503.91
	AQ1	122.0	207.88	245.71	399.66	433.49
120 kVp	LB	206.14	284.16	437.97	607.00	853.00
	AQ1	194.98	290.37	334.27	551.34	825.23
135 kVp	LB	273.73	404.87	499.05	789.89	1060.50
	AQ1	258.54	374.02	483.68	747.39	1044.38

LB - 90 cm wide-bore CT simulator

AQ1- 78 cm standard diagnostic CTequipment

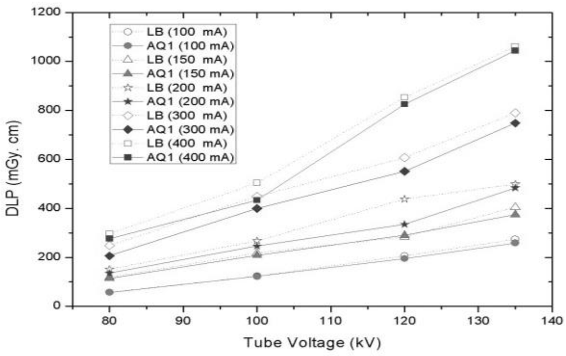

Figure 1: Plot of DLP (mGy.cm) against tube voltage (kVp) at different tube currents (mA) for LB and AQ1.

According to the best knowledge of authors this is the first study done in Sri Lanka related to the above concept and the present study provides a perfect comparison between two units were achieved the dose increment with the simulator CT may be due to but not limited to its inbuilt design to suit the oncology localization requirements. The fixed SFOV of 600 mm used in the simulator CT may be a reason for comparatively higher dose since most of the diagnostic CT equipment has lesser SFOV than the above. Further studies would require to evaluate the other contributing factors for higher doses in LB and its use in the diagnostic setting should be validated using the evidences from similar studies.

Conclusion:

Wide bore simulator is design to address the oncology requirements, such as obtain higher quality images with adequate position freedom. Therefore, it may deliver higher doses than standard diagnostic CT equipment if scanned using same parameters. According to the present study results it is evident that some combinations of kVp and mA generates higher doses in LB than that of AQ1. Though the use of wide bore simulator for routine diagnostic CT examinations is safe for lower kVP and mA, utilization of simulator CT for diagnostic purposes are not encouraged and further studies are required to confirm it.

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