

Head computed tomography protocol audit and correction in two tertiary health institutions in Anambra State of Nigeria

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Abstract

Background and Objective: The optimization of patient protection in computed tomography (CT) requires the application of examination-specific protocols to ensure that the dose to each patient is as low as reasonably achievable. Appropriateness of a protocol reflects in the output of the volume CT dose index (CTDI_{vol}) and dose-length product (DLP). This work aims to review and correct the likely weaknesses in default head CT protocols as a quality control measure.

Materials and Methods: Departmental and Ethical Committee approvals were obtained. This retrospective study was undertaken between March and April 2016. The 75th percentile of the CTDI_{vol} and DLP was calculated for 50 consecutive patients of both genders who were ≥ 18 years of age. On the CT console, radiographer (s)' manipulation of each of the ten common components of default protocols was scrutinized and compared with predetermined standard values from literature. Observed deviations necessitated appropriate interventional measures. A second calculation of the 75th percentile of CTDI_{vol} and DLP was done for another group of 50 patients. Both pre- and post-interventional values were compared with the 60 mGy (CTDI_{vol}) and 1050 mGy-cm (DLP) recommended by the European Commission.

Results: The pre - interventional CTDI_{vol} and DLP outputs were 65 mGy/1634 mGy-cm (Center A) and 86 mGy/1786 mGy-cm (Center B) whereas the post - interventional values were 58 mGy/986 mGy-cm (Center A) and 60 mGy/1030 mGy-cm (Center B), respectively. Weaknesses noted in protocols were excessive scan range (≥ 15 cm), < 1 helical pitch, > 1 s gantry rotation time, absence of gap, erratic manual mA manipulation, and neglect of prospective dose chart. Some posteroanterior scanograms were also wrongly acquired at an azimuth of 0° (anteroposterior).

Conclusion: CT dose output in our locality could be compared to the values of the European Commission if meticulous and regular dose audit and correction is implemented.

Keywords: Computed tomography, computed tomography protocol, correction, dose, dose audit, dose-length product, volume computed tomography dose index

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INTRODUCTION

The main concerns about patient dose in computed tomography (CT) relate to the stochastic effects which encompass carcinogenesis and hereditary changes.^[1] However, since CT is also used for interventional procedures where the same body region may be exposed many times during a single procedure and a patient may undergo multiple procedures within a limited time scale, deterministic effects are not completely out of the picture.^[2,3]

In requesting CT examination, two guiding principles must be followed. First, the examination must be appropriately justified. Second, all technical aspects of the examination must be optimized such that the required levels of image quality can be obtained while keeping the doses low.^[4] Recent overdose incidents^[5] have placed an obligation on the CT community to review the amount of radiation prescribed for CT scans.^[4]

The techniques that significantly influence the radiation dose given to the patient^[6] and the radiation output characteristics of the scanner constitute the clinical protocols which determine the dose to the patient.^[7] Variations in dose output are often noted in clinical practice, due to differences in local scan protocols.^[8] CT protocols have extensive choice of adjustable dose-saving features that have been proven to substantially reduce the dose without detriment to the diagnostic quality of the CT images when properly used.^[9-11]

A protocol is efficient if it minimizes dose while producing images with high diagnostic quality.^[12] The efficiency of CT protocols is determined by two dosimetric quantities at the end of each scan, as per the International Electrotechnical Commission requirements;^[13] volumetric CT dose index ($CTDI_{vol}$) for a single section and dose-length product (DLP) for the entire examination.^[14]

The $CTDI_{vol}$ is a standardized measure of the radiation output of a CT scanner which allows users to compare different scanners and scan protocols^[15] because it takes into account the protocol-specific information.^[16] The SI unit is milligray.^[13] DLP combines the $CTDI_{vol}$ and the scan length to quantify the total radiation dose received by the patient during a CT scan, and it is given in milligray centimeters.^[8]

CT is becoming increasingly available in Nigeria due to the better diagnostic information obtainable, yet there is very little data available to address the dose concern of CT examinations. The published reports on dose outputs are few with significant variations between them.^[7,17,18] There is also no national dose reference level to guide CT users on

acceptable doses. In the interim, the European Commission $CTDI_{vol}$ and DLP reference levels are applied to routine CT examinations in Nigeria.^[7]

If corrections are applied to the CT protocols used,^[19] and regular patient dose audits are done, there will be meaningful reduction of unnecessary patient doses.^[20] This work aims to review, compare, and correct the likely weaknesses in default head CT protocols in two tertiary CT centers with large patients' throughput as a quality control measure.

MATERIALS AND METHODS

Ethical Committee approval was obtained (NAUTH/CS/66/Vol 8/84/of 24-02-2016). This study which involved a retrospective dose audit and a prospective protocol manipulation was undertaken between March and April 2016.

There were six CT centers in the locality but only four scanners had dosimetrics. The only public tertiary institution (Center A) which had the highest throughput of all and the private center with the highest throughput (Center B) among the other three were included in the study. The average monthly head CT throughput in Centers A and B were 76 and 63 patients, respectively.

Center A had a general electric BrightSpeed Excel, 4-slice scanner manufactured in 2007 and installed in 2011. The default protocol was programed by a South African radiographer during installation. Center B had a Toshiba Alexion, 16-slice scanner manufactured in 2013 and installed in 2014. Its default protocols were programed by local engineers. Both scanners had both helical and axial scan modes. There were also features for automatic tube current modulation as well as prospective dose charts.

The retrospective aspect of the study was then embarked upon. The nature and procedure of the research was carefully explained to the CT radiographers and their cooperation was obtained. From the digital archive of the console, 50 consecutive folders of patients aged ≥ 18 years, who were examined before January 2016 and whose images had been reported by the radiologists were chosen. The 75th percentile of the $CTDI_{vol}$ and DLP was then calculated. Subsequently, there was a scrutiny of tube current (mA) and modulation option, tube potential (kVp), gantry rotation time (seconds), scan range (mm), pitch, and azimuth for scanogram.

The prospective part was specifically the adjustment of inappropriate settings during protocol selection for

both scanogram and axial slices. A second calculation of the 75th percentile of CTDI_{vol} and DLP was done for another group of 50 consecutive patients. Feedback on image quality was got from radiologists who were all blinded to the study. Both pre- and post-interventional values were compared with the 60 mGy (CTDI_{vol}) and 1050 mGy-cm (DLP) recommended by the European Commission. Data were analyzed with the aid of computer software, SPSS version 20.0 (SPSS Incorporated, Chicago, Illinois, USA).

RESULTS

Weaknesses noted in protocols were high tube potential (>120 kVp), high tube current (>220 mA), and inactivated automatic tube current modulation (auto mA). Also noted were excessive scan range (≥ 15 cm), low pitch (<1), high gantry rotation time (>1 s), and erratic manual mA manipulation. Some posteroanterior scanograms were also wrongly acquired at an azimuth of 0° [Table 1]. The preinterventional CTDI_{vol} and DLP outputs were 65 mGy/1634 mGy-cm (Center A) and 86 mGy/1786 mGy-cm (Center B) whereas the postinterventional values were 58 mGy/986 mGy-cm (Center A) and 60 mGy/1030 mGy-cm (Center B), respectively [Table 2].

Table 1: Default and adjusted parameters in head computed tomography protocol

Variables	Range	Center A		Center B	
		Default	Adjusted	Default	Adjusted
kVp	80-140	120	120	140	120
mA	10-350	300	220	250	220
mA modulation	Yes/no	No	Yes	Yes	Yes
Gantry rotation time (s)	0.48-4	1	0.7	2	1
Scan range (mm)	180-320	220	150	180	150
Pitch	0.75-1.5	1.5	1.5	0.75	1.5
Scan mode	Helical, axial	Axial	Axial	Helical	Helical
Azimuth	0-360	90/180	90/180	0/90	90/180

Table 2: Pre- and post-intervention dose output

Variables	European Commission	Center A	Percentage of deviation	Center B	Percentage of deviation
Preintervention CTDI _{vol} (mGy)	60	65	7.7	86	30
Postintervention CTDI _{vol} (mGy)	60	58	3	60	0
Preintervention DLP (mGy-cm)	1050	1634	36	1786	41
Postintervention DLP (mGy-cm)	1050	986	6	1030	2

CTDI_{vol} – Volume computed tomography dose index; DLP – Dose-length product

Table 3: Radiologist's impression about the quality of images

	Preintervention CTDI _{vol} and DLP	Radiologist's impression of images	Postintervention CTDI _{vol} and DLP	Radiologist's impression of images	Major observation of radiologist
Center A	65/1634	84% adequate	58/986	96% adequate	Pre- and post-interventional ring artefacts Nil
Center B	86/1786	100% adequate	60/1030	100% adequate	

CTDI_{vol} – Volume computed tomography dose index; DLP – Dose-length product

DISCUSSION

Our findings show that the protocols had a few similarities and consequential differences in their parameters [Table 1]. In addition, the preinterventional dose outputs were considerably higher than those recommended internationally [Table 2]. It was also observed that the radiologists were basically comfortable with the quality of the images irrespective of the dose outcome. Furthermore, while the radiologist in Center B could not pick out any noticeable difference between pre- and post-intervention, in Center A, the radiologist recognized that ring artifacts were not eliminated postintervention [Table 3].

A CT scanner cannot be used efficiently unless it is programed with protocols tailored to the anatomy of interest. In designing a suitable protocol, different adjustable parameters are manipulated.^[9-11] In Center A, the protocols were designed by a foreign personnel, while in Center B, the protocols were activated by local-roving CT engineers. The high-dose outputs recorded point to the inadequacy of those protocols or a neglect of quality control.

Center A was on manual mA selection, a static mode which uses the same preset value of mA for each slice, leading to higher radiation dose to less-dense anatomical regions.^[21] Center B was, however, in line with optimization principles, correctly programed for automatic tube current modulation. This is the popular mA mode as it allows a range of mA values to be used at different points of the patient,^[22] and substantially reduces dose.^[23,24] The concept of automatic tube current modulation is based on the premise that pixel noise is attributable to quantum noise in the projections. By adjusting the tube current to follow the changing patient anatomy, quantum noise can be adjusted to maintain the desired noise level.^[19]

In selecting automatic mA features, however, a minimum and maximum mA value must be selected.^[25] If the system

desires a higher mA without being able to attain it, image noise will increase above the level expected, and if a lower mA is desired, patient dose may be unnecessarily increased.^[22] A retrospective audit of previous images serves as a guide to the protocol programmer on the desirable range of mA for the auto mA modulation. In cases where previous mA settings were high, a phantom scan in which the exposure parameters are progressively reduced and/or increased, can also serve as a guide. The protocol for Center A was, therefore, adjusted to conform to automatic mA modulation with lower and upper borders of 180 and 220 mA, respectively. The values were derived from our clinical experience.

The tube potential determines the radiation quality and its variation causes variation in patient dose. Decrease in kVp causes increase in noise. This is particularly so when the patient size is large. The choice of kVp is, therefore, crucial. An optimal kVp for abdominal scan for an averagely-sized patient may be 120 kVp instead of 140 kVp as this will lead to 20%–40% reduction in patient dose.^[26] From our practice, a kVp of 120 is also optimum for the head, the rationale for decreasing the 140 kVp of Center B to 120 kVp [Table 1].

Reducing the beam intensity (mAs and kVp) is the most significant way of reducing patient dose without causing any adverse effect on image quality. A 50% reduction in tube current reduces dose by half. This is because the current-time settings (mAs) are proportional to the photon fluence and beam energy.^[27–29]

It is, however, necessary to have two important feedback during protocol design and/or adjustment. The first is the CTDI_{vol} and DLP output and the second is an independent assessment of image quality. In this instance, radiologists gave the feedback on image quality.^[25]

There is a tendency to extend the area of coverage to include regions beyond the actual area of interest which will further increase patient dose. It is essential to establish scanning protocols that restrict the examination to what is absolutely essential.^[19] The restriction recommended by us is a scan range of 150 mm. This is sufficient collimation for adult head as it extends from the vertex to the most inferior border of the sphenoidal sinus. To produce a scanogram that covers the entire head, however, if this is indicated, a minimum range of 250 mm is sufficient. During planning for the axial slices, this range would have to be collimated if dose output is to be reduced. Centers with automated programs rarely adjust exposure parameters, the more justification why a dose-crashing protocol must be preset, *ab initio*.

Pitch is defined as table movement per gantry rotation divided by slice thickness or collimator width of the X-ray beam. The scanner in center A only had options for pitch in helical mode (0.75 or 1.5). In axial mode there are no options as the cradle movement and collimation are the same (pitch equals 1). To have a pitch > 1, the 'gap/interval' on the control console has to be increased. A pitch of 1.0 means that the X-ray beams from adjacent rotations are essentially contiguous. Pitches of > 1 imply gaps between the X-ray beams from adjacent rotations. Pitches of < 1 imply X-ray beam overlap (and thus double irradiation of some tissue) and so are not clinically advised.^[30] A pitch of 0.75 was *ab initio* programed into the scanner in Center B possibly because of uncertainty about its function. This will, and definitely, increase radiation dose [Table 2]. We adjusted the pitch to 1.5 which is the maximum on both scanners.

From our practice, it was observed that when parameters were kept constant, helical scan mode gave more dose than axial scan mode. However, there is no consensus on this. While some authors are of the opinion that helical mode delivers less radiation dose,^[31,32] others think in a different manner.^[28] It is advised, however, that the need to prescribe multiple contiguous helical scans should be infrequent with modern high-speed multi-detector row scanners.^[19] In view of this equivocality, the scan modes were left in their default settings of axial and helical for Centers A and B, respectively [Table 1].

In CT scan, even though the patient lies supine for most examinations, the direction of the beam for scanogram is not anteroposterior. Azimuth with a range of 0°–360° provides the leeway to acquire images in posteroanterior (180°) or lateral (90° or 270°) projection. The azimuth in Center B was, therefore, adjusted from 0/90° to 90/180° to direct radiation beam away from the orbit and thyroid gland during scanogram. This technique is corroborated by the fact that thyroid gland often receives the highest amount of dose during scan.^[21]

CONCLUSION

A single-master protocol is adequate to address every head examination where examination-specific manipulations are not needed. Subsets of protocols tuned to different clinical needs can be created from this.^[25] From the corrections made on the existing protocols, acceptable level of image quality is guaranteed without unnecessary doses to patients.

Recommendations

The 75th percentile of the CTDI_{vol} and DLP for a sizeable number of patients from each CT center should be

calculated and where the dose output is higher than the international recommendations, protocol correction should be initiated. This is particularly needful now that the general public in our locality are becoming increasingly aware of radiation as a carcinogen.

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Conflicts of interest

There are no conflicts of interest.

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