

Management of Radiation Dose to Pediatric Patients undergoing Ct Examination at Korle-Bu Teaching Hospital, Accra – Ghana

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Abstract
In this work management of pediatric patients doses for Computed Tomography examinations have been studied at Korle- Bu Teaching Hospital. The assessment of the management system involved: Estimation of Weighted Computed Tomography Dose Index ($CTDI_w$), Volumetric Computed Tomography Dose Index (CTDIvol), Dose Length Product (DLP) and Effective dose (E); and Evaluation of quality assurance and quality control programmes to optimize pediatric patient doses. The frequency of CT examinations for pediatric patients accounted for 1300 out 5200 examinations (25%) of the total examinations recorded for the year 2008-2009.Adult CT exposure parameters such as the KV, mAs, scan length, pitch, and collimation values were being used in pediatric CT examination. Effective dose estimated for children were higher than that for adults by factors of 5.1, 1.8, 3.1 and 3.9 more for head, chest, abdomen and pelvis examinations respectively. From the questionnaire administered and dosimetry results there was no established justification policy, procedures and referral criteria for CT examination requests for children. There was no Quality Assurance Committee to see to the implementation of dose management system dedicated to pediatric patients. There was the need for the Hospital Authorities to formulate policies in the training of CT equipment operators, radiographers and radiologist in modern CT technology as well as in the selection of appropriate parameters tailored to individual patient size that can achieve desirable diagnostic image quality at low doses.
Keywords: CT examination, pediatric, X-ray, CTDIw, CTDIvol, D LP

1.0 Introduction
Computed Tomography (CT) has emerged as one of the most important imaging techniques of modern times. Since its development in the early 1970s with a great promise of exploring inner structure of the human organs, it faced challenge with the introduction and refinement of non-radiation devices, such as ultrasound and MRI in late 1970s, and has emerged not only survivor but rather its clinical applications continue to increase (Aldrich JE et al,2006).The recent advances in CT such as multi detector-row technology, with sub- second acquisition and CT fluoroscopy have boosted CT applications, even more enabling interventional radiological (IR) procedures, which were traditionally performed with C-arm X-ray units. The continual increase in number of slices that can be scanned in one rotation of the X ray tube has brought multi-detector computed tomography (MDCT) into dynamic imaging. Increasing applications mean increasing collective radiation dose to the population (ICRP, 2000). But that is not bad as long as individual CT examination is clinically justified and doses are optimized to be not more than what is necessary. But experience shows that individual patient doses are increasing [Brenner DJ et al, 2004). In one of the reports from the United States, it was estimated that CT scanning accounts for more than 10 % of all radiological examinations and about two-thirds of the radiation dose to patients. Large variation in exposure parameters and patient doses even for a single CT examination have been reported (Mettler Jr,2000).It is noted that at specific exposure parameters, the radiation dose to the patient from various CT models can be totally different due to changing CT geometry and filtration. There was also growing realization that very often CT image quality is much higher than actually required to produce accurate clinical diagnosis and a number of studies reported large dose reductions using modified exposure parameters (Huda W et al, 2000]. Taking all these into consideration, as well as the continuous need to balance between the net benefits and the risks of using such a modality, various international organizations have published guidelines so as to standardize CT examinations and optimize radiation dose (IAEA 2004). DRLs provide the means to improve patient protection, if it is required, identify poor performance and monitor CT performance in periodic measurements. The foregoing discussion reveals the need for proper management of radiation dose in a CT facility. This study aims at assessing the dose management system at the Korle- Bu Teaching Hospital during pediatric CT examinations, and provides practical advice to manage the radiation dose keeping them ALARA while maintaining diagnostic quality

1.2. Objectives
The main purpose of this project is to assess the status of CT dose management system being applied to pediatric patients undergoing CT examination at the Korle-Bu Teaching Hospital in Greater Accra Region of Ghana. There have been many national, regional and global efforts towards ensuring that the principles of justification

and optimization, with dose limitation, which are fundamental principles of radiation protection, quality assurance and quality control are applied in CT dose management practices. Application of such principles to Pediatrics CT dose management procedure is of special concern to this work since previous reports from some developed countries in Africa including Ghana, have shown that exposure parameters used for CT examinations of children are similar to those of adults, and also the lack of CT dose management system in our hospitals has resulted in much higher doses and risks to patients undergoing CT examinations.

1.3 Scope

The research work covers pediatric patients undergoing CT examinations at Korle-Bu Teaching Hospital for the period January 2008 to August 2009.The Korle-Bu Teaching Hospital CT facility was chosen since it has the largest pediatrics patient throughput compared to the other CT facilities in the Greater Accra region of Ghana.

1.4. Justification

The establishment of CT dose management system is important since CT dose is the largest contributor to dose and collective dose due to diagnostic Radiology. CT medical centers need to implement CT dose management system to minimize risk of cancer incidence in the country. This work seeks to establish CT dose management policies and its implementation at Korle-Bu Teaching Hospital. The findings could be implemented in other CT facilities in the country.

1.5. Limitations

The major limitation in this work is due to technical and operational difficulties, as a result of frequent break down of the CT equipment and low pediatric patient turn-over for CT examinations during the period of the study.

1.6. Ct Dose Discriptures

Patient exposure is quite different in CT than in conventional X-ray examinations, with the X-ray tube rotating around the patient producing thin slices of the irradiated body region. Therefore, dose calculation in CT is more complicated and requires (Shrimpton PC et al, 2000) the introduction of special dosimetric quantities such as the Computerized Tomography Dose Index (CTDI) and the weighted CTDI (CTDIw) for a single slice and the Dose Length Product (DLP) for a complete examination. Computerized Tomography Dose Index CTDI is defined by the following equation:

$$CTDI = \frac{1}{NT}\int_{-\infty}^{\infty} D(z)\,dz \qquad (1.6)$$

Where *D*(*z*) = the radiation dose profile along the z-axis,
N = the number of tomographic sections imaged in a single axial scan. This is equal to the number of data channels used in a particular scan.

T = the width of the tomographic section along the *z*-axis imaged by one data channel. In multiple-detector-row (multislice) CT scanners, several detector elements may be grouped together to form one data channel. (McCullough CH.etal,2005) In single-detector-row (single-slice) CT, the *z*-axis collimation (*T*) is the nominal scan width.

CTDIw is used for approximating the average dose over a single slice in order to account for variations in dose values between the center and the periphery of the slice. It is defined by the following equation:

$$CTDI_W = {}^{1}\!/_{3}\, CTDI_c + {}^{2}\!/_{3}\, CTDI_p \qquad (1.6.1)$$

The values of 1/3 and 2/3 approximate the relative areas represented by the centre and edge

Values CTDIw is a useful indicator of scanner radiation output for a specific kVp and mAs.

CTDIvol was introduced to determine the radiation dose in one tube rotation in multi detector-row scanners and allows for variations in exposure in the z direction when the pitch (pitch is the ratio of table feed in one rotation to slice collimation) is not equal to one (CTDIvol = CTDIw / pitch In the case of a single slice spiral system, CTDIvol is equal to CTDIw.

1.6.1. Dose Length Product (DLP)

DLP is used to calculate the dose for a series of slices or a complete examination and is defined by the following equation:

$$\mathrm{DLP} = \sum_{i}^{N} CTDI_W\, \mathrm{T\,N} \qquad (1.6.2)$$

i represents each one of the individual N scans of the examination that covers a length T of patient anatomy. Certain manufacturers display the DLP value in each patient examination.

1.6.2. Effective Dose

The effective dose is a “dose” parameter that reflects the risk of a non-uniform exposure in terms of a whole body exposure. It is a concept used to normalize partial body irradiations relative to whole body irradiations to enable comparisons of risk. The calculation of effective dose requires knowledge of the dose to specific sensitive organs within the body, which are typically obtained from Monte Carlo modeling of absorbed organ doses within mathematical. Anthropomorphic phantoms (Jones DG etal1991), and recently also voxel phantoms based on real humans. Effective dose is expressed in the units of milliSieverts (mSv), and can be compared to the effective dose from other sources of ionizing radiation, such as that from background radiation level, which is typically in the range of 1 to 3 mSv depending upon the location.

1.6.3. Diagnostic Reference Levels (DRLs)

Diagnostic Reference Levels (DRLs) values are proposed by the European Commission and the National Radiological Protection Board (NRPB)(Hatziioannou K etal,2003).These values are not to be used individually. They are intended to be used as a tool to identify situations in which dose management (optimization) should be applied.

1.7. Exposure Parameters That Depend On Ct Dose

Choosing exposure parameters is a complex task and depends to a large extent on the anatomical region to be scanned, the size and the pathology of the patient. The chosen parameters should result in sufficient image quality so as to aid clinical diagnosis. The main problem in determining exposure parameters is image noise and its effect on image (AAPM report 2008) quality. Some parameters that are in control of operators are discussed below: **kVp**: Most CT systems do not provide users with flexibility to adjust kilo voltage (kV) or kilo voltage peak (kVp) in a continuous manner but there are few discreet settings possible. Tube kVp determines the quality and quantity of radiation. The intensity of X ray beam is typically proportional to square of kVp applied to the tube. Thus even minor modifications (FearonT et al, 1985), in the tube potential value can result in significant changes in image noise and considerable change in radiation dose **mAs**: Another important parameter which greatly affects image quality and dose is the product of tube current and rotation time (mAs). Radiation dose, at fixed kVp and filteration, is linearly related to mAs, meaning that by reducing the mAs by half, the dose is also reduced by half. On the other hand, noise is inversely related to mAs. Therefore,(Kopp AF etal,2002) the reduction by half of mAs will result in a 50 % increase in image noise. The reason is that the increase in image noise can greatly influence image quality, which is very important in organs like the liver and pancreas.

Pitch: Pitch is another important parameter for spiral and MDCT. By definition, pitch depends on collimation and table feed. Therefore, if the patient's table moves faster this will increase pitch and consequently decrease the duration of patient exposure and reduce radiation dose. However, a faster moving table results in certain artifacts, which have great impact on image quality. According to Kalra no marked difference in abdominal(. Kalra M.K.2002) image quality was noted between scans obtained with pitch 1.5 and those with pitch 0.75 resulting in 50% reduction of radiation dose.

Scan length: The extent of body length covered in scanning does not affect the CTDI value but certainly affects DLP. The scanning length for a particular type of CT examination can vary due to the pathology of the patient, the size of the patient, and the experience of the user. With the evolution of CT scanners (non-helical machines are almost extinct in developed countries), and especially with the introduction of multi detector-row scanners. (Wildberger JE 2001) and the dramatic reduction of rotation times to sub-second values, users are tempted to extend the region of interest beyond the one actually required. For all these reasons, CT protocols need to be established so as to limit irradiation only to the particular body region in investigation.

1.8. PRACTICAL METHODS FOR CT DOSE MANAGEMENT

1.8.1. Justification

It is one of the ALARA (As Low As Reasonably Achievable) principles and it is the first rule of optimization in any radiology department. Due to the fact that CT procedure is classified as a high radiation dose procedure, it is essential that it is requested by properly trained practitioners in close collaboration with the CT radiologist. International Basic Safety Standards (BSS) require that an examination should be carried out only in the case of a justifiable clinical indication. In certain clinical situations, non-ionizing techniques such as ultrasound or magnetic resonance imaging (MRI) could probably provide similar information without irradiating the patient. The establishment of standard dose management system for the most frequent examinations will limit radiation dose only to the level really required.

1.8.2. CT dose Optimization

Once referral for CT examination has been justified, the radiologist has primary responsibility for ensuring that the examination is carried out conscientiously, effectively, and with good CT dose management technique. This is usually described as the principle of CT dose optimization. Within this process. (Kalra MK et al, 2004) the radiologist has considerable scope for limiting the radiation dose to the patient. The objective is to provide sufficient diagnostic information to influence the clinical management of the patient. Clinical issues define the area to be examined and the extent of the examination required. However even when these conditions are met the radiologist has additional opportunity for limiting the radiation dose to the patient.

1.8.3. Shielding of organs
Shielding should be used in sensitive groups such as children and young patients. Shielding of organs such as the thyroid, eye lens and breast, when they are not in the primary beam can result in 40% to 80% radiation dose reduction (Beaconsfield T et al, 1998). A reduction of 95% in radiation dose can be achieved by shielding the testes in abdominal procedures.

1.8.4. Modification of exposure parameters
The most easy and straightforward way of reducing the dose in CT is to lower the mAs. This can have a significant effect in image quality but in some CT procedures such as chest and the pelvic exam, this degradation does not usually have an impact in clinical diagnosis (Takahashi M, et al 1998). In abdominal procedures, however, large mAs reduction is not usually possible. In these situations, modification of mAs according to patient weight can provide an alternative to dose optimization. Aldrich found that image noise is highly correlated with patient weight and that an acceptable image quality is associated with a noise level of 4.5. He then developed a simple mAs prediction equation to optimize radiation dose for all patient weight categories (ICRP 2000). The International Atomic Energy Agency (IAEA), through a coordinated research project (CRP) that involved six countries and nine new technology CT scanners across the world investigated the potential for patient dose reduction while maintaining diagnostic confidence in routine chest and abdomen CT examinations in adult populations.

1.8.5. Limitation of scan length
In order to limit the region of the patient being irradiated, only radiologists properly trained in CT as well as radiation protection issues related to the CT technique should perform such procedures. Consideration should be given to program the examination protocol according to pathology. The large range in DLP values reported in the literature reveal the differences in technique followed in each CT department (Tsapaki V et al, 2006). For example, some operators examine the upper abdomen in cases of hepatic and pancreatic disease, whereas others examine the whole abdomen, which also includes the pelvic region. According to Hidajat et al, many clinical studies have to be performed so as to gain consensus for the optimal length of examination (Hidajat Netal, 2001)

1.8.6. Use of anatomy-adapted tube current modulation
Tube current modulation is based on the idea that pixel noise on the image results from quantum noise in the different projections taken as the tube rotates around the patient (Greess H, et al 2000). The value of mAs is therefore changed during one rotation according to the patient anatomy in each projection. The idea is similar to the automatic exposure control system in the X-ray radiography equipment. In the projection with less attenuation from the patient, such as the posterior-anterior chest projection, less mAs can be used. In lateral projections in which attenuation from the patient can be high, the mAs can be increased accordingly.

1.8.7. Filtration
X-ray filters are used in radiology for cutting off the X-rays that have lower energy and do not contribute to the image but only to the patient dose. There are studies in the literature that have investigated the use of various filters and their effect on dose reduction. According to these studies, bow-tie or beam shaping filters reduce radiation dose by 50% compared with conventional flat filters. Software noise reduction filters is an alternative, especially in high contrast examinations such as chest CT.

2. METHODOLOGY
The methodology used to assess the CT dose management system at the Korle- Bu Teaching hospital are the following:
1. Assessment of doses incurred by adult and pediatric patients for inter- comparison purposes.
2. Assessment of the status of quality management system for management of patient dose at the CT facility with especial emphasizes on pediatric patients.

2.1. Estimation Of Doses Received By Adult And Paediatric Patients For Comparison
The following dose descriptors were assessed in order to develop an optimum protocol for dose management at the facility:

- **Weighted Computed Tomography dose Index ($CTDI_w$)**
  $CTDI_w$ is given by equation. (2.1) shown below

$$CTDI_W = {}^{1}/_{3}\, CTDI_c + {}^{2}/_{3}\, CTDI_p \qquad (2.1)$$

These values were obtained from the control console of the technique factors used for the scanning procedures. Phantom based measurements could not be done.

- **Dose Length Product (DLP)**
  DLP is used to calculate the dose for a series of slices or a complete examination and is defined by the following equation:

$$DLP(mGy.cm) = CTDI_{VOL}(mGy) \times Scan\ length(cm) \qquad (2.2)$$

Where,

$$CTDI_{VOL} = \frac{N \times T}{I} \times CTDI_W \qquad (2.3)$$

I represent each one of the individual N scans of the examination that covers a length T of patient anatomy. The equipment manufacturer displays the DLP value for each patient examination and these values were collected from the control console.

- **Effective dose (E)**

The effective dose is given by:

$$E(mSv) = K \times DLP \qquad (2.4)$$

K is the Normalized effective dose (E) per dose-length product (DLP) for adults (standard physique) and pediatric patients of various ages over various body regions. Conversion factor for Adult head and neck and pediatric (Shrimpton PC et al, 2003) patients assume use of the head CT dose phantom (16 cm).All other conversion factors assume use of the 32-cm diameter CT body phantom.

2.2. Assessment Of The Dose Management System

A questionnaire was administered to assess the status of quality management system at the CT Facility For dose management, the detail of the questionnaire is provided in Appendix.

The questionnaire covers these areas:

- Application of justification principle for management of patient dose
- Optimization of protection of the patient
- Application of diagnostic reference levels as a dose constraint for the optimization of protection of the patient
- Institutional quality assurance and quality control programme for dose management

3.0 RESULTS AND DISCUSSION

This Chapter outlines the results obtained from this research and discusses the findings in the light of cited literature.

3.2. Frequency of CT examinations

Table 3.1 shows the frequency of CT examinations for adult patients compared with pediatric patients. The frequency of CT examinations for pediatric patients accounts for 25% of the total examinations recorded for the period 2008-2009.

Table 3.1Frequency of CT examinations at Korle-Bu.Teaching Hospital for Adult and Pediatric

CT room	Number per year		Frequency of paedriatic CT examinations (%) of Adult 5200
	Adult	Children (<15 y)	
Number of patients per year	5200	1300	25

3.3. CT Dose Estimation

Table 3.2 shows the CT dose administered to pedatric patients undergoing CT exxamination.The dose is relatively high compared with the European and IAEA guidelines.

Table 3.2.Dose descriptors (CTDIw, CTDIvol, DLP and E) for pediatric CT examinations:

Organ	CTDIw(mGy)	CTDIvol(mGy)	DLP(mGy-cm)	Effective dose(E)(mSv)
Head	67.96	51.8	651.34	7.2
Chest	17.36	12.3	342	13.3
Abdomen	146.98	12.4	276	13.5
Pelvis	17.36	12.4	361.9	17.7

3.4. Results from the questionnaire administered

The questionnaire administered is provided in appendix.1

3.4.1. Justification

A formal justification policy and procedures for examination requests was not in place. A quality assurance Committee has just been formed that will address the issue of justification. There was no referral criteria established.

3.4.2. Optimization of CT doses

There was no programme to ensure that CT dose are made ALARA. No ALARA culture established. No established imaging protocols to manage dose for adult and pediatric patients. No technique charts pasted in the control room of the CT Unit. The choices of imaging protocols depend on the radiographer on duty.

3.4.3. Quality Assurance and Quality Control Programme

There was no formal quality assurance and quality control programme in place. However staff from the Radiation Protection Institute performs some quality audit as part of the authorization process of the Radiation Protection Board of the CT facility periodically. The department lacks qualified personnel and the essential procedures and tools to perform quality control tests at the recommended frequencies. (see appendix 1). There is a programme for radiographs reject analysis which is less than 10 %. Reject rate more than 10 % are followed up to identify the root causes. Some of the causes for rejects are:

- Right technique factors not being used by the Radiographer on duty
- Lack of co-operation from the patient under investigation
- Equipment inefficiency
- Film Processor malfunctioning
- Artifacts on the image
- Image contrast application

There exists an established yearly routine CT maintenance regime conducted by Philips medical Systems in Ghana, yearly. The major challenges facing the facility include high bills for the maintenance and equipment replacement and delays in supply of spare parts required for the maintenance such as x-ray tube inserts detectors and computer system accessories.

3.4.4. Staff Training

There was no formal policy on education and training of staff. However a Scientific Officer Was appointed, and is in charge of continuous professional development (CPD'S). He liaises with the Chief radiographer to select members of staff for further training. In-service training programmes e.g. workshops, seminars, technical staff meetings etc. are organized occasionally by foreign experts and professionals to provide relevant knowledge and skills in handling modern equipment techniques application in Radiology.

4.0. DISCUSSIONS

4.1.1. Frequency of examinations

The frequency of pediatric CT examinations in relation with adult patients was 25% of the total examinations (5200) conducted at the hospital in 2008-2009 periods (Table 3.1). The result is comparable with recent IAEA. Coordinated research findings in eleven countries in Africa , Asia and Eastern Europe including Ghana, where the frequencies ranged from 0.5% to 38% .The mean frequencies for Africa, Asia and Europe were 20 %,16% and 5% respectively. This means that there was an over use of pediatric CT examinations at the Korle-Bu Teaching Hospital of the order of five compared to the Eastern European context.

4.1.2. Dose descriptors

The values obtained for $CTDI_{w,}$ $CTDI_{vol}$ and DLP were not significantly different from that obtained for adults patients because no consideration was made for size and age of the patients. There will be significant dose reduction if the technique factors recommended by AAPM are adopted as shown in Table in appendix. Effective dose estimated for children for the examinations considered were higher than that for adults. There were 5.1, 1.8, 3.1 and 3.9 times more for head, chest, abdomen and pelvis examinations respectively. Huda et al also calculated effective dose and showed that somewhat higher values for children than adults; for example, data from one particular institution indicated values of 6.0 mSv (newborn) and 1.5mSv (adult) during head examinations (equivalent factor of 4) , and 5.3mSv (newborn) and 3.1mSv (adult) during abdomen examinations (equivalent factor of 1.7).

4.2. Dose Management System

From the questionnaire administered and Dosimetry results there is no established justification Policy, procedures and referral criteria for CT examination requests for children. There is no quality assurance Committee to see to the implementation of dose management system dedicated to pediatrics patients. There was no policy to consider alternative imaging modalities such as magnetic resonance imaging and high-resolution ultrasound as means for dose reduction. This has great implication on individual dose, collective dose, and radiation risk of the induction of cancer in future. The relative higher effective dose demands a conscious effort to reduce doses so as to limit the probability of stochastic effects in the pediatric population.

4.2.1. Justification and Optimization.

In view of the high effective dose incurred by patients the Hospital management should adopt the Justification and optimization principles and establish a Quality Assurance Committee that would be in charge of the implementation of the Quality Management policy. There was the need for the hospital authorities to formulate policies in the training of CT equipment operators, radiographers and radiologist in modern CT technology as well as in the selection of appropriate parameters tailored to individual patient size that can achieve desirable diagnostic image quality at low doses.

Under Justification, the action to be undertaken by physicians and radiologist should include:

- Ensure that patients are not irradiated unjustifiably
- Request for CT examination should be generated only by properly qualified medical or dental practitioners depending upon national educational and qualification system adopted. The physician is responsible for weighing the benefits against risks
- Clinical guidelines advising which examinations are appropriate and acceptable should be available to clinicians and radiologists
- Consider whether the required information can be obtained by MRI,or ultrasonography

5.0 CONCLUSIONS

The findings from this research indicate that there must be an established policy on dose management system that address issues of:

- Justification that ensures that the benefits of CT examinations far out weights the risk of CT exposure ;
- Optimization that ensures that justified exposures are kept as low as reasonably achievable;
- Optimum technique factors that take into account age and size of the patients
- Use of diagnostic reference levels for the optimization of protection of patients
- Management policy on dose reduction that ensure roles of physicians, radiologist and operators of the CT machine are clearly defined especially as they affects CT dose reduction and image quality ;
- Availability of a qualified medical Physicist who will take of quality assurance and quality control issues ;
- Training of staff for protection of the patient under CT examination.

The high values of the dose descriptors (CTDIw, CTDIvol, DLP and E) for pediatric Examinations, observed in Table 3.2 were due to the lack of the above mentioned dose reduction management culture at the Korle- Bu Teaching Hospital CT Centre. Ultimately, CT dose management requires a team of professionals, technologists, physicians, administrators, and medical physicists to ensure the most effective and judicious use of this remarkable diagnostic tool.

5.1. Regulatory Authority

The Medical professional bodies in Ghana in collaboration with Regulatory Authority that is the Radiation Protection Board(RPB) should promote research in pediatric CT dose management system in existing CT facilities and those to be established in future as part of the authorization requirements for such practices. The requirement for authorization may
include:

1. Adoption of the justification principles in clinical requests
2. Application of the optimization principles that take into account the scan parameters that influence dose ; kVp , mAs, beam collimation, pitch , scan length and filtration related to patient anatomy and projection of the examination
3. Periodic monitoring of the dose descriptors; CTDIw , CTDIvol , D LP and estimation of effective dose to verify compliance adopted diagnostic reference levels (DRLs) in conjunction with image quality assessment; and Reduce inappropriate referrals which can be replaced other imaging modalities such as MRI and ultrasound

5.2 RECOMMENDATIONS

From the findings of this work the recommendations below are address to relevant Stakeholders:

5.2.1. HOSPITAL AUTHORITIES

- Hospital authorities should institute pediatric dose management system involving the principles of justification, optimization of patient dose , quality management and quality control of equipment used for the imaging procedures
- The Hospital Authorities should establish a radiation Protection Committee to oversee the dose management system.
- Hospital authorities at Korle-Bu should consider engaging qualified Medical physicist to implement the technical aspects of the dose management system whenever possible.

REFERENCES

1. AAPM Task Group 23 Report, January, 2008: CT Dosimetry Diagnostic Imaging Council CT Committee. The Measurement, Reporting, and Management of Radiation Dose in CT
2. Aldrich JE, Bilawich AM, Mayo JR. Radiation doses to patients receiving computed tomography examinations in British Columbia. Can Assoc Radiol J 2006; 57(2):79-85.
3. Beaconsfield T, Nicholson R, Thornton A et al. Would thyroid and breast shielding be beneficial in CT of the head? Eur Radiol 1998; 8(4):664-7.
4. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening. Radiology 2004; 232(3):735-8.
5. Fearon T, Vucich J. Pediatric patient exposures from CT examinations: GE CT/T 9800 scanner. AJR Am J Roentgenol 1985; 144(4):805-9.
6. Greess H, Wolf H, Baum U et al. Dose reduction in computed tomography by attenuation-based on-line modulation of tube current: evaluation of six anatomical regions. Eur Radiol 2000; V Tsapaki et al. Biomed Imaging Interv J 2007; 3(2):e43 7 10(2):391-4.
7. Hatziioannou K, Papanastassiou E, Delichas M et al. A contribution to the establishment of diagnostic reference levels in CT. Br J Radiol 2003; 76(908):541-5.
8. Hidajat N, Wolf M, Nunnenmann A et al. Survey of conventional and spiral CT doses. Med Phys 2001; 218:395-401
9. Huda W, Scalzetti EM, Levin G. Technique factors and image quality as functions of patient weight at abdominal CT. Radiology 2000; 217(2):430-5.
10. International Atomic Energy Agency (IAEA). Optimisation of the radiological protection of patients undergoing radiography,fluoroscopy and computed tomography. Vienna, 2004; IAEATECDOC- 1423.
11. . International Commission on Radiological Protection. Managing Patient Dose in Computed Tomography. Pergamon, 2000. (Annals of ICRP; 84)
12. .Jones DG, Shrimpton PC. Survey of CT practice in the UK. Part 3: normalized organ doses calculated using Monte Carlo techniques Chilton: NRPB, 1991; NRPB-R250.
13. Kalra MK, Prasad S, Saini S et al. Clinical comparison of standard-dose and 50% reduced-dose abdominal CT: effect on image quality. AJR Am J Roentgenol 2002; 179(5):1101-6
14. Kalra MK, Maher MM, Toth TL et al. Strategies for CT radiation dose optimization. Radiology 2004; 230(3):619-28.
15. Kopp AF, Heuschmid M, Claussen CD. Multidetector helical CT of the liver for tumor detection and characterization. Eur Radiol 2002; 12(4):745-52.
16. McCollough CH, Bruesewitz MR, Kofler JM, Jr. (2006) "CT dose reduction and dose management tools: Overview of available options." *Radiographics* 26:503-512.
17. Mettler FA Jr, Wiest PW, Locken JA et al. CT scanning: patterns of use and dose. J Radiol Prot 2000; 20(4):353-9.
18. Shrimpton PC, Hillier MC, Lewis MA, Dunn M. (2006) "National survey of doses from CT in the UK: 2003." *Br J Radiol* 79:968−980.
19. Takahashi M, Maguire WM, Ashtari M et al. Low-dose spiral computed tomography of the thorax: comparison with the standard-dose technique. Invest Radiol 1998; 33(2):68-73.
20. . Tsapaki V, Aldrich JE, Sharma R et al. Dose reduction in CT while maintaining diagnostic confidence: diagnostic reference levels at routine head, chest, and abdominal CT—IAEAcoordinated research project. Radiology 2006; 240(3):828-34.
21. Wildberger JE, Mahnken AH, Schmitz-Rode T et al. Individually adapted examination protocols for reduction of radiation exposure in chest CT. Invest Radiol 2001; 36(10):604-11.

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