Original Article

FACTORS THAT CAN BE ATTRIBUTABLE TO RADIATION DOSE REDUCTION AMONG PEDIATRIC AGE GROUP UNDERGOING BRAIN COMPUTED TOMOGRAPHY

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ABSTRACT

Objectives: To identify factors that can decrease radiation dose among pediatric age group during brain CT scan examination.

Methodology: From June to July 2008 at King Hussein Medical Center, 150 children aged from 2 months -13 years, brain CT scan was obtained by changing radiation exposure parameters including kilo voltage peak, milliampere per second (kVp, mAs), pitch, number of slices and slice thickness. Dose report was recorded by CT scan machine including: The Dose Length Peak (DLP), CTDI (CT dose index) automatically. The patient, age and sex were also considered.

Results: Eighty nine were females (59.3%) and 61 patients were males (40.6%) with an average weight 0f 16Kg (range 3.2- 21). A statistically significant negative linear correlation was seen between number of slices and body weight, 0.56, 0.58. The most valuable applied pediatric scanning protocol during brain CT scan was modified protocol with low Ma less than150 mA, the tube current ranged from 80 to 280 mAs, with a median tube current of 159 mAs., followed by increasing the pitch value up to 1.5,reducing number of slices and slice thickness Number of slices and slice thickness and pitch were inversely proportional to radiation dose, while the Ma (current tube)is directly proportional to the radiation dose. We found little variation in the kilovoltage used.

Conclusion: The main aim of all radiological investigations especially in children is maximum diagnostic benefit and less radiation dose and to achieve that it is worth while to consider adjustment of pediatric protocols, equipement modification and lower radiation dose settings.

KEY WORDS: Dose Length Peak, CT Dose Index, Radiation dose, Computed tomography, Pediatric Patients.

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INTRODUCTION

The use of brain computed tomography has increased rapidly in the past two decades.[1] However it is generally felt that up to one third of CTs performed on children are not pertinent to either the diagnosis or management nor is it necessarily the best test.[2] Children are not only more sensitive to radiation than adults, but they will have more years in which cancerous changes might occur.[3] Dr Levatter et al also mentioned that the rate of increase of CT examination is probably higher in children than adults who are more sensitive to radiation induced cancer.[4] For patient protection we should use the right technical parameters to avoid excessive, harmful and unnecessary radiation dose for these investigated children by CT scan and the clinicians should always be conscious and be strongly attentive to minimize CT scan radiation dose for children. To reduce the radiation dose, appropriate strategies have been developed to optimize scanning practices based on clinical indications, the age or body size of the patients, and the area being investigated, low radiation settings.[5] Technical developments including automated exposure control[6] help to optimize the relationship between image noise and radiation dose[2] which also help in balance image quality and radiation dose.

Various quantitative measures are used to describe the radiation dose delivered by CT scanning, the most relevant being absorbed dose, effective dose, and CT dose index (or CTDI). The absorbed dose is the energy absorbed per unit of mass and is measured in grays (Gy). One gray equals one joule of radiation energy absorbed per kilogram. The organ dose (or the distribution of dose in the organ) will largely determine the level of risk to that organ from the radiation. For risk estimation, the organ dose is the preferred quantity. CT dose index, although useful for quality control, is not directly related to the organ dose or risk. The effective dose, expressed in sieverts (Sv), is used for dose distributions that are not homogeneous; it is designed to be proportional to a generic estimate of the overall harm to the patient caused by the radiation.[7] Physicians, CT technologists, CT manufactures and other medical organizations share the responsibility to reduce radiation doses to children

METHODOLOGY

In June 2004, 150 brain CT scans were obtained in 89 female and 61 male, referred to the radiology department for different causes. A brief clinical history was also obtained. Adjustments were made in the exposure parameters to determine the amount of radiation children who might receive from CT scan. We performed brain CT scan following modified pediatric CT scan protocol, by changing exposure parameters to assess their effect on radiation dose. Brain computed tomography was done using GE Light Speed Plus machine (GE Healthcare, CT, USA). Images were obtained using a multi-slice spiral computed tomography(CT) system of 5 mms slice thickness without automatic selection of effective – mAs (E-Mas) All HCTs were reviewed by radiology specialist. Radiation dose and exposure factors (scanning parameters) were analyzed. Scanning parameters that affect radiation dose include peak kilovoltage, tube current-milliampere – second), pitch, number of slices and slice thickness.

Patients were categorized into four groups regarding the applied modified scanning protocol .We modified in our study just one exposure parameter reduce mA, reduce kVp, increased pitch and slice thickness, which are inversely proportional to radiation dose, however adjustment of two or three exposure parameters were also possible

RESULTS

From 150 patients referred to our radiology department 32.2% underwent brain CT scan for head injury, 21.1% for abnormal movements including convulsions, 14.4% for chronic headache and 31.3% for developmental delay, psychiatric disorders and miscellaneous reasons. Almost 83.4% brain CT scan results were normal. Reviewing the literature radiation revealed that dose reduction depends on many exposure factors and in our study we classified children into various groups: first group included modification and reduction of the mAs(n=90 patient(60%), second group of children were with high pitch(n=38 (25.3%),third with low Kvp(n=12 (8%),and the last group was children with applied modified scanning protocol with increasing number of slices and slice thickness(n=10(6.6%). Low mA was the most common technique used by (60%), followed by high pitch (25.3%) and low peak kilo voltage (8%). The trend was to increase slice thickness as the age of the children increased but we usually used slice thickness of 5mm.

The tube current ranged from 90 to 280 mAs, with a median tube current of 159 mAs. The dose is directly proportional to the selected tube current–time product; therefore a reduction in mAs by 50% results in a reduction of dose by half Age-based adjustments were made. However, 11-26% of CT examinations of children younger than 9 years are performed using less than 150 mA. We found little variation in the kilovoltage used. For 34% patients less than 140 kVp used for brain, and for 66% routinely used 140 kVp for brain scanning among pediatric population. Other modifications including shielding of radio sensitive organs, avoiding multiphase examinations, using automatic modulation of tube current, using thicker collimation were also applied. The radiation dose (CTDI is measured in mlligrays as displayed on the CT monitor as well as DLP) was calculated by the CT scan machine automatically, after we did adjustments and modification of exposure parameters. DLP ranged from 200mGy -2100.

DISCUSSION

CT is an important imaging modality for examining children, and its use is increasing. Given the recent attention to radiation risks and CT in children and the need for adjustments in parameters in this population, a broader understanding of the actual practice of body CT in pediatric patients would be helpful.[8]

We evaluated examination protocols used for brain CT of pediatric patients and we found that CT dose is recommended to be as low as reasonably achievable to meet clinical needs, therefore CT dose reduction will require a combination of approaches.[3]

Current guidelines do not recommend obtaining brain CT scan for children, unless the history and physical examination indicate that, otherwise every child requires an accurate, efficient, and optimal, diagnostic workup, avoiding excessive testing and radiological investigations which is potentially harmful. CT scan should not be ordered for children below ten years indiscriminately.[9] Richard Smart et al has mentioned that it's both economically and ethically desirable to restrict the use of diagnostic radiation to only those who will benefit from it.[10] If CT parameters used for pediatric patients are not adjusted on the basis of examination type, age and/or size of the child, then some patients will be exposed to an unnecessarily high radiation dose during CT examinations.[11]

Special considerations are also required to protect children who are generally more sensitive to the short - and long- term detrimental effects of radiation exposure.[9] Prudent clinicians should order only those studies that result in clinically important information and efforts should be made to minimize radiation exposure.[12] CT radiation doses need to take into account patient age and the selected X- ray technique, cross sectional areas and mean Housenfield unit (HU) The radiation dose reduction to particular organs from any given CT study depend on many factors including replacement of CT use, with other imaging modalities such as ultrasonography and magnetic resonance imaging (MRI) which have less radiation dose. We also noticed decrease in the number of CT studies that are ordered.

The automatic exposure-control option on the latest generation of scanners is also helping in radiation dose reduction. Multiple factors can affect radiation dose and the most important are the number of scans, the tube current and scanning time in milliamp-seconds (mAs), size of the patient, the axial scan range, the scan pitch or advancement of the scanning plane through patients, the degree of overlap between adjacent CT slices, the tube voltage in the kilovolt peaks (kVp) and the specific design of the scanner being used. Finally we used a reconstruction as recommended by the manufactures for brain ct scan.[13]

Many of these factors are under the control of the radiologist or radiology technician. The mA-s being the most important factor affecting dose reduction, because increased dose per milliampere-second will result in increased radiation risk and increased exposure risk with p' 0.001. For helical CT at a fixed X-ray energy, scanning time, the radiation dose to the patient is directly related to the X-ray tube current.[14] The dose is directly proportional to the selected tube current–time product; therefore a reduction in mAs by 50% results in a reduction of dose by half.[13] In our department during brain CT scanning the tube current ranged from 90 to 280 mAs, with a median tube current of 159 mAs. Kilo voltage of 120 may not be the optimal level for examining infants[8] so we use a typical 140 kvp x-ray beam

Several studies have suggested that a technique with significant reduction in exposure parameters (milliampere –seconds) could be adopted for pediatric CT protocol without significant loss of information.[1] Adjustment of pediatric protocol, means that children should not be scanned using adult exposure parameters, so we should use lower Ma-s, followed by high pitch which is inversely proportional to the radiation dose(: a decrease in pitch by half increases the dose by two), low peak kilovoltage, lesser number of slices and lesser slice thickness and lower radiation dose settings. As such we use CT scanner without automated dose adaptation, we should look up tables with reference to a suitable brain CT scan parameters especially for children. Finally we found that by applying these modifications on the scanning protocol we can achieve low radiation dose and minimize it to lower levels and this confirms the importance of careful selection of technical parameters for each type of examination.[11] However inappropriate reduction of radiation exposure causes artifact noise and loss of signal intensity, sometimes resulting in poor image quality.[10]

Therefore the radiologists must be attentive to their responsibility to maintain an appropriate balance between diagnostic image quality and radiation dose. Major national and international organizations responsible for evaluating radiation risk have established immediate and long term strategies to minimize radiation exposure in children. These include: perform only necessary CT examination; adjust exposure parameters for pediatric CT based on: child size/weight. Region scanned: the region of the body scanned should be limited to the smallest necessary area, organ systems scanned: lower mA settings should be considered for skeletal and lung imaging. Long term strategies include encouraging development and adoption of pediatric CT protocols, educating working staff through journal publications and conferences within and outside radiology specialties, conducting further research to determine the relation between CT quality and dose, to customize CT scanning for individual children to optimize exposure settings and to assess the need for CT in an individual patient. An estimate made by Brenner et al estimated a lifetime increased risk of cancer for children younger than 15 years that results from CT scans that 600,000 abdominal and head CT examinations annually on children under the age of 15 years could result in 550 cases of cancer attributable to CT radiation.[14]

In the light of rapidly increasing frequency of pediatric CT examinations, dose reduction while preserving the value of CT examination and image quality is a challenging task. Therefore, if a CT scan has to be done on a child, radiologists need to ensure that the dosage is reduced to the minimal appropriate levels without loss of diagnostic information by adjusting and modifying the applied pediatric CT scanning protocols, using low radiation dose settings.

Another most effective way to reduce the population dose from CT is simply to decrease the number of CT studies that are prescribed. At ages up to 10 years they are in general more sensitive by a factor of three.[5] The dose is directly proportional to the selected tube current–time product; therefore a reduction in mAs by 50% results in a reduction of dose by half. Kamel et al reduced the tube current–time product used for CT of the paediatric pelvis from 240 mAs to 80 mAs, achieving a substantial reduction in dose without a recognizable deterioration of diagnostic image prescribed).

Exposure of pediatric CT will result in significantly increased radiation risk because of the increased dose milliampere-second.[1] Tube potential determines the X-ray beam energy, and radiation dose is proportional to the square of the tube voltage[3] any reduction in tube current and voltage[3] pitch is defined as the ratio of table……… Slice thickness. In general, thinner CT slice thickness is appropriate in examining infants and small children, although the optimal collimation depends on the indication for the examination (helical[11]).

Therefore radiation dose, used for adults should not be used for children Reviewing the literature and comparing the approximate e quivalent dose to relevant organ (mSv) there is big difference between the adjusted settings that are designed for children and for their body weight not for adults. The reduction in radiation approximately 50% (almost to the half), little is known about its ill and harmful effects. It will require a combination of approaches which include user education for ordering physician and radiological technologist. Only then we will succeed in lowering the radiation dose in CT in favour of the child, by working together besides patients' education and equipment modification.

REFERENCES

1. David J, Brenner. Estimated risks of radiation- Induced fatal cancer from pediatric CT. Amer J Radiol 2001;176:289-96.
2. Thomas L, Slovis. Children, Computed Tomography Radiation Dose and the as low as reasonably achievable (ALARA) concepts. Pediatrics 2003;112(4):971-2.
3. Linton OW, Mettler FA. National Conferences on dose reduction in CT, with an emphasis on pediatric patients. Amer J Radiol 2003;181:321-9.
4. Ross EL. Levatter Radiation risk of body CT: What to tell our patients and questions. Radiology 2005;968-70.
5. Karaulut N, Aryyurek M. Low dose CT: Practices and strategies of radiologists in university hospitals. J Turkish Society of Radiology. Diagnostic and Interventional Radiology 2006.
6. Menke J. Comparison of different body size parameters for individual dose adaptation in body CT of adults. Radiology 2005;236:565-71.
7. Brenner DJ, Hall EJ. Computed tomography-An increasing Source of radiation Exposure. 2007;29(22):357:2277-84.
8. Hollingsworth C, Frush DP. Helical CT of the body: A survey of Techniques Used for Pediatric Patients. Amer J Radiol 2003;180:401.
9. Chefi T, Miller S. Radiation dose and cancer risk among pediatric patients undergoing interventional neuroradiology procedures. Pediatric Radiology 2006;36(suppl)14:159-62.
10. Smart RC. What are the risks of diagnostic medical radiation? Med J Australia 1997;166:589-91.
11. Pages J, Buls N. CT doses in children: a multi centre study. British J Radiology 2003;76:803-11.
12. Smiths AK. What are the risks to the fetus associated with diagnostic radiation exposure during pregnancy. J Family Practice 2006;55(5):441-444.
13. Faunama Y, Awai K. Reduction of radiation dose at HRCT of the temporal bone in children. Radiation Medicine 2005;23(8):578-83.
14. Fefferman NR, Bomsztyk E. Appendicitis in Children: Low dose CT with a Phantom-based Simulation Technique - Initial Observations Radiology 2005;237:641-6.