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 of 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 than 150 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, equipment 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. 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. Children are not only more sensitive to radiation than adults, but they will have more years in which cancerous changes might occur. 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-milliamper – 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.

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.

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 work-up, avoiding excessive testing and radiological investigations which is potentially harmful. CT scan should not be ordered for children below ten years indiscriminately. 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. 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.

Special considerations are also required to protect children who are generally more sensitive to the short- and long-term detrimental effects of radiation exposure. Prudent clinicians should order only those studies that result in clinically important information and efforts should be made to minimize radiation exposure. 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.

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 en-
ergy, scanning time, the radiation dose to the
patient is directly related to the X-ray tube cur-
rent.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
infants8 so we use a typical 140 kvp x-ray
beam
Several studies have suggested that a
technique with significant reduction in expo-
sure 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 param-
eters, 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 set-
tings. As such we use CT scanner without au-
tomated 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 ra-
diation 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 re-
duction 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 appro-
priate balance between diagnostic image qual-
ity and radiation dose. Major national and in-
ternational organizations responsible for evalu-
ating radiation risk have established immedi-
ate and long term strategies to minimize radi-
ation 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 lim-
ited to the smallest necessary area, organ sys-
tems scanned: lower mAs settings should be con-
sidered for skeletal and lung imaging. Long
term strategies include encouraging develop-
ment and adoption of pediatric CT protocols,
educating working staff through journal pub-
llications and conferences within and outside
radiology specialties, conducting further re-
search to determine the relation between CT
quality and dose, to customize CT scanning for
individual children to optimize exposure set-
tings and to assess the need for CT in an indi-
vidual patient. An estimate made by Brenner
et al estimated a lifetime increased risk of can-
cer for children younger than 15 years that re-
sults 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. There-
fore, 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 ad-
justing 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 di-
rectly 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 de-
teriation of diagnostic image prescribed).
Exposure of pediatric CT will result in significantly increased radiation risk because of the increased dose milliampere-second. Tube potential determines the X-ray beam energy, and radiation dose is proportional to the square of the tube voltage any reduction in tube current and voltage 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.

Therefore radiation dose, used for adults should not be used for children. Reviewing the literature and comparing the approximate equivalent 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