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ORIGINAL RESEARCH

EVALUATION OF A CT HEAD RADIATION DOSE REDUCTION PROTOCOL IN CHILDREN USING ANATOMICAL DELINEATION, DIAGNOSTIC CONFIDENCE AND IMAGING QUALITY OF CT BRAIN AS PARAMETERS

***Anurag Bhushan, Sarita Magu, Nitin Yadav, Seema, Perdeep Singh Gahlot and Rohtas K Yadav**

Department of Radiodiagnosis, Pt. B D Sharma PGIMS, Rohtak, Haryana, India

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ABSTRACT

Objective: To evaluate a CT head radiation dose reduction protocol in children using anatomical delineation, diagnostic confidence and imaging quality of CT brain as parameters.
Method: The study prospectively reviewed head CT studies of 100 children, 50 with normal protocol and 50 with reduced radiation protocol. Image quality was assessed using five point grading scale based on anatomical delineation, diagnostic confidence and overall image quality.
Results: The relative dose reduction between normal and reduced radiation protocol was approximately 15%. There was no statistically significant difference (p>0.05) in overall image quality by both observers.
Conclusion: Pediatric CT dose can be reduced by approximately 15% while still maintaining anatomical delineation, diagnostic confidence and overall image quality.

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INTRODUCTION

Since the advent of clinical computerized technology (CT) in the early 1970s by Sir Godfrey Hounsfield its use in the investigation of both adult and pediatric pathology has continued to grow (Rao *et al*., 2013). The last three decades have seen major advances in CT. Over the recent years there has been increasing concern about the long term effects of exposure to ionizing radiation particularly in the pediatric population. Children's less mature, rapidly dividing tissues are more sensitive to the effects of ionizing radiation. In addition, children's longer life expectancy means they have a much longer latent period of oncogenic effects of ionizing radiation compared with adults. Several studies have tried to estimate the risk of radiation induced cancer from pediatric CT (Brenner *et al*., 2001). They estimated the lifetime cancer mortality risks attributable to radiation exposure from CT head in a one-year-old to be 0.07% and from CT abdomen to be 0.18%. More recent data suggest that the brain is significantly more radiosensitive than was previously thought, the risk increasing with decreasing age. The estimated risk of cancer death for those undergoing CT is 12.5/10000 population for each pass of the CT scan through the abdomen (Tsapaki *et al*., 2010).

Corresponding author: **Anurag Bhushan,**
Department of Radiodiagnosis, Pt. B D Sharma PGIMS, Rohtak, Haryana, India.

Therefore, concerns regarding a reduction in radiation dose have been recently raised during CT acquisitions (Tang *et al*., 2012). Although decreasing tube current is the most common means of reducing CT radiation dose (Sohaib *et al*., 2001; Hamberg *et al*., 2003; Frush *et al*., 2002; Kopp *et al*., 2002), this alteration also reduces the contrast to noise ratio (CNR) which may affect the diagnostic outcome of the examination. Although CT comprises a relatively small fraction (4%) of all radiological examinations, it contributes to as much as 35% of the collective radiation dose to the population from radiological examinations, since the radiation dose for each CT examination is relatively high (Jangland, 2004). Several authors have focused on reducing the radiation dose to the patient by decreasing the mAs-value (Jurik, 1997; Kamel *et al*., 1994; Verdun, 1996). Doing this increases image noise, and if the diagnostic accuracy is still acceptable, it is a profitable way of reducing the radiation dose. Most centers use 120 kVp, but there is no consensus over optimal tube current[13]. Tube currents from 200 to 533 mAs for chest CT have been reported. Tube currents have been chosen arbitrarily without assessing impact on image quality and lesion detectability. Appropriate tube current is more difficult to define for CT than for conventional radiography because CT is a digital technique in which acquisition and display are not related. Therefore when tube current is excessive, the CT image does not become too dark but merely improves because of decreased image noise.

Because radiation dose is linearly related to amperage at a fixed kilovoltage, reduction in the miliamperage or tube current used is equivalent to dose reduction. Thus optimal CT tube current is an appropriate balance between image quality and radiation (Nishizawa, 1991). Image quality in CT, as in all medical imaging, depends on 4 basic factors: image contrast, spatial resolution, image noise, and artifacts (International Atomic Energy Agency, 2009). Depending on the diagnostic task, these factors interact to determine sensitivity (the ability to perceive low-contrast structures) and the visibility of detail. In radiography, image noise is related to the numbers of X-ray photons contributing to each small area of the image (e.g., to each pixel of a direct digital radiograph) (Goldman, 2007). In the brain, use of CT has to be balanced against the need to minimize radiation exposure and the increased availability and use of MRI to manage intracranial pathology in some settings. MRI gives superior differentiation of the tissues but the long scan times inevitably means that patient motion becomes an issue resulting in increased need for sedation or GA.

MATERIALS AND METHODS

This study population included 100 patients referred from different outpatient and inpatient departments of Pt.B.D.Sharma PGIMS, Rohtak. Patients less than 14 years of age with suspected brain pathology referred from different outpatient and inpatient departments were included in the study. CT images with poor image quality from uncertain protocol, technical error, severe motion or streak artefacts, resulting in the radiologists being unable to interpret the imaging study, were excluded from the study.

Details of imaging techniques used

All patients with suspected brain pathology, categorized randomly into two groups by lottery system (group A and group B), were subjected to CT Brain examination on spiral CT machine: one group with normal protocol and other group with dose reduction protocol. The data included age; sex; indications for scan categorized into four items: trauma, tumor, congenital and infection; and scan parameters: kVp, mA. The dose reduction was done as per Table 1.

Table 1. Dose reduction criteria

Age group	Tube current in Normal protocol (group A)	Tube current in Dose reduction protocol (group B)
0 -3 years	110mAs	90mAs
3 -6years	160mAs	130mAs
6 -14years	180mAs	150mAs

Assessment of image quality

Qualitative assessment: All imaging studies were reviewed in blind random order and independently by two experienced radiologists. The guidelines for image assessment were adapted from the standard international atomic energy agency(IAEA) protocol. The quality of each image were assessed in terms of anatomical criteria (Table 3), diagnostic confidence (Table 4) and overall quality using a five point scale grade for each element (Tables 2). If there was a greater than two grading score discrepancy by the two assessors, the image was reviewed again until an agreement was reached. Diagnostic confidence was assessed in terms of clinical disease or pathological lesions in head (Kritsaneepaiboon *et al*., 2014).

Table 2. Five point grading scale

Score	Anatomical criteria	Diagnostic confidence	Overall quality
1	Not possible	Non- diagnostic	Non-acceptable, repeat scan
2	Difficult	Low	Low
3	Acceptable	Acceptable	Acceptable
4	Good	Good	Good
5	Excellent	Excellent	Excellent

Table 3. Anatomical criteria

Grey-white differentiation
Delineation of ventricular contours
Delineation of basal ganglia
Definition of gyri

Table 4. Diagnostic confidence

Pathologies assessed
Bleeding
Infarction
Mass lesion

Statistical analysis

Different findings between the normal protocol and reduced radiation protocol images were compared to check for any significant differences by using Independent sample t-test. The statistical significance level was set at 0.05.

OBSERVATIONS AND RESULTS

To study the effect of tube current on the anatomical delineation, diagnostic confidence and overall quality of CT films observed by observer 1, we applied independent sample t test (Mullins, 2014). Table 5 and table 6 show that no significant difference was observed in anatomical delineation scores between normal current (M = 4.10, SD = 0.814) and decreased current (M = 3.98, SD = 0.845); t (98) = 0.723, p=0.471. Similarly no significant difference was observed in diagnostic confidence scores between normal current (M = 4.48, SD = 0.614) and decreased current (M = 4.50, SD = 0.580); t (98) = 0.167, p=0.620, overall image quality scores between normal current (M = 4.24, SD = 0.687) and decreased current (M = 4.20, SD = 0.700); t (98) = 0.288, p=0.983. These results suggest that decreased tube current in the study does not have significant effect on the anatomical delineation, diagnostic confidence and overall image quality of CT films observed by observer 1. It is clear from the table 7 and table 8 that no significant difference was observed in anatomical delineation scores between normal current (M = 3.76, SD = 0.771) and decreased current (M = 3.42, SD = 0.950); t (98) = -1.966, p=0.520. Similarly no significant difference was observed in diagnostic quality scores between normal current (M = 4.48, SD = 0.707) and decreased current (M = 4.34, SD = 0.688); t (98) = -1.003, p=0.318 and overall image quality scores between normal current (M = 4.44, SD = 0.705) and decreased current (M = 4.24, SD = 0.744); t (98) = -1.380, p=0.171. These results suggest that decreased tube current in the study does not have significant effect on the anatomical delineation, diagnostic confidence and overall image quality of CT films observed by observer 2.

Table 5. Mean of findings of evaluation of films by observer 1

	mAs	NUMBER	MEAN	STD.DEVIATION
Observer 1 anatomical delineation	Decreasd	50	3.98	0.845
	Normal	50	4.10	0.814
Observer 1 diagnostic confidence	Decreased	50	4.50	0.580
	Normal	50	4.48	0.614
Observer 1 quality confidence	Decreased	50	4.20	0.700
	Normal	50	4.24	0.687

Table 6. Levene's test for equality of variances of observer 1

	mAs	F	Sig	t	df	Sig.(2-tailed)
Observer 1 anatomical delineation	Equal variances assumed	0.034	0.854	-0.723	98	0.471
	Equal variances not assumed			-0.723	97.868	0.471
Observer 1 diagnostic confidence	Equal variances assumed	0.247	0.620	0.167	98	0.867
	Equal variances not assumed			0.167	97.687	0.867
Observer 1 quality confidence	Equal variances assumed	0.000	0.983	-0.288	98	0.774
	Equal variances not assumed			-0.288	97.966	0.774

Table 7. Mean of findings of evaluation of films by observer 2

	mAs	Number	Mean	std.Deviation
Observer 2 anatomical delineation	Decreasd	50	3.42	0.950
	Normal	50	3.76	0.771
Observer 2 diagnostic confidence	Decreased	50	4.34	0.688
	Normal	50	4.48	0.707
Observer 2 quality confidence	Decreased	50	4.24	0.744
	Normal	50	4.44	0.705

Table 8. Levene's test for equality of variances of observer 2

	mAs	F	Sig	t	df	Sig.(2-tailed)
Observer 2 anatomical delineation	Equal variances assumed	5.249	0.024	-1.966	98	0.520
	Equal variances not assumed			-1.966	94.031	0.520
Observer 2 diagnostic confidence	Equal variances assumed	0.097	0.756	-1.003	98	0.318
	Equal variances not assumed			-1.003	97.932	0.318
Observer 2 quality confidence	Equal variances assumed	0.002	0.967	-1.380	98	0.171
	Equal variances not assumed			-1.380	97.710	0.171

Hence, it was concluded that both observers found no significant difference in the anatomic delineation, diagnostic confidence and over all image quality between normal protocol and reduced radiation protocol.

DISCUSSION

Medical imaging has become a significant source of radiation exposure. In the developed nations, the contribution from medical imaging can be greater (Kubo, 2019). In the United States, medical radiation exposure is reported to have exceeded natural back ground radiation from environment. If we leave this upward trend unchecked, we will take a risk of increase in malignant disease in the future. Prevention of further expansion of medical radiation exposure is necessary. Growth of medical radiation exposure is largely attributable to the increase in the number of CT examinations (O'Connor, 2012). Since children are more sensitive to radiation and at a relatively greater risk of carcinogenesis than are adults, it is even more important to avoid unnecessary radiation exposure in this group than in the adult population (Kritsaneepaiboon, 2014). An optimal CT radiation dose in MDCT studies can be achieved by modifying the acquisition parameters, using the automatic exposure control, and adjusting acquisition parameters for patient size or iterative reconstruction. Kritsaneepaiboon *et al*. (2014) retrospectively did a study to compare the multidetector CT(MDCT) radiation doses between default settings(phase 1) and a revised dose reduction protocol (phase 2) and to determine whether the diagnostic confidence can be maintained with imaging quality made under the revised protocol in paediatric head, chest and abdominal CT studies. They found that paediatric CT radiation doses can be significantly reduced from manufacturer's default protocol while still maintaining anatomical delineation, diagnostic confidence and overall imaging quality. Ledenius[21] *et al* used computer-simulated images that were based on existing patient examinations (retrospective material) and studied several different tube currents per patient, i.e. paired data. They did a study to investigate the effect of tube current on diagnostic image quality in paediatric cerebral multidetector CT (MDCT) images in order to identify the minimum radiation dose required to reproduce acceptable levels of different diagnostic image qualities. Their ages ranged from newborn to 15 years. Three experienced radiologists blindly and randomly assessed the resulting images from two different levels of the brain with regard to reproduction of structures and overall image quality. Final data were evaluated using the non-parametric statistical approach of inter-scale concordance. The minimum value of tube current–time product (mAs) required to reproduce an image of sufficient diagnostic quality was established in relation to the age of the patient. The corresponding CT dose index values by volume ($CTDI_{vol}$ (mGy)) were also established. In conclusion, acceptable reproduction of low contrast structures was possible at $CTDI_{vol}$ values down to 20 mGy (patients 1–5 years old). We studied 100 patients divided in three age groups.

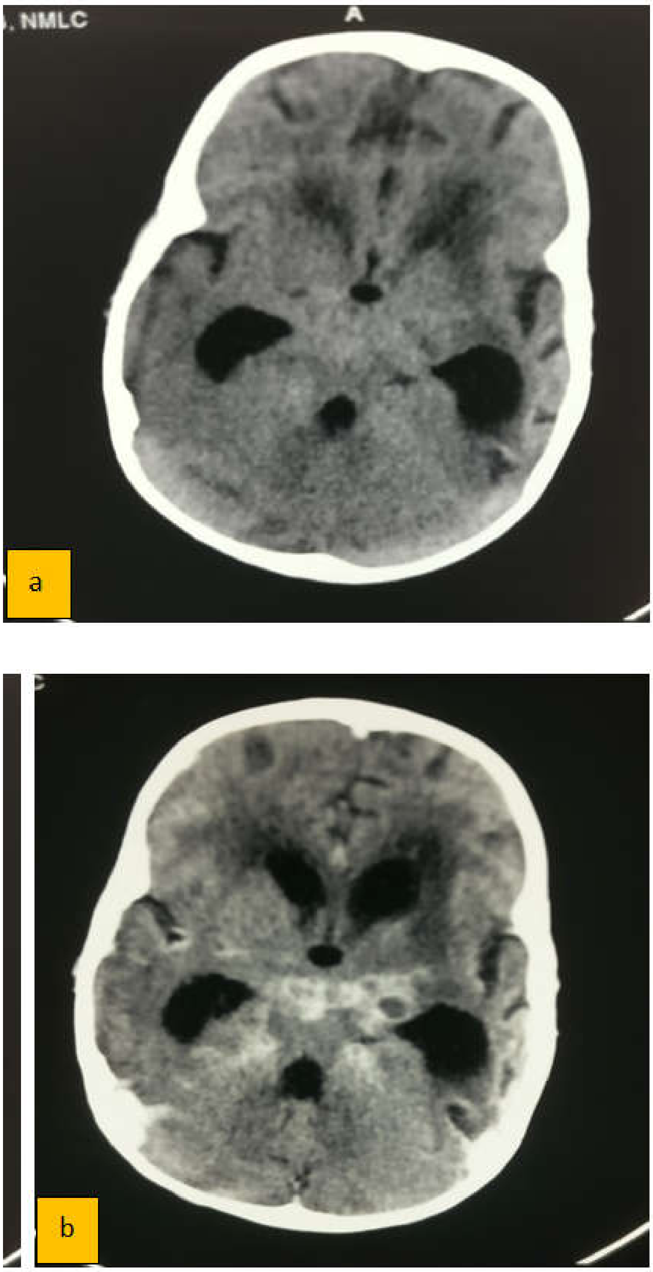

Figure 1. NCCT(a) AND CECT(b) head in a 4 year old child with decreased mAs protocol in a patient of meningitis showing acceptable image quality at reduced radiation dose protocol

It is important to use patients of similar size and developmental stage when assessing the effect of a dose reduction, as the image quality at a constant radiation dose is dependent on the patient attenuation. This study was limited by only using two observers who were experienced radiologists in the field. The results may have been different if less experienced radiologists had participated in the study. Reductions in radiation dose should therefore be implemented with care, using a safety margin and supervision for a period of time. There is a risk of bias in assessing the overall impression of image quality, as radiologists tend to recognise and favour their old settings. The age distribution of patients in this study was representative of patients within our paediatric department and surgery department. The majority of patients (between 5 years and 10 years old) are at an active age, resulting in an increased number of accident-related injuries. Among the younger children (under 1 year old), pathology is often suspected at birth, resulting in a scarcity of patients between 6 months and 1 year old. Follow-up MDCT examinations of shunt-treated hydrocephalus patients are common in paediatric patients, with the ventricles being of special interest. These patients are repeatedly scanned during an extended period of time, leading to relatively high accumulated patient doses. Protocols especially designed for hydrocephalus follow-up examinations were already in use prior to this study, with the radiation doses being up to 50% lower than those in the standard protocols. The images produced at these radiation doses agree relatively well with the results of this study as regards the minimum tube current–time product required to reproduce the ventricles acceptably for patients older than 1 year. In our study tube current was reduced approximately by 15%. The anatomic delineation, diagnostic confidence and overall image quality showed no significant difference between normal radiation protocol and reduced radiation protocol (Figure 1a & b). Based on the results of this study, the tube currents in our standard protocols for patients aged between 1 and 10 years of age can be lowered by approximately 15%.

Conclusion

This was a prospective study to assess the radiation dose reduction protocol and evaluate anatomical delineation, diagnostic confidence and imaging quality of CT brain in children using this protocol**.** 100 patients of pediatric age group were subjected to CT scan head examination on spiral CT machine. 50 of them were subjected to normal protocol and 50 of them were subjected to decreased radiation protocol (decreased tube current) randomly. All of 100 CT films were assessed randomly by the two observers and scores were given on the basis of anatomic delineation, diagnostic confidence and overall quality. After assessment by the two observers we applied student t test to know whether there is significant difference between the images of normal protocol and reduced radiation protocol. After applying it, we observed that there was no significant difference between the images of normal protocol and reduced radiation protocol. We conclude that tube current can be reduced up to certain level (in our study: 15%) without significant decrease in image quality and diagnostic confidence.

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