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Effect of low radiation doses in pediatric computed tomography using adaptive statistical iterative reconstruction technique

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Abstract:
Background:
During last decades, computed tomography (CT) gains a promptly augmented significance resulting from their precision, short acquisition time, and cost-effectiveness. Besides, while the use of CT has led to major advances in modern medical practice, an increasing concerns for patient safety has accompanied this trend, as CT delivers higher levels of radiation than most other diagnostic imaging routines.
***Materials and Methods**: Quantitative and qualitative study of CT-image quality were performed via different pediatric case studies having the same k-factor (Age range 5:10 Years) undergoing follow-up brain-CT. A full standard practice dose (148 mAs) without application of Adaptive Statistical Iterative Reconstruction (ASIR) routine was compared with other dose reduced practice through application of gradual decreasing currents (100, 80, 60, and 40 mAs) combined with application of 60% and 80% ASIR. Obtained data suggested that reduction in current up to 100 mA with application of ASIR may enhance image quality and increase image signal to noise ratio (SNR) in expense of the delivered effective dose (ED). Further reduction in current up to 60 mA result in an images with nearly the same signal to noise ratio combined with a reduction in ED.*
***Results**: The study was performed on 5 cases aged from 5 to 10 years with no ASIR at 148 mA and 120 KV. The current was the decreased from 148 to (100, 80, 60, 40) mA and with applying ASIR (60, 80%). The data recorded in table (1) taken as an average of three different cases at the same conditions*
***Conclusion:** Reduction of current to 40 mA result in a more effective dose reduction combined with an abrupt change in both resolution and contrast up to 70% of the original one giving acceptable image quality with lower ED*
***Key Word**: Computed tomography (CT); Adaptive Statistical Iterative Reconstruction (ASIR); Image Quality; Effective dose (ED); Signal to noise ratio (SNR); Pediatric CT*

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I. Introduction

During last decades, computed tomography (CT) gains a promptly augmented significance resulting from their precision, short acquisition time, and cost-effectiveness. Besides, while the use of CT has led to major advances in modern medical practice, an increasing concerns for patient safety has accompanied this trend, as CT delivers higher levels of radiation than most other diagnostic imaging routines [1, 2].

CT is the primary medical cradle of radiation exposure, subsidizing about 50% of the overall effective dose (ED). Risk model predictions and results from recent large-scale epidemiological studies projected an increased risk of cancer in radiosensitive children linked to CT exposure [3].

The main contributor to the general population of radiation from the medical imaging is from computed tomography. The numeral of CTs conducted on Childs has increased, in particular throughout visits to the emergency departments. Ionizing radiation is a recognized carcinogen, and its traditional effects are a disquiet, especially in children with accumulated radiation. At the cellular level, the children have a larger radiation exposure and extended lifetimes in which harmful effects can marked [4-8].

Zacharias et al reviewed the common ideologies of radiation dose reduction and basic physics principles that contribute to radiation dose, and precise CT joined dose-reduction tools motivated on the pediatric population [9].

In CT-scans, image quality noise follows a square root trend with radiation dose. Therefore, reduction of radiation dose can be attained through what is called reconstruction routes to provide less-noise images. Adaptive Statistical Iterative Reconstruction routine (ASIR) is a reconstruction routine designed to reduce image noise as compared to Filtered Back Projection routine (FBP).

It is accomplished by reducing the sum of two terms: one cost function, which incentivizes weak statistics on image noise, and one nonparametric time. New work has shown that cataracts caused by radiation have a much greater capacity than originally thought and it would be beneficial to lower the exposure for head CT scans.

Recent studies have cautioned of a decrease in low contrast detectability in hypo-attenuated brain regions following a stroke by using iterative reconstruction using repeated dose-reduced protocols. Failure of such subtle lesions may have severe implications for patients, so the dose of head CT by applying iterative reconstruction needs thorough testing before clinical implementation [1, 5, 9].

The effective dose of one pediatric CT may be less than 1.0 mSv; however, doses of up to 24.0 mSv have also been reported with a tumor risk rising consecutively. One of 1000 children will die from cancer following a single non-optimized head CT [6].

Owing to the smaller target diameters involved, slightly lower doses of radiation (mAs) can be used for CT scans with no loss of quality in children. As a general rule, for pediatric examinations at 120 kV the formula mAs = (body weight [kg] + 5) × f has been established for various manufacturers' 16-slice CT machines. The recommended value of f varies according to the part of the body: chest f = 1, abdomen f = 1.5, head f= 2–5. In children, due to short scan times, the dose can be reduced by up to 25% [7].

The aim of the presented work is to study the effect of applied current change in (mAs) in the effective dose (ED) and resolution of CT image in case of pediatric brain with constant k-factor.

II. Material And Methods

Presented study includes the CT-brain examination for patients with constant value of k-factor Aged (5:10 Years). Selected patients distributed randomly within the study period of prospective annexation. CT-Brain examinations were operated at Mansoura Advanced Radiology Center, Mansoura city, Egypt.

Patients have been scanned on the CT scanner (Revolution EVO Gen 3 GE Healthcare 128 detectors-USA) and reconstructed using the ASIR technique (60% and 80% ASIR) the age range of studied patient having the same k-factor ranging between 5-10 Years. All patients under investigation were scanned without contrast. The demographic data of patients were serene from booking demand forms.

There was no neurological or systemic illness in all children that may have affected the brain (e.g. diabetes, chronic obstructive pulmonary disease, asthma, metabolic disorders).

This prospective comparative study was carried out on patients of Department of general Medicine at Dr. Ram ManoharLohia Combined Hospital, VibhutiKhand, Gomti Nagar, Lucknow, Uttar Pradesh from November 2014 to November 2015. A total 300 adult subjects (both male and females) of aged ≥ 18, years were for in this study.

III. Results and Discussion

The study was performed on 5 cases aged from 5 to 10 years with no ASIR at 148 mA and 120 KV. The current was the decreased from 148 to (100, 80, 60, 40) mA and with applying ASIR (60, 80%). The data recorded in table (1) taken as an average of three different cases at the same conditions.

To calculate the studied parameters six regions of interest were selected in all cases, three in white matter region and three in gray matter region as shown in Figure (1). Gray and white matter region and area of interest in brain CT, red circles represent area of interest in white matter, green circles represent area of interest for gray matter. The areas of interest were adjusted to be about 0.8+0.005 cm2. The CT protocol details can be found in table (1) while a flowchart illustrating the inclusion of patients emerges in Figure (2).

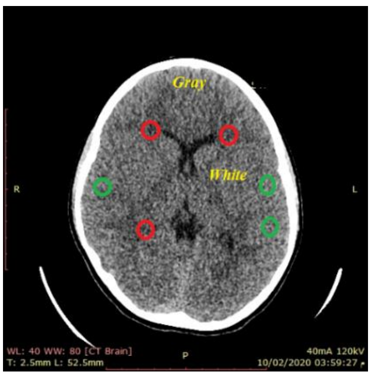


Fig 1: Gray and white matter region and area of interest in brain CT, red circles represent area of interest in white matter, green circles represent area of interest for gray matter.

Table (1) details of used CT protocols

Scanner	Revolution EVO Gen 3
Technique	Helical
KV	120
mA	148 (standard practice) 100, 80, 60, 40 (dose reduced series)
CTDI (mGy)	30.35 (standard practice)
Rotation time (s)	0.6
Collimation (mm)	20
Scan field of view	Head
Slice thickness (mm)	2.5
Reconstruction kernel	Standard
ASIR	0 (standard practice) 60% and 80% (dose reduced series)

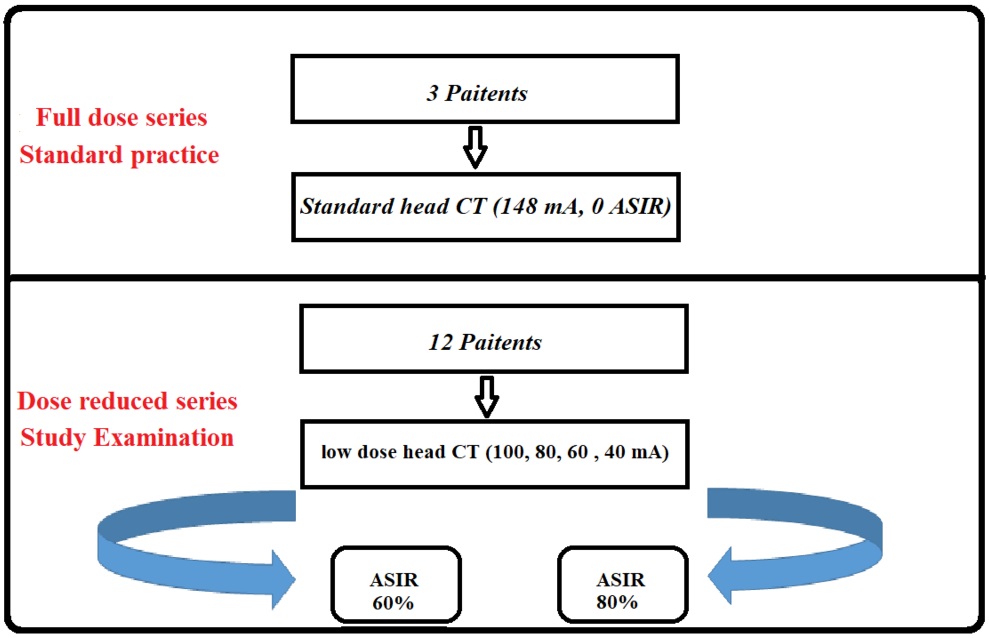


Fig 2: flowchart describing the patient inclusion

Both signal to noise ratio (SNR) and contrast to noise ratio were calculated using the following equations:

$$SNR = \frac{HU_{gray\ matter}}{SD_{gray\ matter}} \qquad (2)$$

$$CNR_{tissue\ 1, tissue\ 2} = \frac{\frac{1}{n_{tissue\ 1}} \Sigma HU tissue\ 1 - \frac{1}{n_{tissue\ 2}} \Sigma HU tissue\ 2}{\frac{1}{2}\left(\frac{1}{n_{tissue\ 1}} \Sigma noise tissue\ 1 + \frac{1}{n_{tissue\ 2}} \Sigma Noise\ tissue\ 2\right)} \qquad (3)$$

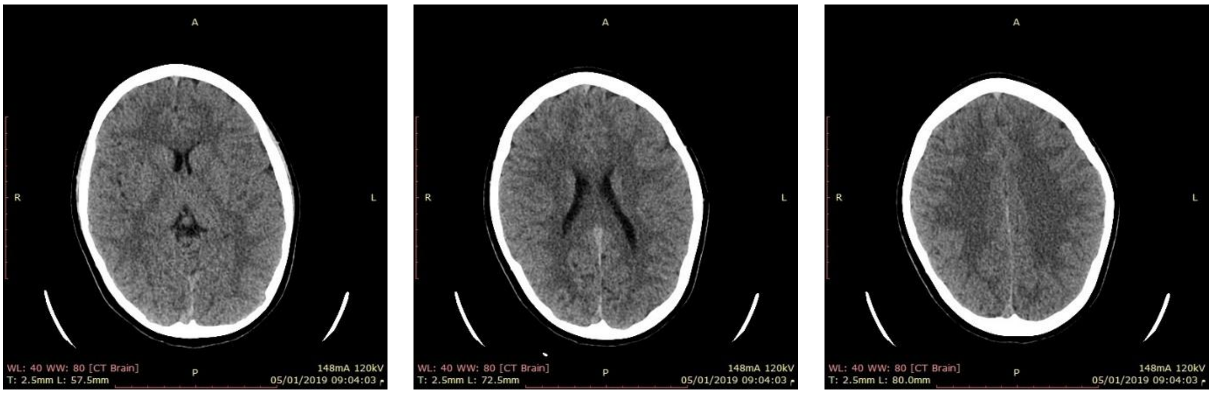
SNR and CNR is the signal to noise ratio and contrast to noise ratio respectively. N is the number of regions of interest that considered as 9 points in the gray matter (Tissue1) distributed over 3 different levels of brain and 9 points in the white matter (Tissue2) distributed over 3 different levels of brain, HU is an abbreviation for the Hounsfield unit and SD is an acronym for the standard deviation.

Figure (3) shows an exemplified CT image corresponding to three different brain levels of a patient subjected to full dose standard practice with 148 mAs current and 0 ASIR.

Quantitative and qualitative image quality was evaluated in all patients with application of different currents with two different ASIRs namely 60 and 80%. Figure (4) reveals an exemplified CT image corresponding to three different brain levels of a patient subjected to a reduced current (60 mA) at two different ASIRs. Other data obtained corresponding to different reduced currents (100, 80, 60, and 40 mA) were calculated and introduced in table (2).

Table (2) ED, SNR, and CNR calculated at different reduced currents

Current mAs	Scan Length mm	ED	SNR ASIR 60%	SNR ASIR 80%	CNR ASIR 60%	CNR ASIR 80%
100	177.5	2.46	7.66	8.88	1.88	2.17
80	155.0	1.87	6.79	7.56	1.42	1.46
60	155.0	0.84	6.37	7.39	1.56	1.85
40	150.0	0.54	4.61	5.36	1.30	1.56
			Non-ASIR		**Non-ASIR**	
148	147.5	2.01	6.6		1.5	



Level 1 (148 mA, 0 ASIR) **Level 2 (148 mA, 0 ASIR)** **Lvel 3 (148 mA, 0 ASIR)**

Fig 3: CT images for three different brain levels with standard practice (148 mA, 0 ASIR)

Level 1 (60 mA, 60% ASIR) **Level 2 (60 mA, 60% ASIR)** **Level 3 (60 mA, 60% ASIR)**

Level 1 (60 mA, 80% ASIR) **Level 2 (60 mA, 80% ASIR)** **Level 3 (60 mA, 80% ASIR)**

Fig 4: CT image of a patient subjected to a reduced current (60 mA) at two different ASIRs.

Percentage reduction in both signal to noise ratio (RSNR) and in contrast to noise ratio (RCNR) were also calculated (see table 3) to evaluate both in quantitative and qualitative the optimum condition for dose reduced head computed tomography (CT) protocols reconstructed using adaptive statistical iterative reconstruction route (ASIR).

Table (3) Percentage reduction in both signal to noise ratio (RSNR) and in contrast to noise ratio (RCNR) at two different ASIRs.

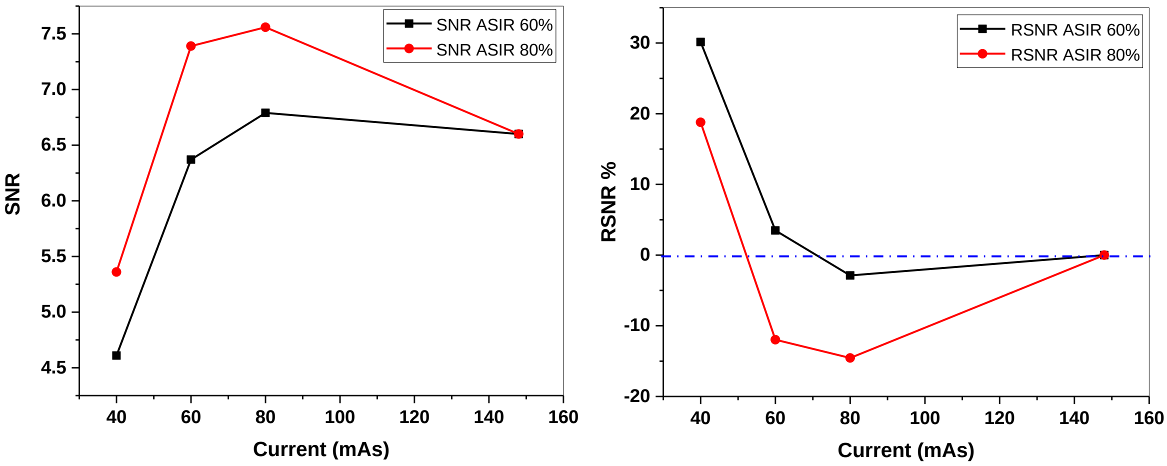
Current mA	ASIR							
	60%		80%		60%		80%	
	SNR	RSNR	SNR	RSNR	CNR	RCNR	CNR	RCNR
148	6.60	0.00	6.60	0.00	1.5	0.00	1.5	0.00
80	6.79	-2.88	7.56	-14.55	1.42	5.33	1.46	2.67
60	6.37	-3.49	7.39	-11.97	1.56	-4.00	1.85	-23.33
40	4.61	30.15	5.36	18.79	1.3	13.33	1.56	-4.00

Finally, signal to noise ratio (SNR), contrast to noise ratio (CNR), and effective dose (ED) were calculated using the following equations.

Effective Dose (ED) = k × DLP (1)

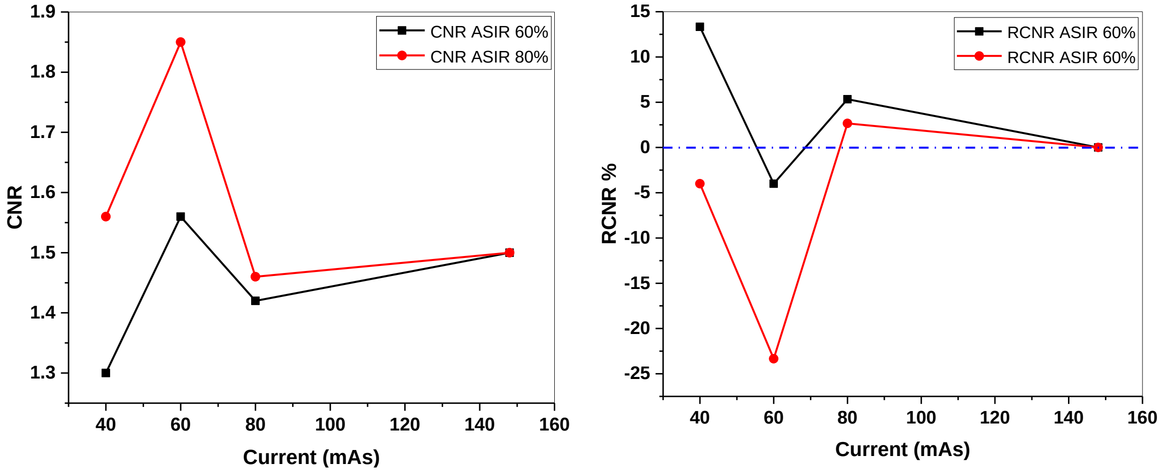
Where k is the conversion factor for calculation of effective dose taken to be 0.004 for the age range (5:10 Years), and DLP is an abbreviation for dose-length product recorded from the dose record.

Figures (5- a, b) show the variation of signal to noise ratio associated with different reduced currents and also the percentage reduction of SNR correlated with the standard route (148 mA). It was obvious that change in the current was accompanied with a change in both SNR and RSNR. It was noticed also that current reduction to about (100Am) associated with mathematical treatment via ASIR 60% leads to an increase in the image quality and also in the effective dose. Further reduction in current leads to a gradual decrease in SNR until the last reduced current (40 mA) associated with an abrupt change in SNR with a reduction of about 30%. Same situation was also observed using ASIR 80% but usually with a higher SNR and lower reduction percent in resolution. Obtained data suggested that application of reduced current (60 mA) with application of 80% ASIR may result of nearly the same image quality as that of standard routine but with a reduced effective dose which are preferable in case of pediatric CT. Same results was also supported by calculations of contrast to noise ration and their reduction percentage shown in Figures (6-a, b).



(a) **(b)**

Fig 5: variation of (a) SNR and (b) percentage reduction of SNR associated with different reduced currents.



(a) **(b)**

Fig 6: variation of (a) CNR and (b) percentage reduction of CNR associated with different reduced currents.

IV. Conclusion

Pediatric brain CT-image were recorded as an average of three different cases of child's having the same k-factor (Age range 5:10 Years) undergoing full standard practice dose with 148 mA current without application of (ASIR). Previously mentioned cases were compared with other cases subjected to a gradual reduced current (100, 80, 60, and 40 mAs) combined with application of 60% and 80% ASIR. Obtained data support reduction of current up to 60 mA to attain image quality with reduced dose and reduction of current to 40 mA to obtain acceptable image quality. In addition, application of 80% ASIR give image quality (SNR and CNR) better than that obtained with 60%ASIR.

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