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RESEARCH **Open Access**

Value of using adaptive statistical iterative reconstruction-V (ASIR-V) technology in pediatric head CT dose reduction

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Abstract

Background: With widespread use of pediatric head CT, it is critically important to protect patients from radiation hazards, using reduced dose CT techniques. In this regard, adaptive statistical iterative reconstruction-V (ASIR-V) algorithm can decrease image noise, generating CT images of reasonable diagnostic quality with less radiation. The objective of this study was radiation dose assessment, quantitative and qualitative evaluation of reduced dose pediatric head CT using ASIR-V 60% and 80% reconstruction.

Results: Retrospective analysis was performed on two groups of pediatric head CT examinations, a reduced dose CT examination group with ASIR-V reconstruction (ASIR group) (n = 27) and a standard dose CT examination group without ASIR reconstruction (non-ASIR group) (n = 14). The average effective dose (ED) of ASIR group was significantly lower than that of the non-ASIR group (1.04 ± 0.1 mS vs 3.48 ± 0.45 mS; $p = 0.001$). Quantitative analysis revealed comparable results of signal to noise ratio (SNR) and contrast to noise ratio (CNR) of ASIR and non-ASIR groups ($p > 0.05$). Qualitative evaluation of resulting images by two readers revealed comparable results of both ASIR and non-ASIR groups ($p > 0.05$) with excellent inter-reader agreement ($\kappa = 0.97$). Both quantitative and qualitative assessment demonstrated better ASIR-V 80% than ASIR-V 60% reconstructed images.

Conclusion: ASIR-V algorithm is a promising technology for effective dose reduction of pediatric head CT with preservation of diagnostic image quality.

Keywords: Computed tomography (CT), Adaptive statistical iterative reconstruction (ASIR), Pediatric, Standard dose, Reduced dose, As low as reasonably achievable (ALARA)

Background

The use of computed tomography (CT) has been constantly increasing over the last decades in all age groups. CT technology has changed significantly especially with the availability of technically complex, faster multidetector row CT scanners [1–3]. However, the increased use of CT has resulted in rising concern about its concomitant radiation dose. At present, CT-derived dose accounts for 75% of the dose given at medical imaging [4]. Radiation-risk issues are attracting attention, particularly in pediatric age as children have longer life expectancy and larger proportion of dividing cells compared to adults, leading to higher radiation risks with the same exposure dose [2, 5, 6].

The increasing awareness of potentially harmful effects associated with radiation exposure led to optimization of CT scans according to the principle of reducing radiation doses to "as low as reasonably achievable" (ALARA) [7, 8]. This was achieved by the development of a variety of dose reduction techniques, such as tube current modulation, lowered tube voltage, adaptive beam collimation, and partial scanning. Recent innovations for dose reduction with enhancement of image quality

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include filtered back projection and iterative reconstruction algorithms [1, 5].

Among iterative reconstruction techniques, adaptive statistical iterative reconstruction (ASIR) is a widely studied method. First, ASIR applies both filtered back projection (FBP) and iterative reconstruction resulting in a similar image quality as FBP with reduced radiation dose. However, ASIR has image degradation due to artificial textures and decreases spatial resolution with higher percentage of blending use degrading resulting images [1, 5, 8–11]. A full iterative reconstruction method, model-based iterative reconstruction (MBIR), an incorporating extensive model of acquisition process, was introduced to overcome this limitation [12]. However, MBIR requires more time-consuming image reconstruction due to its complexity with a mean reconstruction time of 32 min [13]; thus, it has not been widely used in clinical practice. Recently, a hybrid with ASIR, ASIR-V was developed; it is based on advanced physics modeling in addition to statistical noise and object modeling. This resulted in better noise reduction performance even with application of lower dose CT protocols [6, 8, 10, 14].

Most of the available studies in literature declared the role of ASIR with reduction of tube voltage for radiation dose reduction and preservation of resulting CT image quality. Moreover, many studies mentioned that the use of high levels of ASIR algorithm reconstruction yields softened resulting CT images with concern that fine anatomical features may be obscured [6, 7, 15–18]. However, the innovated third generation of ASIR, ASIR-V has provided better noise reduction than the older ASIR generations, with resultant better image resolution [14, 19]. This study aimed at quantitative and qualitative evaluation of reduced dose head CT examination with different low mA and ASIR 60% and 80% algorithm reconstruction compared to standard dose non-ASIR reconstructed head CT examination in pediatric patients.

Methods

Study design and patients

The institutional review board approved this retrospective study. In the period of January 2018 until December 2019, 41 consecutive pediatric patients underwent non-contrast brain CT for different clinical indications. Patients were aged from 3 to 10 years (median age, 6 years). They were divided into two groups, the first group (non-ASIR group) consisted of 14 patients undergoing head CT with the standard CT dose without ASIR reconstruction and the second group (ASIR group) comprised 27 patients undergoing reduced dose head CT with post-processing using ASIR-V algorithm in order to decrease effective dose (ED) with reasonably accepted image quality. Inclusion criteria were pediatric patients 3–10 years old with good general condition and exclusion criteria were occurrence of motion artifacts to avoid degradation of image quality and space-occupying lesions deforming the brain morphology.

Patient CT scanning

All patients underwent non-contrast head CT examinations with a CT scanner (Revolution EVO; GE Healthcare, Waukesha, WI, USA). First, the non-ASIR CT group (n = 14) were examined with the routine head CT protocol with the standard radiation dose: 148 mA, 120 kV, helical mode, gantry rotation speed 0.6 s, table speed 10.6 s, pitch 0.531:1, slice thickness 2.5 mm, field of view 25 cm, matrix = 512 × 512, reconstruction 1.25 mm. Then, the ASIR group (n = 27) were examined with the revised reduced radiation dose protocol using a tube current range of 40–100 mA, and all other factors were kept constant the same as the non-ASIR CT scanning protocol (Table 1).

The patient images of the first group were reconstructed with filtered back projection (FBP). The patient images of the second group were reconstructed with ASIR 60% and ASIR 80% algorithm. Then, the images were uploaded to an image archiving and communication system for image analysis (Fig. 1).

CT dose analysis

The CT dose index volume (CTDI vol) and dose length product (DLP) (mGy centimeter) for each patient CT study were derived from the output (dose report), which are fixed numbers when a fixed tube current is used in

Table 1 Used non-contrast CT protocols

Scanner	Revolution EVO Gen 3
Technique	Helical
KV	120
mA	148 (standard dose)
	40, 60, 80, 100 (reduced dose)
CTDI vol (mGy)	35.61 (standard practice)
Gantry rotation time (s)	0.6
Pitch	0.531:1
Collimation (mm)	20
Field of view	25 cm
Matrix	512 × 512
Slice thickness (mm)	2.5
Reconstruction options	First group: FBP
	Second group: ASIR-V 60% and 80%

KV kilovolt, *mA* milliampere, *CTDI vol* CT dose index volume, *FBP* filtered back projection, *ASIR-V* adaptive statistical iterative reconstruction

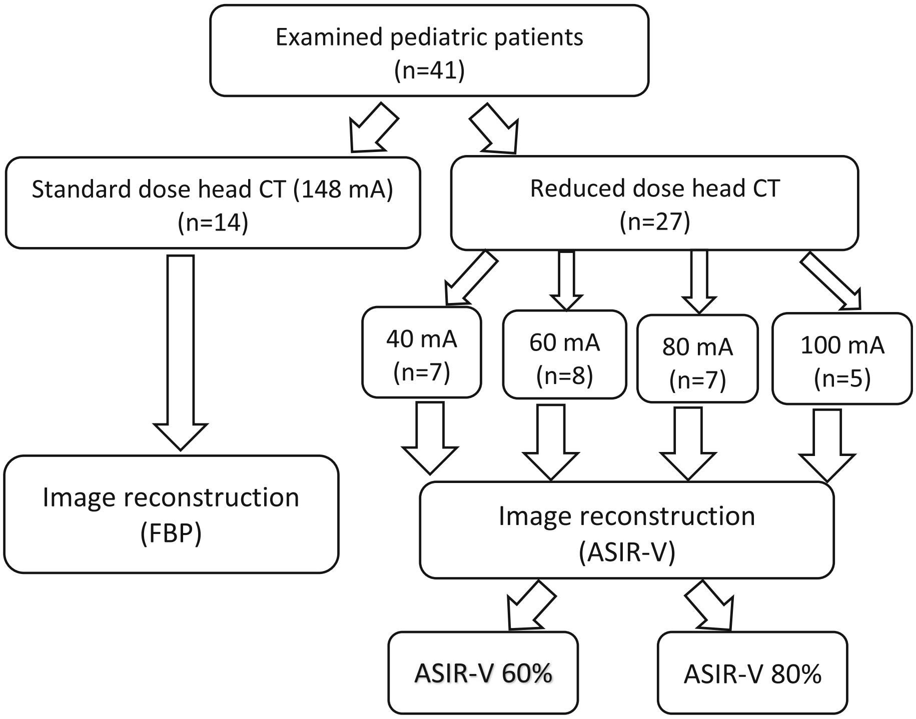

Fig. 1 Flowchart of head CT acquisition and reconstruction of ASIR and non-ASIR groups

the CT acquisition protocol. The ED in (mSv) were calculated using the following formula:

$$\mathrm{ED(mSv)} = \mathrm{DLP} \times \mathrm{K}$$

where *K* factor is the conversion factor for calculation of effective dose [7, 16].

Quantitative analysis

For each examination, three levels were chosen for placement of regions of interest (ROIs), the level of centrum semiovale, corona radiata, and thalamus. At the level of centrum semiovale and corona radiata, six ROIs were placed in each cerebral hemisphere, three in white matter and three in gray matter. At the thalamic level, five ROIs were placed in each cerebral hemisphere, two in white matter and three in gray matter. Each ROI area measured 57 ± 24 mm^2 to ensure homogeneity of measured tissue (Fig. 1). Then, signal to noise ratios (SNR) was calculated using the following formula:

$$\mathrm{SNR} = \frac{\mathrm{HU\ GM}}{\mathrm{SD\ GM}}$$

where HU GM is HU value in gray matter (GM), and SD GM is standard deviation value in gray matter [1].

Contrast to noise ratios (CNR) were calculated using the following formula:

$$\mathrm{CNR}_{\mathrm{GM.WM}} = \frac{\frac{1}{n\ \mathrm{GM}}\Sigma \mathrm{HU\ WM} - \frac{1}{n\ \mathrm{WM}}\Sigma \mathrm{HU\ WM}}{\frac{1}{2}\left(\frac{1}{n\ \mathrm{GM}}\ \Sigma \mathrm{noise\ GM} + \frac{1}{n\ \mathrm{WM}}\Sigma \mathrm{Noise\ WM}\right)}$$

where *n* GM is the number of ROIs for the gray matter (GM), *n* WM is the number of ROIs for the white matter (WM), ΣHU WM is the sum over all CT-number measurements of white matter (WM), ΣHU GM is the sum over all CT-number measurements of gray matter (GM), Σnoise GM is the sum over all noise measurements of the gray matter, and Σnoise WM is the sum over all noise measurements of the white matter [17] (Fig. 2).

Qualitative analysis

All acquired CT examinations were analyzed by two independent neuro-radiologists (MS, SF) with 33 and 15 years of experience who were blinded to the protocol and use of ASIR algorithm for reconstruction.

The gray and white matter differentiation, sharpness (i.e., ability to differentiate sulci and gyri), the visibility of the ventricular system, and overall image

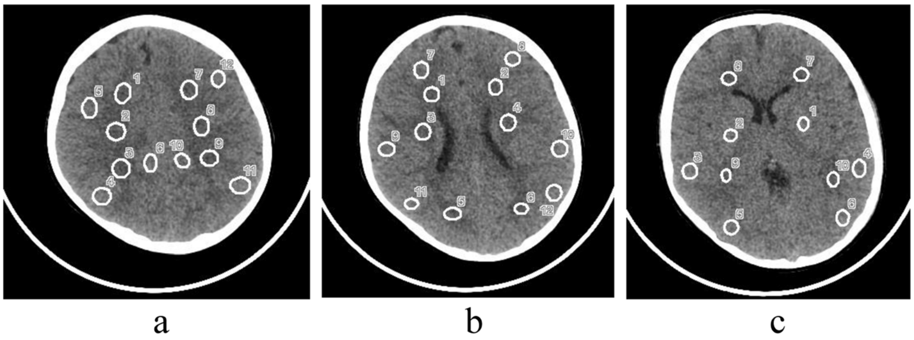

Fig. 2 Sites of chosen gray matter and white matter ROIs for calculation of SNR and CNR. **a** Sites of gray matter ROIs (4–6, 10–12)and white matter ROIs (1–3, 7–9) at the level of centrum semiovale. **b** Sites of gray matter ROIs (1–6) and white matter ROIs (7–12) at level of corona radiata. **c** Sites of gray matter ROIs (1–6) and white matter ROIs (7–10) at level of thalamus

quality were evaluated by both readers independently. Four-point grading system was applied: images of excellent quality were graded 4, images of average quality were graded 3, images of suboptimal diagnostic quality were graded 2, and images of poor non-diagnostic quality were graded 1. Window level (40–60 HU) and window width (80–100 HU) were fixed for all images. In the subjective image quality assessment, the image noise, artifacts, and diagnostic acceptability were taken into consideration.

Statistical analysis

The obtained data were analyzed using Statistical Package for Social Science version 22 (SPSS Incorporation, Chicago, Illinois, USA). Qualitative data were described using number and percent. Quantitative data were described using mean and standard deviation for normally distributed parametric data after testing normality using Shapiro-Wilk test or median and range for non-normally distributed parametric data. An unpaired Student t test was used for continuous variables. Significance of the obtained results was judged when p value was ≤ 0.05.

The two studied groups were compared using quantitative and qualitative data. One way ANOVA test was used for comparison of more than 2 independent groups with parametric data. For qualitative assessment, Chi-square test was applied for comparison of 2 or more groups. The kappa statistics (κ) were applied to estimate the proportion of inter-reader agreement of both readers beyond that expected by chance for qualitative CT image assessment. The κ values were interpreted as follows: κ values between 0.81 and 1.00 represent perfect, κ values between 0.61 and 0.80 represent substantial agreement, κ values between 0.41 and 0.60 represent moderate agreement, and κ values between 0.21 and 0.40 represent fair agreement [20].

Results

Patient demographics

A total number of 41 pediatric patients, 26 males and 15 females, aged 3–10 years (the median age, 6 years), were comprised in this study. They were divided into two groups: the first group (non-ASIR group) (n = 14) examined with the standard dose CT technique with FBP reconstruction and the second group (ASIR group) (n = 27) examined with the reduced dose CT technique with ASIR-V 60% and 80% algorithm reconstruction. Out of studied children, 70.7% (n = 29) showed normal head CT examinations (no pathology) and 29.3% of them (n = 12) showed mild pathologies (mild sinusitis n = 9, small subgaleal hematoma n = 2, fissure fracture = 1). Patient demographic characteristics and CT findings were summarized in (Table 2).

CT dose analysis

The CTDI vol of the non-ASIR group with standard dose CT scanning was 35.61 mGy. The average CTDI vol of the ASIR group was 14.36 ± 3 mGy, which was significantly lower than the non-ASIR group ($p < 0.001$). The CTDI vol demonstrated gradual decrease in the ASIR group decreasing the used tube current, reaching 8.9 mGy with 40 mA. The average scanned DLP of the

Table 2 patient demographic characters and CT findings (n = 41)

	Non-ASIR group	ASIR group
N	14	27
Age (median, range)	4 years (3–9 years)	6 year (3–10 years)
Male to female ratio	4:3	2:1
CT findings (*n*)		
No pathology	9	20
Mild sinusitis	4	5
Small subgaleal hematoma	1	1
Fissure fracture	0	1

ASIR adaptive statistical iterative reconstruction

ASIR group was significantly lower than the DLP of the non-ASIR group (256.7 ± 37.8 mGy.cm versus 614.23 ± 112.31 mGy.cm; p = 0.0001). Consequently, the ED of the ASIR group was significantly lower than that of the non-ASIR group (1.04 ± 0.1 mSv versus 3.48 ± 0.45 mSv; p = 0.001). The ED of the ASIR group was demonstrated a gradual decline decreasing the used mA. CT dose analysis measures were demonstrated in (Table 3).

Quantitative image analysis

The non-ASIR group SNR was 7.44 ± 0.81. The average SNRs of the ASIR group were 6.43 ± 1.01 with ASIR-V 60% reconstruction and 7.37 ± 0.75 ASIR-V 80% reconstruction, respectively, with no demonstrated significant difference from the non-ASIR group. Among the ASIR group, the highest reported SNR was 8.88 ± 0.517, which showed with 100-mA tube current CT acquisition and ASIR 80% reconstruction; it was significantly a higher value than the non-ASIR group (p = 0.0019). The reported SNRs with 40-mA tube current CT acquisition and ASIR 60% and ASIR 80% reconstructions were 4.9 ± 1.13 and 5.67 ± 1.11, respectively, with significantly lower values than the non-ASIR group ($p \leq 0.001$).

No significant difference was noticed between the average CNRs of the ASIR group with ASIR 60% reconstruction and ASIR 80% reconstruction were 1.54 ± 0.37 and 1.63 ± 0.27, respectively. The ASIR group CNRs with both tested ASIR percentages in the current study showed comparable results with the CNR in the non-ASIR group which was 1.89 ± 0.35. The use of 40-mA and 80-mA tube current with both ASIR 60% and ASIR 80% reconstruction displayed significantly lower CNR than that of the non-ASIR group values ($p < 0.05$). Table 4 and Figs. 3 and 4 clarified the quantitative analysis results.

Qualitative image assessment

There was no statistically significant difference between the ASIR and non-ASIR groups as regard gray-white matter differentiation and sharpness by both radiologists. The 60% ASIR images with 40-mA tube current adjustment CT examinations showed significantly lower lateral ventricle visibility than that of the CT images of the non-ASIR group (first radiologist, p = 0.03; second radiologist, p = 0.038). Otherwise, no significant difference of lateral ventricle visibility among CT images of the non-ASIR and ASIR groups with 60-, 80-, and 100-mA CT x-ray tube current modulations. Regarding the overall diagnostic quality, none demonstrated significant difference among CT images of the non-ASIR and ASIR groups with the all studied reduced CT x-ray tube current modulations. Nevertheless, both resulting 60% and 80% ASIR images of the ASIR group with 60- and 100-mA CT x-ray tube current adjusted CT examinations revealed better overall diagnostic image quality than that of the non-ASIR group.

The qualitative assessment showed no statistically significant difference between both examined groups by both radiologists. There was no found statistically significant difference in gray-white matter differentiation between both examined groups (first radiologist, p = 0.3; second radiologist, p = 0.32). As regard sharpness, no statistically significant difference was revealed for both groups (first radiologist, p = 0.58; second radiologist p = 0.06). However, the LD group showed better sharpness than the STD group, especially with ASIR 80% reconstruction. Moreover, there was no statistically significant difference in lateral ventricle visibility for the examined groups (first radiologist, p = 0.52; second radiologist, p = 0.07). Nevertheless, the LD group with ASIR 80% reconstruction displayed the best lateral ventricle visibility. The overall diagnostic quality showed no statistically significant difference between STD and LD groups (first radiologist, p = 0.6; second radiologist, p = 0.47). Nevertheless, ASIR 80% reconstructed images of the low dose group revealed the best overall diagnostic quality.

The inter-observer agreement was demonstrated to be perfect for gray-white matter differentiation (κ = 0.857), for sharpness (κ = 0.86), and for overall diagnostic quality (κ = 0.97). A substantial inter-observer agreement was noticed for lateral ventricle visibility (κ = 0.714). Figs. 5 and 6 presented examples of the results of the qualitative analysis of image quality.

Table 3 Comparative data of radiation CT dose analysis data of the ASIR and non-ASIR groups

Tube current (mA)	CTDI vol (mGy)	DLP (mGy cm)	Test of significance with non-ASIR group	ED (mSv)	Test of significance with non-ASIR group
ASIR (n = 27)	14.36 ± 3	256.7 ± 37.8	t = 8.66, p = 0.0001*	1.04 ± 0.1	t = 13.24, p = 0.001*
40 mA (n = 7)	8.9 ± 2.14	146.03 ± 12.84	t = 10.86, p = 0.0001*	0.63 ± 0.04	t = 16.1, p = 0.001*
60 mA (n = 8)	12.13 ± 2.6	208.94 ± 24.9	t = 9.96, p = 0.0001*	0.84 ± 0.067	t = 16.32, p = 0.001*
80 mA (n = 7)	16.18 ± 3.09	278.58 ± 43.7	t = 7.55, p = 0.0001*	1.11 ± 0.09	t = 13.63, p = 0.001*
100 mA (n = 5)	20.22 ± 4.2	393.73 ± 71.4	t = 4.71, p = 0.0008*	1.57 ± 0.19	t = 9.07, p = 0.001*
148 mA (non-ASIR) (n = 14)	35.61 ± 6.7	614.23 ± 112.31		3.48 ± 0.45	

*Statistically significant if $p < 0.05$
All parameters are described as mean ± standard deviation
ASIR adaptive statistical iterative reconstruction, *mA* milliampere, *CTDI vol* CT dose index volume, *DLP* dose length product, *ED* effective dose

Table 4 Comparison of quantitative image analysis data of the ASIR and non-ASIR groups

Tube current (mA)/reconstruction	**SNR**		**CNR**	
	Non-ASIR		**Non-ASIR**	
148 mA/non-ASIR	7.44 ± 0.81		1.89 ± 0.35	
Tube current (mA)/ASIR reconstruction	**SNR**	**SNR**	**CNR**	**CNR**
	ASIR 60%	**ASIR 80%**	**ASIR 60%**	**ASIR 80%**
ASIR (*n* = 27)	6.43 ± 1.01	7.37 ± 0.75	1.54 ± 0.37	1.63 ± 0.27
Test of significance with non-ASIR group	$t = 2.37$, $p = 0.07$	$t = 0.176$, $p = 0.96$	$t = 2.11$, $p = 0.9$	$t = 2.43$, $p = 0.687$
40 mA/ASIR (*n* = 7)	4.9 ± 1.13	5.67 ± 1.11	1.28 ± 0.28	1.48 ± 0.31
Test of significance with non-ASIR group	$t = 5.94$, $p = 0.001$*	$t = 4.18$, $p = 0.005$*	$t = 3.99$, $p = 0.0008$*	$t = 2.62$, $p = 0.016$*
60 mA/ASIR (*n* = 8)	6.37 ± 0.78	7.39 ± 0.53	1.56 ± 0.47	1.85 ± 0.28
Test of significance with non-ASIR group	$t = 3.02$, $p = 0.06$	$t = 0.155$, $p = 0.877$	$t = 1.88$, $p = 0.075$	$t = 0.276$, $p = 0.786$
80 mA/ASIR (*n* = 7)	6.79 ± 1.24	7.56 ± 0.74	1.42 ± 0.46	1.64 ± 0.08
Test of significance with non-ASIR group	$t = 1.45$, $p = 0.163$	$t = 0.329$, $p = 0.746$	$t = 2.62$, $p = 0.017$*	$t = 2.17$, $p = 0.08$
100 mA/ASIR (*n* = 5)	7.66 ± 0.88	8.88 ± 0.517	1.88 ± 0.24	2.17 ± 0.36
Test of significance with non-ASIR group:	$t = 0.51$, $p = 0.616$	$t = 3.67$, $p = 0.0019$*	$t = 0.06$, $p = 0.95$	$t = 1.53$, $p = 0.146$

*Statistically significant if $p < 0.05$
All parameters are described as mean ± standard deviation
ASIR adaptive statistical iterative reconstruction, *mA* milliampere, *SNR* signal-to-noise ratio, *CNR* contrast-to-noise ratio

Discussion

Due to the tremendous benefits of computed tomography (CT), it has been widely utilized globally in diagnostic imaging. Based on data provided by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), it is estimated that nearly half a million patients benefit from CT examinations everyday [21]. This widespread CT utilization raised the potential radiation risks particularly in children, such as cancer risk, over-exposures, or unjustified use of imaging [7, 22–31]. This issue directed recent CT researches and innovations to radiation dose reduction methods with preservation of resulting image quality [5, 8, 9].

Iterative reconstruction algorithm was introduced recently as a dose reduction strategy with preservation of image quality. The vendors tend to apply their own iterative reconstruction methods to achieve dose reduction without preservation of the image quality

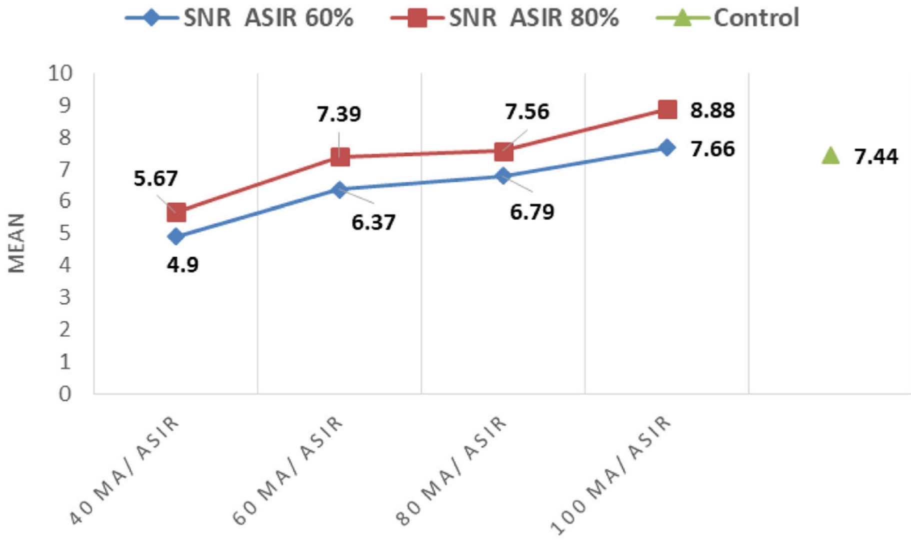

Fig. 3 The mean values of measured SNR in the CT images with the different used reduced mAs, with 60% ASIR-V (blue) and 80% ASIR-V reconstruction (red) of the ASIR group and non-ASIR standard dose (control) group CT images (green)

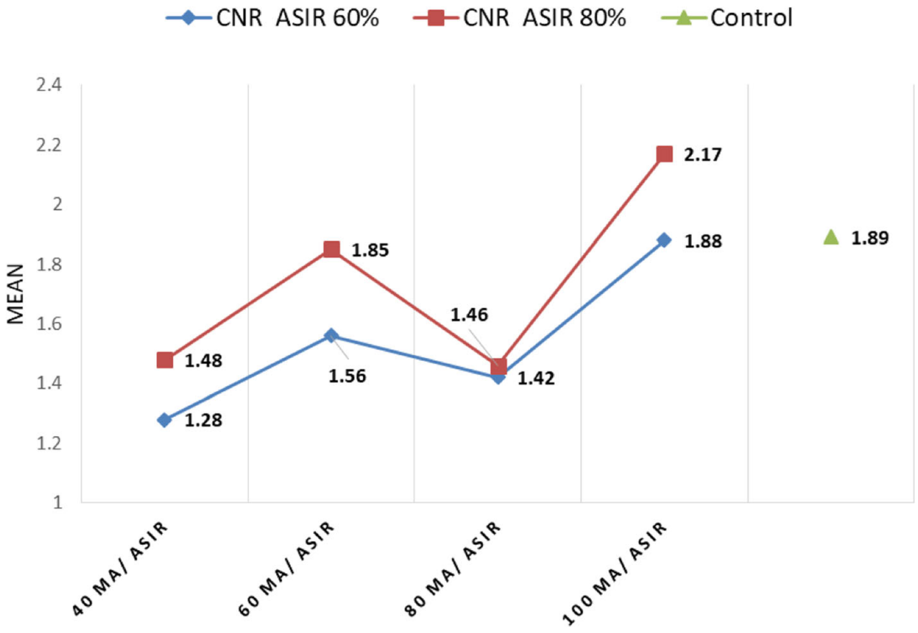

Fig. 4 The mean values of measured CNR in the CT images with the different used reduced mAs, with 60% ASIR-V (blue) and 80% ASIR-V reconstruction (red) of the ASIR group and non-ASIR standard dose (control) group CT images (green)

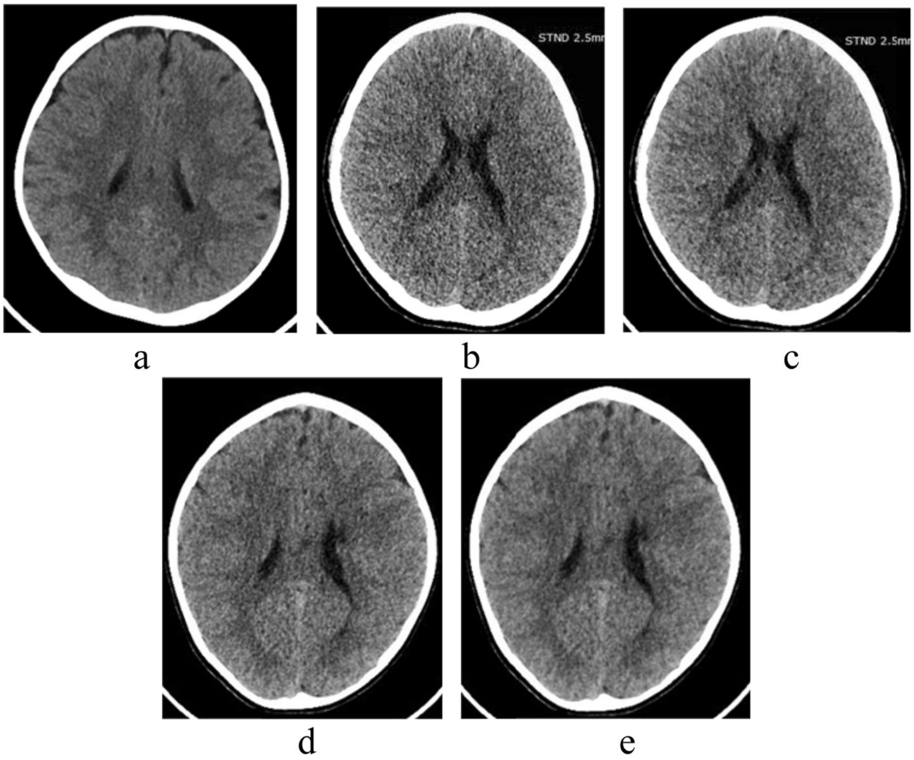

Fig. 5 Image quality of CT images at the level of corona radiata. Non-ASIR CT image (**a**), 60% ASIR-V (**b**), and 80% ASIR-V (**c**) CT images using 40-mA tube current reduced CT protocol, and 60% ASIR-V (**d**) and 80% ASIR-V (**e**) CT images using 60-mA tube current reduced CT protocol

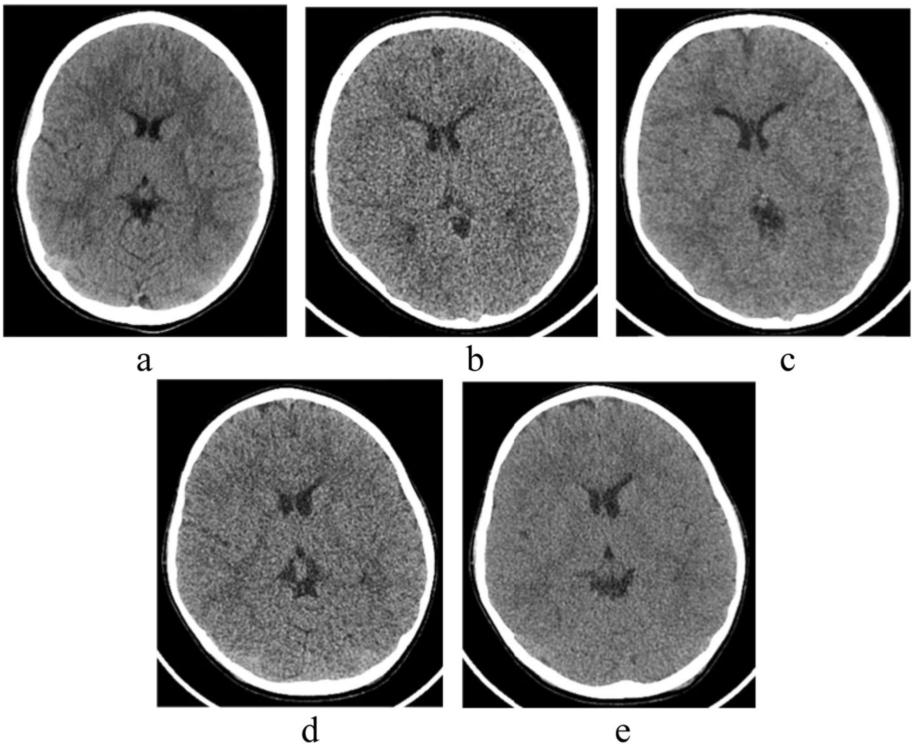

Fig. 6 Image quality of CT images at the level of thalamus. Non-ASIR CT image (**a**), 60% ASIR-V (**b**), and 80% ASIR-V (**c**) CT images using 80-mA tube current reduced CT protocol, and 60% ASIR-V (**d**) and 80% ASIR-V (**e**) CT images using 100-mA tube current reduced CT protocol

(GE: ASIR; Toshiba Medical Systems: Adaptive Iterative Dose Reduction; Siemens: Iterative Reconstruction in Image Space; and Philips Healthcare: iDose). With these methods, 30–80% dose reduction is expected [4, 8, 31]. ASIR, the algorithm used in this study, has developed in many types till the recently developed one, a hybrid ASIR-V with better resulting noise reduction performance even with lower dose CT protocols application [6, 8–10, 14, 19, 28].

This study investigated application of ASIR-V algorithm in pediatric head CT examination. Two groups were studied, the first one was the ASIR group with the standard CT radiation dose protocol and filtered back projection reconstruction and the other group was the ASIR group with reduced CT radiation dose protocol (multiple low mA CT acquisitions) with ASIR-V 60% and 80% reconstruction. The results were a tremendous reduction of the average CTDI vol, DLP, and the ED in the ASIR group, to 40.3% of the CTDI vol, 41.8 of the DLP, and 30% of the ED of the non-ASIR group. Similarly, many studies have shown that IR algorithms have the potential to reduce the radiation dose of cranial CT scans by 20–45% [1, 9, 29]. Similarly, in a study using 40% ASIR algorithm for head CT, the total DLP was decreased by 19% with better image quality [28]. Another study scanned pediatric phantoms using 40% ASIR-V with 10% reduction of mA in head CT examination protocol and declared nearly 30% reduction of CTDI vol [6]. A study was conducted using ultralow dose head CT examination for craniosynostosis with model-based ASIR reconstruction and proved the possibility for dose reduction to be comparable to that of plain skull radiography [5].

The quantitative assessment of the resulting CT images in the current study demonstrated comparable SNR and CNR of both ASIR and non-ASIR groups. It was noticed that the CT images with ASIR-V 80% reconstruction showed higher SNR and CNR than those reconstructed with ASIR-V 60% algorithm. This was in concordance with many studies that proved that increasing ASIR percentage led to decrease of image noise and increase of CNR [1, 5, 6, 30]. The SNR and CNR of the ASIR group with 40-mA CT examination were significantly lower than that of the non-ASIR group. This may be explained that significant reduction of the tube current could lead to consequent increase of image noise. However, in the ASIR group with 60- and 100-mA CT examinations, the CNRs were comparable with that of the non-ASIR group; this matched with many studies that stated that the contrast resolution of ASIR reconstructed CT head images showed comparable or better contrast resolution than that reconstructed with FBP [1, 6, 17].

Qualitative assessment revealed comparable results between both groups, keeping with the as low as reasonably achievable rule (ALARA). This result was similarly yielded by many studies conducted on ASIR algorithm despite that these studies examined ≤ 50% ASIR reconstruction [4–6, 14, 28, 31]. It was noticed in the current study that 80% ASIR-V reconstructed images of showed the best sharpness and overall diagnostic image quality. It was reported that the main aim of iterative reconstruction is the preservation of image quality with CT dose reduction or improvement of image quality with the use of the standard CT dose [6, 8].

With the analysis of this study resulting data, it was realized that the 60-mA CT acquisition with ASIR-V 80% reconstruction was the least possible tube current reduction CT protocol yielding a reasonable effective radiation dose reduction (75.6% dose reduction) with contrast resolution and image quality comparable to that of the standard dose non-ASIR CT examination.

The current study had many strengths, including more than 50% reduction of the CT x-ray tube current in the applied low dose CT acquisition protocol and the implementation of ASIR-V 60% and 80% for reconstruction which was to the best of our knowledge not applied before in ASIR reconstructed head CT studies. However, there were many drawbacks in this study, including the small number of the studied groups. A larger number of studied patients can lead to more significant results. Also, the investigation of the non-ASIR standard dose CT protocol and the ASIR reduced dose CT protocol in the same group of patients can yield more accurate results.

Conclusion

In conclusion, the implementation of ASIR-V algorithm proved to be a promising tool for lowering pediatric head CT radiation dose while maintaining diagnostically acceptable resulting images achieving the "ALARA" rule in pediatric patients, protecting this most vulnerable age group to radiation risks. Future studies on ASIR-V on larger pediatric age groups with more detailed assessment of image quality are needed for image quality adjustment using ASIR-V algorithm.

Abbreviations

ASIR: Adaptive statistical iterative reconstruction; ASIR-V: Adaptive statistical iterative reconstruction-V; CT: Computed tomography; ED: Effective dose; ALARA: As low as reasonably achievable; FBP: Filtered back projection; MBIR: Model-based iterative reconstruction; CTDI vol: CT dose index volume; DLP: Dose length product; ROI: Region of interest; SNR: Signal-to-noise ratio; CNR: Contrast-to-noise ratio; HU: Hounsfield units; SD: Standard deviation; GM: Gray matter; WM: White matter

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Not applicable.

Authors' contributions

FMS: Prepared CT cases, performed CT data analysis and statistical analysis, prepared figures and tables, and wrote and revised the manuscript. AMS: Data collection and CT dose and image quantitative analysis, reviewed literature, and shared in manuscript editing. YNE: Data collection and CT dose and image quantitative analysis, and reviewed the literature. SAE: Suggested and developed the research idea, reviewed literature, performed CT qualitative data analysis, and revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Institutional Research Board of Mansoura Faculty of Medicine at Mansoura University in Egypt; reference number of approval, R.20.06.862. Informed consent was waived because this was a retrospective study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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