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The Influence of Adaptive Statistical Iterative Reconstruction Algorithm on Image Quality and Volume CT Dose Index in Head CT Scan Compared To Filtered Back Projection

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ABSTRACT

Introduction: This study aimed to compare the image quality and volume dose index of head CT scan between two adaptive statistical iterative reconstructions (ASIR) and the filtered back projection (FBP) algorithms.

Material and Methods: CT number, noise and signal to noise ratio(SNR) for white matter(WM), gray matter(WM), cerebrospinal fluid(CSF) and skull bone were investigated in brain CT scans of 60 patients. All images were reconstructed by FBP and ASIR 40% algorithms. A water phantom was also used to compare the average CT number; noise, signal-to-noise (SNR), and contrast-to-noise ratio (CNR) between algorithms under different acquisition parameters. Volume computed tomography dose index ($CTDI_{vol}$) and (dose-length product) DLP were obtained from scanner software. Data were analyzed by T-test and Mann-Whitney statistical test with a significance level of less than 0.05.

Results: Image noise of gray matter, CSF and skull bone was significantly lower for ASIR algorithm ($P<0.05$). The difference in SNR for white matter and gray matter was not significant between the two algorithms but it was higher for CSF and bone for ASIR. In phantom study, Image noise, CTDIvol and DLP in both axial and spiral scan modes were higher for FBP algorithm ($P<0.05$). In addition, there was no significant difference in SNR and CNR between the two algorithms ($P>0.05$).

Conclusion: ASIR algorithm reduces the dose and image noise in head CT scan compared to the filtered back projection. In addition, using ASIR algorithm the image noise does not increase with lower mA.

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Introduction

CT scan is a cross-sectional x ray imaging modality which is most widely used in the diagnosis of various diseases [1, 2]. According to the report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), about half a million people undergo CT scan tests every day [3]. Brain CT scan is one of the most commonly CT requests[4, 5]. Despite its many advantages, CT scan burdens a high radiation dose to the patient[6]. According to studies conducted in this regards, a significant percentage of the cumulative dose from diagnostic imaging methods has been assigned to CT scan [7-11]. It is necessary to reduce the radiation dose but image quality should not be sacrificed. Different acquisition parameters including peak kilovoltage(kVp), milliamperes(mA), scan time, filtration, collimation, pitch factor, detector sensitivity and reconstruction algorithm influence on absorbed dose and image quality in CT scan[12, 13]. Reconstruction algorithm is one important factor which has a great impact on selecting acquisition parameters and image quality [14]. Different image reconstruction algorithms in CT scan are back projection, FBP, Fourier transform and iterative reconstruction (IR) [15]. FBP algorithm has been the standard algorithm for image reconstruction in CT for many years but streak artifacts and image noise increases if radiation dose is reduced exceedingly [14, 16, 17]. One of the proposed methods to reduce the dose while maintaining image quality is ASIR algorithm [17, 18]. This study was conducted to determine the effect of ASIR algorithm on image quality and CTDIvol in head CT scan and compare it with FBP.

Materials and Methods

In this study, the effect of ASIR and FBP algorithms on image quality and CTDIvol in head CT scan was investigated. A 16-slice GE optima CT540 CT scanner was used. CT number, noise and SNR of white matter, gray matter, CSF and skull bone were determined in CT

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images of 60 patients. Images were reconstructed with FBP and ASIR 40%. Before study, the code of ethics (IR.UMSHA.REC.1399.977) was adopted. For each patient, the brain scan was performed using a routine protocol. CT number and standard deviation (SD) of different tissues as noise were measured by drawing regions of interest (ROIs) with sizes ranging from 15 to 40 mm^2. SNR for each tissue considered as CT number divided by SD of the same tissue. CNR for white and gray matter was calculated by following equation [19]:

$$CNR = \frac{MEAN_{CTN1} - MEAN_{CTN2}}{\sqrt{SD1^2 + SD2^2}}$$

In this equation, $mean_{CTN1}$ and $mean_{CTN2}$ are the average CT numbers of the gray matter and white matter, respectively. SD1 and SD2 are the standard deviation of the CT numbers.

Table 1. Acquisition parameters for CT scan of the phantom for which the images are reconstructed with FBP and ASIR algorithm

Parameter	Algorithm	
	FBP	ASIR
kVp	120	120
mA	180	140
Rotation time(s)	0.8	0.8
Pitch factor*	1	1
Collimation(mm)	16×1.2	16×1.2

*Pitch factor is only defined in spiral mode.

In order to evaluate the effect of the algorithms under different acquisition parameters (different mA), a phantom of distilled water was scanned. Table 1 shows the acquisition parameters of the phantom CT scan for FBP and ASIR algorithms. All the parameters were the same for both algorithms excluding mA. It was 140 for FBP and 100 for ASIR algorithms.

The phantom was placed on the head holder and a topogram was taken. Using head acquisition parameters, scan performed in axial and spiral modes. Images were reconstructed by FBP and ASIR40% algorithms.

CT number and standard deviation (SD) of water were measured by drawing regions of interest (ROIs). The standard deviation was considered as noise. The SNR calculated by dividing the average CT number of water by its noise. CNR was obtained from the following equation:[20].

$$CNR = \frac{(CTNwaterphantom - CTNair)}{SDair}$$

CTDIvol and DLP for each algorithm were obtained from scanner software. The scanner had a valid quality control certificate. After determining the distribution of data by Kolmogorov Smirnov test, CT number, noise, SNR, CNR, CTDIvol and DLP compared statistically between two algorithms using T-test and Mann-Whitney statistical test with a significance level of less than 0.05.

Results

Figure 1 shows the CT images of a head (a) and water phantom (b). The CT number and noise of gray matter, white matter, CSF and bone have been determined by 4 ROIs on the head image (a). The CT number and noise of water and air were measured by 2 ROIs on phantom image (b).

CT number and SNR of white matter, gray matter, CSF and skull bone are shown in table 2. For all these tissues CT number is higher for FBP algorithm ($P<0.05$). Image noise of CSF, gray matter and skull bone for ASIR algorithm is less than FBP ($P<0.05$). SNR Difference for white matter and gray matter between two algorithms was not significant ($P>0.05$) but it was higher for CSF and bone with FBP algorithm ($P<0.05$). CNR of gray matter and white matter for FBP algorithm was lower than ASIR ($P<0.001$).

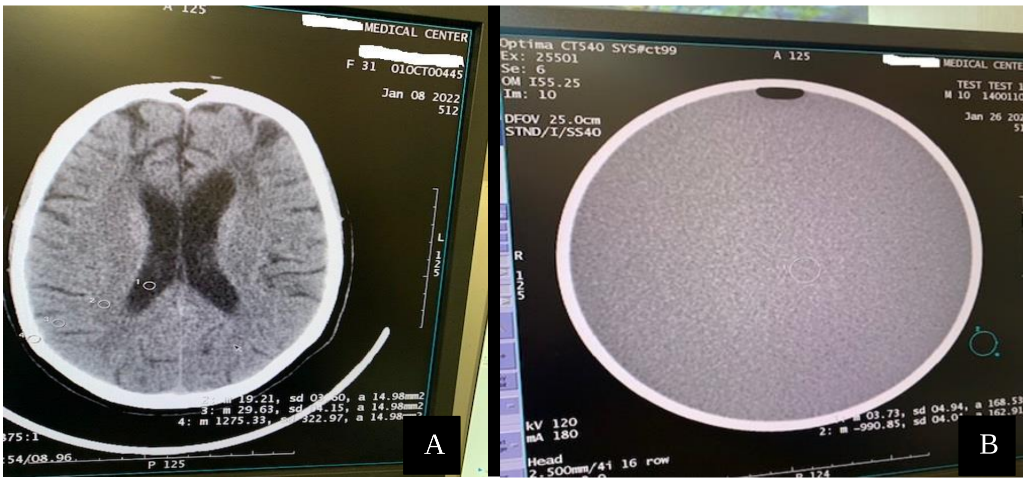

Figure 1. CT images of a head (a) and water phantom (b). The CT number and noise of gray matter, white matter, CSF and bone have been determined by 4 ROIs on the head image (a). The CT number and noise of water and air were measured by 2 ROIs on phantom image (b).

Table 2. CT number, noise, CNR and SNR of white matter, gray matter, CSF and skull bone for FBP and ASIR algorithms. CTDIvol and DLP are the same for two algorithms

parameter	Tissue	algorithm		P-value
		FBP	ASIR	
CT number(HU)	White matter	34.57±4.61	23.64±5.43	<0.001
	Gray matter	40.56±4.39	33.64±5.38	<0.001
	CSF	4.49±2.67	3.13±3.39	0.009
	Bone	1215.45±235.51	1066.28±229.71	0.016
noise	White matter	6.18±1.35	4±0.99	0.227
	Gray matter	4.97±1.19	3.92±0.87	0.024
	CSF	6.05±1.42	2.75±0.82	0.032
	Bone	175.9±68.87	157.67±101.97	0.003
SNR	White matter	5.87±1.61	6.18±1.84	0.383
	Gray matter	8.49±1.69	9.02±3.04	0.491
	CSF	2.02±1.15	1.17±1.44	0.001
	Bone	8.3±5.47	4.71±1.88	<0.001
CNR	Gray matter and White matter	0.75±0.53	1.81±0.79	<0.001
CTDIvol(mGy)		35.51±0.66		-
DLP(mGy.cm)		525.09±22.46		-

Table 3. CT number, noise, SNR and CNR in phantom scan in axial mode

Parameter	Algorithm		P-value
	FBP(Mean±SD)	ASIR(Mean±SD)	
CT number(HU)	6.14±0.79	4.23±0.57	0.031
noise	5.52±0.44	4.92±0.28	0.164
SNR	181.51±13.78	200.02±11.08	0.103
CNR	1.11±0.16	0.85±0.15	0.147
CTDIvol(mGy)	35.54±0.34	32.70±0.62	0.002
DLP(mGy.cm)	319.86±2.57	294.27±5.56	0.006

Table 4. CT number, noise, CNR, and SNR for the water phantom in spiral mode

Parameter	Algorithm		P-value
	FBP(Mean±SD)	ASIR(Mean±SD)	
CT number(HU)	3.8±0.48	-1.37±0.33	<0.001
noise	5.42±1.36	4.34±0.87	0.243
CNR	188.06±33.75	234.02±45.55	<0.001
SNR	0.72±0.19	0.41±0.12	0.001
CTDIvol(mGy)	36.09±0.94	32.26±0.30	0.008
DLP(mGy.cm)	324.84±8.5	299.37±2.67	0.008

CTDIvol and DLP were the same for two algorithms because each patient has been exposed one time hence acquisition parameters and dose indexes were the same for two algorithms. CT number, noise, SNR and CNR in phantom scan in axial mode are shown in Table 3. CT number of water with ASIR algorithm was lower than FBP ($P=0.031$). The different in noise, CNR and SNR between the two algorithms were not significant ($P<0.05$). CTDIvol and DLP with FBP algorithm were higher than ASIR ($P<0.05$).

Table 4 shows the CT number, noise, CNR, and SNR for the water phantom in spiral mode. In the spiral mode, the CT number, SNR, CTDIvol and DLP with ASIR algorithm were lower than FBP ($P<0.05$). The difference in image noise between the two algorithms was not significant ($P=0.243$). CNR with ASIR algorithm was higher than FBP ($P<0.001$).

Discussion

In this study, ASIR algorithm significantly reduced the average CT numbers of different brain tissues including white matter, gray matter, CSF and bone compared to FBP. In addition, Image noise of CSF, gray matter, and skull bone was less with ASIR algorithm. CNR of gray matter and white matter for FBP algorithm was lower than ASIR. In phantom study despite lower mA for ASIR, the different in noise, CNR and SNR between the two algorithms were not significant in axial scan mode but CTDIvol and DLP were higher with FBP algorithm. In the spiral mode, the noise is almost the same, CT number and SNR decreased but CNR increased. In CT scan various acquisition parameters including kVp, mA, scan time, collimation, pitch factor and reconstruction algorithm influence on absorbed dose and image quality [12, 21]. Identical acquisition parameters used in CT scan of the patients head causes

CTDIvol and DLP to be the same for two algorithms. ASIR is based on advanced statistical noise and object modeling which results in less noise in head CT and preserved the image quality in phantom scan compared to FBP [17]. The findings of this study are consistent with the results of researches conducted in this field. In a study by Guziński et al. ASIR algorithm improved image quality of the posterior fossa of the brain while decreasing DLP by 19%. SNR of white matter and gray matter in the cerebellum improved by 34 and 36%, respectively. also CNR of these tissues improved by 142% [19]. Sherif et al. reported the effective dose of 1.04 ± 0.1 mSV using the ASiR-V algorithm in head CT of children compared to 3.48 ± 0.45 mSv with FBP algorithm. No significant difference between SNR and CNR was observed between the two algorithms[22]. ASiR-V algorithm resulted in dose reduction of 12.8 to 34% as well as noise reduction from 10.73 to 9.22 compared to FBP algorithm in Hyun Gi Kim et al study. Also, CNR increased from 1.07 to 1.46 at the centrum semiovale level and from 1.33 to 2.18 at the basal ganglia level with ASIR-V [23]. In the study by Romangnoli et al., the effective dose of whole body CT scan was 15.6 ± 5 mSv for ASIR and 21.8 ± 5.3 mSv for FBP and the difference was significant. The image quality in all low-dose scans was good and their diagnostic value was equal or higher than the FBP algorithm [24]. In the study of David Kaul et al. applying ASiR40% in pulmonary CT angiography with kVp 120 and 100 caused reduction in effective doses by 33.8 and 54.4%, respectively [25]. The results of Ghadimi et al. study showed that the ASIR significantly reduces the effective dose and the overall risk of carcinogenesis in coronary CT angiography [26]. The strength of this study is that the influence of ASIR compared to FBP algorithm investigated using patients and phantom CT images. We investigated the influence of ASIR algorithm only in brain CT scan. It is suggested to evaluate the performance of ASIR vs. FBT in different CT protocols.

Conclusion

ASIR algorithm reduces the dose and image noise in head CT scan compared to the FBP. Also, using ASIR algorithm the image noise does not increase with lower mA but more studies are needed in this field.

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