Journal of Engineering and Applied Sciences 12 (24): 7431-7434, 2017
ISSN: 1816-949X

Imaging Radiation Dose Reduction with Adaptive Statistical Iterative Reconstruction in Brain CT

[1]Yoon-Jeong Kim, [1]Dan-Bi Lee, [1]Ino Yu, [2]Su-Chul Han, [1]Hong-Ryang Jung and [1]Cheong-Hwan Lim
[1]Department of Radiological Science, Hanseo University, Seosan, Korea
[2]Division of Medical Radiation Equipment, Korea Institute of Radiological and Medical Sciences, Seoul, Korea

Abstract: We compared and analyzed patient doses depending on the application of FBP (Filtered Back Projection) and ASIR (Adaptive Statistical Iterative Reconstruction Algorithm). A64-MDCT Optima ™ CT 660 system was used for imaging. For quantitative analysis, images containing both sides of orbit and basal ganglia were obtained. After setting a 40~45 mm^2 area as Region of Interest (ROI), the average CT number was measured. A Statistical Program, SPSS 22.0 was used for the calculations and ANOVA, Kruskal-Wallis and paired t-tests were performed after the normality and equivalence tests. For quantitative analysis, a comparison of SNR of each scan type was carried out. From the Kruskal-Wallis test, the SNR of axial scan was 0.13±0.67 and the SNR of Helical scan was 0.12±0.64. There was a significant difference for the axial scan values (χ^2 = 12.54, p<0.05) but there was no corresponding significant difference for those from the Helical scan (χ^2 = 0.49, p>0.05). When ASIR was applied in the axial scan, the value of $CTDI_{vol}$ decreased by 21.46 mGy (47.8%) at maximum. The value of DLP decreased by 343.42 mGy·cm (47.8%) at maximum. When ASIR was applied in the Helical scan, the value of $CTDI_{vol}$ decreased by 18.52 mGy (49.9%) at maximum and the value of DLP decreased by 328.92 mGy·cm (49.9%) at maximum. This study could confirm a dose reduction through applying FBP and ASIR algorithm for each scan type in brain CT imaging.

Key words: FBP (Filtered Back Projection), ASIR (Adaptive Statistical Iterative Reconstruction Algorithm), dose reduction, patient, quantitative, equivalence

INTRODUCTION

With the current advances in medical technology and further near-term advances, the average life span may indeed reach 100 years. As people have a greater interest in health management for a better quality of life, the number of patients visiting the hospitals and clinics for primary or follow-up care has been increasing. With these increased visits, the number of CT tests being performed is also increasing and this includes brain CT tests. With increased CT use per patient, the exposure dose that a patient receives is also increasing. It is known that exposure dose from a CT test is more than that from a general X-ray test. In addition to obtain a better image in a CT test, there has been a trend of exposure doses becoming higher. All those factors have led to an average patient receiving higher doses of radiation from CT scans. To decrease exposure during medical procedures, various methods are now being devised. Of these, examples include using a noise reduction filter or utilizing BMI (Body Mass Index) measures to adjust exposure dosage. Recently as ASIR (Adaptive Statistical Iterative Reconstruction Algorithm), a method to reduce exposure dose while minimizing the degradation of imagewas introduced (Hyunchul, 2010). For the study on exposure dose reduction in a brain CT scan, this study compared and analyzed exposure dose depending on the application of FBP (Filtered Back Projection) and ASIR (Adaptive Statistical Iterative Reconstruction Algorithm) according to scan type.

MATERIALS AND METHODS

The equipment involved the 64-MDCT Optima™ CT660 (GE Healthcare, Chicago, IL, USA) used in scanning for this study and the test conditions were as follows (Table 1). As for the object of a scan, it was used the head phantom that (Cardinal Health, Dublin, OH, USA) made up of body tissue material (Fig. 1a). With SOML (Supra Orbito Meatal Line) of the head phantom as an origin and after fixing it vertically to the brain fixation device on the table, the scan range was set from skull base to vertex by scanning scout image (120 kV, 10 mA) for the criteria (Fig. 1b). The FBP and ASIR algorithm were

Corresponding Author: Cheong-Hwan Lim, Department of Radiological Science, Hanseo University, Seosan, Korea

Table 1: Exposure conditions of this study

Material/Scan types	Head phantom Axial	Helical
Thickness (mm)	5/20	5/5
kVp	120	120
mA	115	200
Rotation time	2	1
Pitch	-	0.969:1
Algorithm	FBP/ASIR	FBP/ASIR

Unit; Optima^{TM} CT 660 (64-MDCT); Detector; Coverage (20 mm); DFOV (240 mm)

(a) (b)

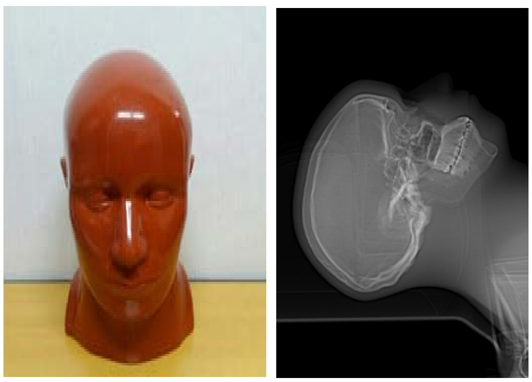

Fig. 1: a) Head phantom and b) Scout image of head phantom in CT

applied for image acquisition for each scan type. In case of ASIR, the scan was carried out by applying a 10~50% of change. After image acquisition to reduce errors, data was acquired by 5 times of iterative measurements.

For quantitative analysis, the image containing both sides of orbit and basal ganglia was used. By setting the range of 40~45 mm^2 area as Region of Interest (ROI), the average of CT number was measured. Noise was defined as Standard Deviation (SD) of CT number ROI and with this, the Signal to Noise (SNR) parameter was calculated. For the measurement of exposure dose, DLP and $CTDI_{vol}$ values provided in the equipment were used. $CTDI_{vol}$ is CTDI at the axle of scanning and the formula to obtain the value in consideration of exposure fluctuation at the Z axil is as follows (Ko and Kang, 2010):

$$CTDI_{vol} = CTDI_W \times NT/I \quad (1)$$

$$DLP = CTDI_{vol} \times length\ (cm) \quad (2)$$

Where:

I = The distance of table movement per each rotation of spiral CT

NT = The total thickness of beam during the acquisition of image

$$CTDI_W = 1/3\ CTDI_{(center)} + 2/3\ CTDI_{(surface)} \quad (3)$$

All data was recorded as average±standard deviation and for statistical analysis in each position, CT number (HU), Noise (SD) and SNR (Signal-to-Noise Ratio) values were obtained and evaluated. As a statistical program, SPSS 22.0 (SPSS Inc., Chicago, IL, USA) was used and ANOVA test, Kruskal-Wallis test and paired t-test were used after normality test and equivalence test. Confidence level (CI) used was 95% and for level of significance, $p<0.05$.

RESULTS AND DISCUSSION

In the evaluation of noise, the average value of noise in orbit and basal ganglia, the region of interest were measured as 4.68±0.54 at FBP, 3.90±0.83 at 10%, 3.91±0.34 at 20%, 3.89±0.62 at 30%, 3.65±0.43 at 40% and 4.14±0.72 at 50% for the axial scan. Correspondingly, the average value of noise was measured as 5.30±0.63 at FBP, 4.32±0.57 at 10%, 4.45±0.58 at 20%, 4.26±0.90 at 30%, 4.05±0.55 at 40% and 4.30±0.64 at 50% f or the Helical scan. As a result of analyzing FBP and each % of ASIR for the axial and Helical scans, the significance probabilities were below 0.001 ($p<0.05$), making the difference values significant. It was confirmed that image noise was significantly low when ASIR was applied rather than FBP (Table 2).

For quantitative analysis, comparison evaluation for SNR of each scan type was carried out. From the Kruskal-Wallis test, SNR of axial scan was 0.13±0.67 and SNR of Helical scan was 0.12±0.64. There was a significant difference in axial scan ($\chi^2 = 12.54$, $p<0.05$) but there was no significant difference in Helical scan ($\chi^2 = 0.49$, $p>0.05$) for this measurement (Table 3).

In axial scan as a result of dose evaluation, the $CTDI_{vol}$ value was measured as 41.14±0.02 mGy at FBP, 37.56±0.03 mGy at 10%, 32.22±0.04 mGy at 20%, 28.62±0.02 mGy at 30%, 25.04±0.03 mGy at 40% and 19.68±0.02 mGy at 50% for and the DLP value was measured as 658.23±0.36 mGy·cm at FBP, 601±0.48 mGy·cm at 10%, 515.14±0.55 mGy·cm at 20%, 457.9±0.40 mGy·cm at 30%, 400.66±0.60 mGy·cm at 40% and 314.81±0.38 mGy·cm at 50%. In the Helical scan, $CTDI_{vol}$ value was measured as 36.99±0.02 mGy at FBP, 33.27±0.02 mGy at 10%, 29.57±0.03 mGy at 20, 25.86±0.02 mGy at 30, 22.17±0.02 mGy at 40% and 18.47±0.01 mGy at 50% for and the DLP value was measured as 657.02±0.36 mGy·cm at FBP, 590.93±0.18 mGy·cm at 10, 525.18±0.56 mGy·cm at 20, 459.42±0.42 mGy·cm at 30, 393.85±0.36 mGy·cm at 40% and 328.1±0.33 mGy·cm at 50% (Fig. 2).

Table 2: Quantitative analysis of noise

Variables	Scan types Axial (Average±SD)	Helical (Average±SD)
FBP (0%)	4.68±0.54	5.30±0.63
ASIR (10%)	3.90±0.83	4.32±0.57
ASIR (20%)	3.91±0.34	4.45±0.58
ASIR (30%)	3.89±0.62	4.26±0.90
ASIR (40%)	3.65±0.43	4.05±0.55
ASIR (50%)	4.14±0.72	4.30±0.64
p-value	0.001(<0.05)	0.001(<0.05)

Table 3: Quantitative analysis of SNR

Scan types	Average±SD	χ^2	p-values
Axial	0.13±0.67	12.54	0.028
Helical	0.12±0.64	0.49	0.992

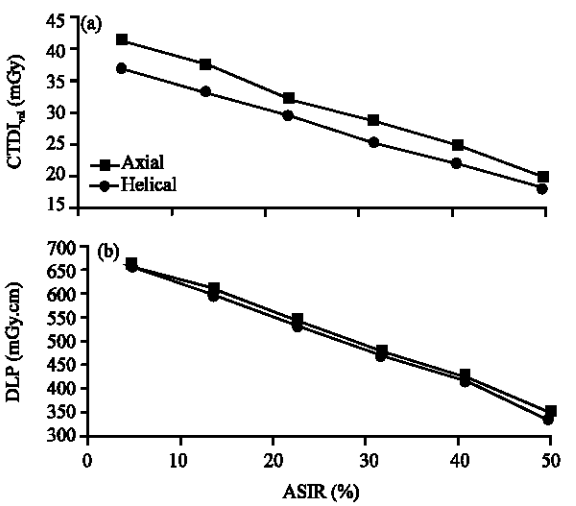

Fig. 2: Comparison of dose between axial and Helical scan, according to ASIR (%) and 0% means FBP application: a) CTDI and b) DLP

When ASIR was applied in the axial scan, the value of $CTDI_{vol}$ decreased by 21.46 mGy (47.8%) at maximum and the value of DLP decreased by 343.42 mGy·cm (47.8%) at maximum. When ASIR was applied in the Helical scan, the value of $CTDI_{vol}$ decreased by 18.52 mGy (49.9%) at maximum and the value of DLP decreased by 328.92 mGy·cm (49.9%) at maximum.

ASIR algorithm is not an existing method of algorithm application but a method to iteratively reconstruct image statistically. Its application allowed a dose decrease while enabling generating images of diagnostic value (Hyunchul, 2010). Recently as the range and importance of the clinical application of MDCT in brain-nervous system diagnosis have increased, the interest in exposure dosesin the test has also increased and various researches to reduce radiation exposure are being reported.

Vorona *et al*. (2013) reported a decrease in average CTDI by 22.1% and DLP by 23.9% through applying 20% of ASIR in brain CT imaging for 20 pediatric patients. As a result, Kilic *et al*. (2011) measured the dose of 149 adult patients in a brain CT test and it was reported that CTDI of cerebrum and occipital fossa decreased by 31% and by 35%, respectively and DLP decreased by 31% while the quality of image did not change significantly. On the other hand, this study and that of Hyunju (2015) carried out exposure dose reduction by ASIR for head phantom instead of actual patients. In case by Hyunju (2015) study dose was measured by differentiating the level of ASIR for axial and Helical scan. As a result, it could be confirmed that CTDI decreased by 47.8 and by 49.9% at maximum and DLP decreased by 47.8 and 49.9%, respectively, at maximum. Even in this study as the doses were measured by differentiating the levels of the ASIR for the phantom, there was significance in results, since, CTDI and DLP, a measure of radiation, decreased by 47.8 and by 49.9% at maximum in the axial scan and CTDI and DLP in Helical scan decreased by 49.9 and 49.9% at maximum, respectively.

Besides a brain CT test in a cardiovascular system CT imaging test (Flicek *et al*., 2010) decreased the doses by 50% as a result of reconstructing the images through applying 40% of ASIR for patients and were able to reconstruct the images without a significant change in the quality of image. Also, Brady *et al*. (2014) reported that in a chest and abdominopelvic cavity CT by applying 40% of ASIR, they decreased the doses by 72 and 64%, respectively, at maximum. From the research by Hyunchul (2010) when they applied 50% of ASIR for phantoms in brain CT images, the noise levels of the central and peripheral parts decreased by 46.9, 48.2, 43.2 and 47.9%, respectively as these changes were also statistically significant.

CONCLUSION

In the image noise analysis of this study as the noise of the images decreased statistically by 22 and 23%, respectively in the axial and Helical scans by applying ASIR, it was a desirable outcome. However, in case of the axial scan, since, significant differences were shown at the 50% points, it could be confirmed that when applying ASIR beyond a certain level, it can be undesirable. In cardiovascular system contrast CT imaging study as a result of applying ASIR with different levels such as 0, 20, 40, 60, 80 and 100%, Leipsic *et al*. (2010) reported that, only images applied with 40 and 60% of ASIR showed significant enhancement diagnostically. Also in a chest CT imaging study as a result of applying 70% of ASIR to 23 patients, Singh *et al*. (2011) reported that, the diagnostic data could notbe obtained due to the degraded quality of the images. It is possible to apply ASIR from 10-100% levels and if too much ASIR is applied, the noise becomes too small and the imagesstart to look artificial and begin to lose diagnostic value. On whether the applied ASIR can be increased to 100% is appropriate for diagnosis or notit has not actually yet been established. Actual users prefer a 30 or 40% level for ASIR which reduces the noise while providing the same diagnosis data when compared to the image not altered (Silva *et al*., 2010).

LIMITATIONS

The limitation of this study is that the experiments were performed only with a phantom head and as such clinical results could not be obtained and a small amount of data was obtained from each experiment. In addition, since, the evaluation of image was only composed of quantitative evaluations such as dose, SNR and noise, etc., it is not known whether the images were valuable for diagnosis.

RECOMMENDATIONS

In the future if a studyisperformed with actual patients, the data yield will be greater. As this study could confirm dose reduction through applying FBP and ASIR algorithm for each scan type in brain CT, it is judged that excessive application of ASIR can result in image artifacts and selecting an appropriate level of ASIR is important.

REFERENCES

Brady, S.L., B.M. Moore, B.S. Yee and R.A. Kaufman, 2014. Pediatric CT: Implementation of ASIR for substantial radiation dose reduction while maintaining pre-ASIR image noise. Radiol., 270: 223-231.

Flicek, K.T., A.K. Hara, A.C. Silva, Q. Wu, M.B. Peter and C.D. Johnson, 2010. Reducing the radiation dose for CT colonography using adaptive statistical iterative reconstruction: A pilot study. Am. J. Roentgenol., 195: 126-131.

Hyunchul, J., 2010. Usefulness of Adaptive Statistical Iterative Reconstruction Method in Cardiovascular CT Test. Sooncheonghyang University, Asan, South Korea.

Hyunju, K., 2015. A study on the appropriate radiation dose criteria according to BMI index in CT test for the assessment of abdominal body fat. Master Thesis, Soonchunhyang University, Asan, South Korea.

Kilic, K., G. Erbas, M. Guryildirim, M. Arac and E. Ilgit *et al*., 2011. Lowering the dose in head CT using adaptive statistical iterative reconstruction. Am. J. Neuroradiology, 32: 1578-1582.

Ko, S.J. and S.S. Kang, 2010. Optimization of exposure parameters in brain computed tomography. J. Radiol. Sci. Technol., 33: 355-362.

Leipsic, J., T.M. LaBounty, B. Heilbron, J.K. Min and G.B.J. Mancini *et al*., 2010. Adaptive statistical iterative reconstruction: Assessment of image noise and image quality in coronary CT angiography. Am. J. Roentgenol., 195: 649-654.

Silva, A.C., H.J. Lawder, A. Hara, J. Kujak and W. Pavlicek, 2010. Innovations in CT dose reduction strategy: Application of the adaptive statistical iterative reconstruction algorithm. Am. J. Roentgenol., 194: 191-199.

Singh, S., M.K. Kalra, M.D. Gilman, J. Hsieh and H.H. Pien *et al*., 2011. Adaptive statistical iterative reconstruction technique for radiation dose reduction in chest CT: A pilot study. Radiol., 259: 565-573.

Vorona, G.A., G. Zuccoli, T. Sutcavage, B.L. Clayton and R.C. Ceschin *et al*., 2013. The use of adaptive statistical iterative reconstruction in pediatric head CT: A feasibility study. Am. J. Neuroradiology, 34: 205-211.