Indian Journal of Science and Technology, *Vol 9(48), DOI: 10.17485/ijst/2016/v9i48/108735, December 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Radiation Dose Reduction in MDCT through Tube Current Optimization of Pre-Contrast Media on CT Brain Angiography Subtraction Technique

Ki-Seon Lim[1] and Youl-Hun Seoung[2*]

[1]Department of Radiology Chung Buk National University Hospital ,Cheongju, 361-240, South Korea;
lks7491@naver.com
[2]Department of Radiological Sicence Cheongju University, Cheongju, 360-764, South Korea;
radimage@cju.ac.kr

Abstract

Background/Objectives: The purpose of this study was to reduce of radiation dose through optimizing the tube current exposed pre-contrast media in multi-detector computed tomography (MDCT) brain angiography subtraction technique (BAST). **Methods/Statistical Analysis**: The tube voltage were fixed and the tube current was set to 100 vs 70 mAs, 100 vs 50 mAs and 100 vs 30 mAs for the two respective inspections performed pre-contrast media. The average diameters of the posterior cerebral artery, the anterior cerebral artery and the basilar artery were measured to verify the statistical difference on 30 patients. In addition, the radiation dose in the tube current is measured. **Findings**: When the tube current was set adjusted from 100 mAs to 30 mAs, the average diameters of the left/right posterior cerebral artery, the left/right anterior cerebral artery and the basilar artery indicated no significant difference. And the result of measured weighted CTDI values are 8.9 mGy in 100 mAs, 6.24 mGy in 70 mAs, 4.71 mGy in 50 mAs, 2.63 mGy in 30 mAs and could be reduced up to 70.5%. This study is limited in that it was conducted based on a small experimental group to minimize the number of people being exposed to radiation. However, as a result of continuously applying the experiment results to the current clinical environment, there has been no request for a re-inspection due to the low radiation dose. **Improvements/Applications**: The use of subtraction technique is expected to decrease the exposure dose while operating CT brain angiography on patients and actualize the safe CT brain angiography.

Keywords: Bain Angiography, MDCT(Multi Detector Computed Tomography), Radiation Dose Reduction, Subtraction Technique, Tube Current Optimization

1. Introduction

Since the introduction to the field of medical imaging in 1972, Computed Tomography (CT) has been rapidly making progress in its technical and clinical performances. Currently, the spiral CT and as well as the latest scanner with less-than-a-second-time-frame and multi-slicing function in particular has been settling as an important tool required in the modern medicine for diagnosing various diseases and lesions based on its prompt image-acquiring speed. In particular, because of the strength that the motion-based artifacts can be decreased through acquiring images of brain blood vessel within a short period of time, CT is one of the most commonly selected methods for inspecting brain blood vessel. Such brain blood vessel is an essential structure of the human body required for maintaining life, and it is surrounded by very complicated and dense structures[1, 2]. However, since such CT-based brain blood vessel inspection is incapable of diagnosing Internal Carotid Artery (ICA) which passes through cavernous portion and petrous portion, there are diagnostic limitations in comparison to Magnetic Resonance Angiography(MRA) and Conventional Cerebral Vascular Angiography (CCVA)[3, 4].

The digital subtraction technique is used to resolve such problem. However, in order to use such technique,

---

**Author for correspondence*

the involved patient must be exposed once prior to injecting the contract media to the involved brain section and once more after injecting the contract media to the identical brain section. This serves as the weakness since the exposure dose received by the patient is quite considerable in comparison to other general CT-based brain inspections. In addition, due to the development of CT equipment, the scope of CT inspection has been expanded and the inspection method has been diversified as well. As for the brain perfusion CT used for evaluating the blood flow, US FDA (Food and Drug Administration) reported an occurrence of band-like alopecia in 2009 and warned that the radiographic exposure up to 8 times stronger than the normal radiographic exposure is the cause[5]. Accordingly, the European Union has been particularly applying various guidelines and regulations to CT. In addition, EURATOM CEC has classified CT along with interventional radiology as the high-dose radiation procedures[6, 7]. In addition, approximately 1.5~2.0% of the cancers occurring in US are caused by the CT-based radiographic exposure. Accordingly, the risk of such CT-based radiographic exposure has been attracting the interest and therefore it is necessary to come up with techniques for reducing such radiographic exposure resulting from diverse CT inspection methods [8, 9].

The purpose of this study was to evaluate usefulness of 3-dimensional (3D) brain angiography acquired through reducing the exposure dose of radiation pre-contrast media in CT brain angiography subtraction technique.

2. Materials and Methods

2.1 Subjects and Materials

Among patients who visited and received CT brain angiography at C University Hospital located in Cheongju of Choongbuk, Korea from June 2015 to March 2016, the images of the 30 brain-disease-free patients (14 males, average age: 55.8, 16 females, average age: 56.7) who agreed to participate in this research were selected as the subjects.

As shown in Figure 1, the 64 multi-detector CT (Brilliance 64, ver. 2.6.2, Philips, Netherlands) was selected as the CT equipment for this inspection.

Iomeron 400 (lomeprol 816.50mg/ml, Bracco Imaging, Korea) was selected as the contrast media. 3D software (Aquarious, ver. 4.4.11, Terarecon, USA) was used to analyze the subject images.

Figure 1. 64 channel Multi Detector CT.

As shown in Figure 2, the pencil-shaped equipment used for measuring the dose is CT-exclusive ionization chamber (Model 500-200, Fluke Biomedical, Cleveland, OH, USA) with its sensitivity set to 10 R.cm/nC, its internal chamber diameter set to 6.4 mm, its chamber wall thickness set to 54 mg/cm^2 and its valid measuring length set to 10 cm. In addition, the electrometer (Model 06-526, Fluke Biomedical, Cleveland, OH, USA) was used for displaying the energy ionized from the ionization chamber in the exposure dose. The US FDA-approved standard head phantom (Model 76-414, Fluke Biomedical, Cleveland, OH, USA) was used as the phantom for measuring the dose. This phantom is made of acrylic materials and contains holes with a diameter of 1.27±0.04 cm (east, west, south and north) in the center section and 4 surrounding sections (east, west, south and north) for inserting the ionization chamber.

2.2 CT Scanning

As for the conditions for operating CT brain angiography, the tube voltage was fixed to 120 kVp prior to injecting the contrast media. The tube current was set to 100 mAs and 70 mAs respectively to conduct two respective inspections for Group A, 100 mAs and 50 mAs respectively to conduct two respective inspections for Group B, and 100 mAs and 30 mAs respectively to conduct two respective inspections for Group C. The scanning was conducted based on such group classification. At this point, the section thickness was set to 0.9mm, the pitch was set to 0.671, the field of view (FOV) was set to 220 mm, and the reconstruction algorithm was set to brain standard algorithm identically for all groups.

Figure 2. An equipment for measuring CT dose and ionization chamber.

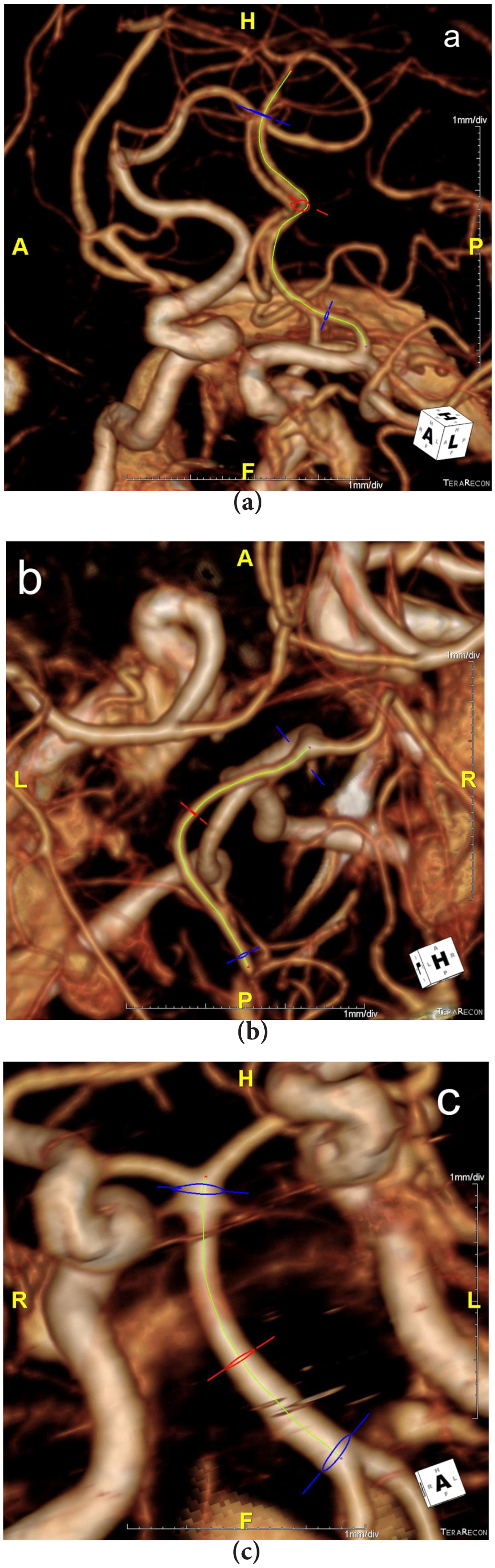
The bolus tracking method was used to inject the contrast media, and the region of intrest (ROI) was set to the carotid artery, and the CT scanning was initiated from the carotid artery bifurcation 3 seconds after the trigger threshold reached 150 HU. At this point, the contrast media injection speed was 4.0 mm/sec.

2.3 Analysis of Vascular Anatomy in CT images

As for the analysis of the acquired images, the left and right posterior cerebral artery (PCA), the left and right anterior cerebral artery (ACA) and the basilar artery (BA) were analyzed. In addition, the precedent thesis dealing with the frequency analysis related to the occurrence of cerebrovascular diseases was used as a reference for setting the standards for selecting blood vessels to be analyzed[3].

As shown in Figure 3, the 3D blood vessel-analyzing software (Aquarius, ver. 4.4.11, Terrarecon, USA) was used to automatically measure the diameter of blood vessels to prevent subjective errors. The subject blood vessels for analysis were selected from the 3D volume rendering data and the left/right sections of such subject blood vessels were identically synchronized and analyzed.

In addition, as shown in Figure 4, the diameter of blood vessels was displayed not only in 3D images, but also in multiplanar reconstruction (MPR) images and section images.



(a)

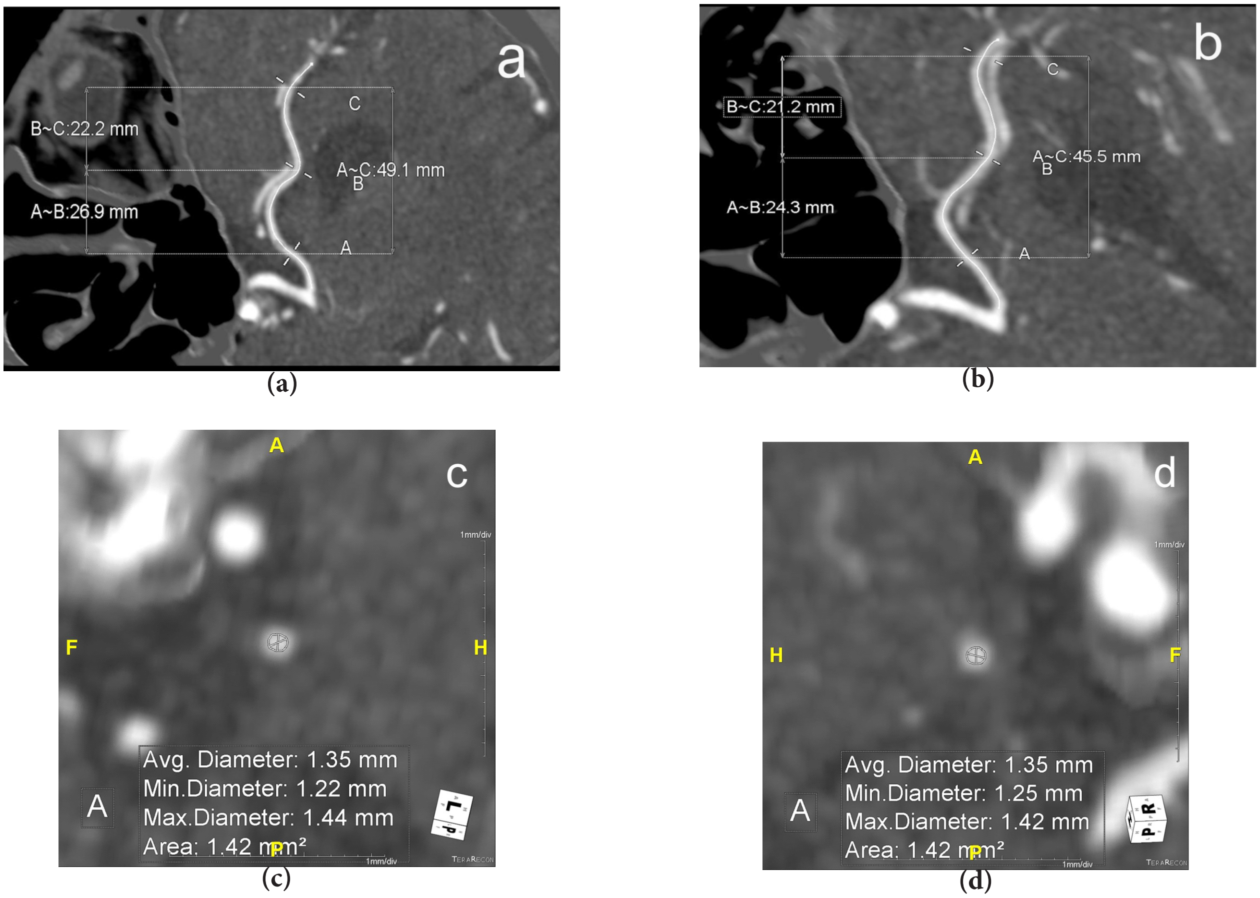
(b)

(c)

Figure 3. The measured on the average diameter of vascular anatomy in brain by CT 3D, **(a)** ACA **(b)** PCA **(c)** BA.

2.4 Evaluation of CT Radiation Dose

As for the evaluation of the exposure dose to the patient, the CT-exclusive ionization chamber was used to measure the radiation dose according to the tube current reduction. To evaluate the dose, the head phantom was placed on the center of the equipment table and positioned on the center of the gantry. Then the ionization



(a) (b) (c) (d)

Figure 4. Lt. and Rt. PCA curved MPR image(a,b) and cross sectional image(c,d).

chamber was respectively inserted into the center section and 4 surrounding sections of the phantom for two respective measurements, and the average value of the radiation dose was converted into the weighted computed tomography dose index (CTDIw, mGy) through equation (1).

$$CTDI(mGy) = 10 \times CTDI(cGy) = \frac{f(cGy / R \times C \times M(R \cdot cm)}{N \times T(cm)} \quad (1)$$

f : Exposure to dose conversion factor in acryl (= 0.78)
C : Chamber calibration factor (=1)
M : Exposure value in monitor (R) Chamber length factor (10 cm)
N : No. of slice
T : Slice thickness (cm)

At this point, as shown in Figure 5, the holes without the inserted ionization chamber were filled with the filling made of identical acrylic materials to prevent attenuation, and the ionization chamber was alternately inserted into the center section and 4 surrounding sections to acquire images.

As for the inspection conditions, the FOV was set to 250 mm, the incidence angle was set perpendicular to the phantom, and the axial mode was used to conduct a full single 360 rotation. The detector combination was set to 4 5 mm so the length of z-axis can be set to 20 mm, and the tube voltage and current were changed to match those values used for inspecting the patient to measure CTDIw.

2.5 Statistical Analysis

The resulted data were applied to SPSS software (SPSS 15.0 for Windows, SPSS, Chicago, IL USA) to conduct the statistical analysis. The paired t-test was conducted to compare the significant difference among the blood vessel diameters according to the changes in the tube current. At this point, the difference was considered significant when the significance percentage (*p*-value) was smaller than 0.05.

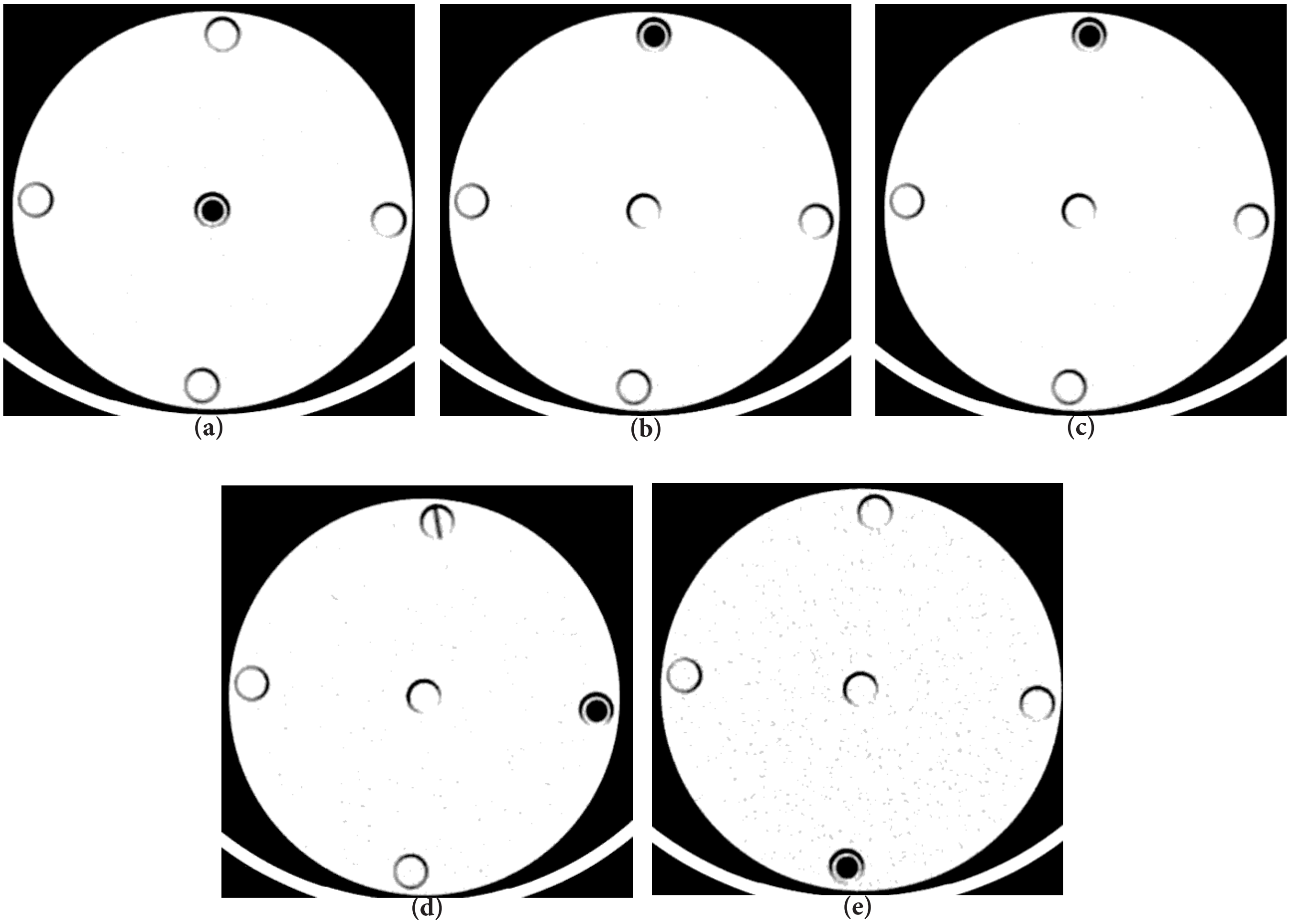


Figure 5. Ion chamber image of central and four-ways portion.

3. Results

3.1 Analysis Results of the Average Diameter on Vascular Anatomy

As show table 1, there were no significant differences for the average diameter of vascular anatomy in brain. The *p*-value of diameter in left PCA was 0.265 (range, 100mAs to 70mAs), 0.466 (range, 100mAs to 50mAs), 0.460 (range, 100mAs to 30mAs). The *p*-value of diameter in right PCA was 0.376 (range, 100mAs to 70mAs), 0.561 (range, 100mAs to 50mAs), 0.313 (range, 100mAs to 30mAs). The *p*-value of diameter in left ACA was 0.163 (range, 100mAs to 70mAs), 0.132 (range, 100mAs to 50mAs), 0.773 (range, 100mAs to 30mAs). The *p*-value of diameter in right ACA was 0.151 (range, 100mAs to 70mAs), 0.814 (range, 100mAs to 50mAs), 0.766 (range, 100mAs to 30mAs). The *p*-value of diameter in BA was 0.423 (range, 100mAs to 70mAs), 0.234 (range, 100mAs to 50mAs), 0.320 (range, 100mAs to 30mAs).

3.2 The Result of Evaluating Images

As shown in Figure 6, the result of measured weighted CTDI values are 8.9mGy in 100mAs, 6.24mGy in 70mAs, 4.71mGy in 50mAs, 2.63mGy in 30mAs and could be reduced up to 70.5%.

4. Discussion

The development of CT equipment has expanded the scope of CT inspection and the number of CT inspections has been indicating an increase. As reported in the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the use of CT for managing daily patients has been increasing the burden of radia-

Table 1. The result showed the p-value on the average diameter of vascular anatomy in brain according to changes on tube current

mAs	PCA-LT (mm)	PCA-RT (mm)	ACA-LT (mm)	ACA-RT (mm)	BA (mm)
100	22.0±0.96	24.0±0.90	20.9±0.42	21.6±0.82	35.8±0.88
70	22.7±0.93	22.0±0.88	19.3±0.28	19.6±0.50	36.5±0.83
p-value	0.265	0.376	0.163	0.151	0.423
100	19.7±0.51	17.0±0.30	18.7±0.40	16.1±0.30	29.3±0.73
50	18.3±0.41	17.3±0.35	19.5±0.40	15.9±0.31	28.8±0.74
p-value	0.466	0.561	0.132	0.814	0.234
100	20.4±0.71	17.9±0.35	20.0±0.34	19.3±0.49	30.2±0.69
30	19.4±0.46	17.5±0.28	20.0±0.32	19.2±0.48	29.4±0.76
p-value	0.460	0.313	0.773	0.766	0.320

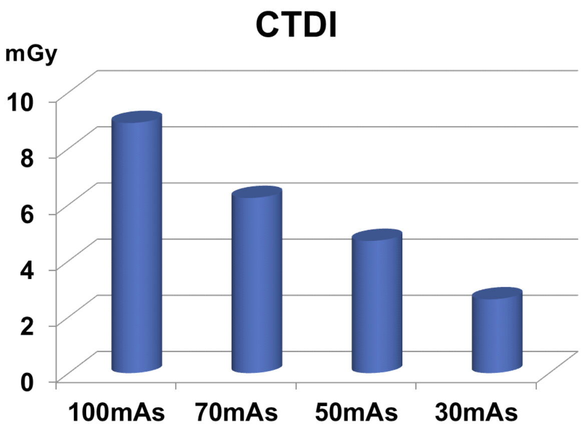


Figure 6. The result showed the weighted CTDI according to changes on tube current.

tion resulting from CT. Considering that CT inspection is widely used and that just a few CT inspections may result in approximately 50~150mSv of radiation and that such CT inspection is frequently and repeatedly operated on one patient, the risk is considerably significant. Despite such risk, CT equipment has been making progress by enhancing its ability to detect diseases through developing diverse inspection methods. However, such inspection methods are not followed by specific radiation subtraction techniques[10]. The CT brain angiography subtraction technique is a very useful technique for evaluating intracranial aneurysms, but its weakness is that the brain has to be scanned twice[11]. To resolve such problem, the CT brain angiography using the CT brain angiography subtraction technique and the CT brain angiography using the dual-energy were compared. As a result, it has been reported that the CT brain angiography using the dual-energy reduced the dose by 60%. However, there are limitations since the CT equipment using the dual-energy is relatively more expensive and the exposure condition was fixed to 130mAs prior to injecting the contrast media in the CT brain angiography subtraction technique in the comparative experiment. However, in this experiment, although the scan dose was reduced by up to 70.5% prior to injecting the contrast media in the CT brain angiography subtraction technique, not a single problem occurred in restructuring the brain blood vessels in 3D. This research is limited in that it was conducted based on a small experimental group to minimize the number of people being exposed to radiation. However, as a result of continuously applying the experiment results to the current clinical environment, there has been no request for a re-inspection due to the low radiation dose.

5. Conclusion

It was found that even if testing by reducing tube current of pre-contrast media to 30mAs during CT brain angiography subtraction technique, it does not affect 3D CT brain blood vessels and this radiation reduction technology expected to implement safer CT brain angiography for patients.

6. References

1. Lell M, Anders K, Klotz E, Ditt H, Bautz W , Tomandl B F. Clinical evaluation of bone-subtraction CT angiography

(BSCTA) in head and neck imaging. European Radiology. 2006; 16(4):889–897.

2. Cheng B, Cai W, Sun C, Kang Y, Gong J. 3D bone subtraction CT angiography for the evaluation of intracranial aneurysms: a comparison study with 2D bone subtraction CT angiography and conventional non-subtracted CT angiography. Acta Radiologica. 2015; 56(9):1127–1134.
3. Wang H, Li W, He H, Luo L, Chen C, Guo Y. 320-Detector row CT angiography for detection and evaluation of intracranial aneurysms: Comparison with conventional digital subrtaction angiography. Clin Radiol. 2013; 68(1):15–20.
4. Jayakrishnan V K, White P M, Aitken D, Crane P, McMahon A D, Teasdale E M. Subtraction helical CT angiography of intra-and extracranial vessels: technical considerations and preliminary experience. AJNR American Journal of Neuroradiology. 24(3); 451–455.
5. Kim C G. The Development of Bismuth Shielding to Protect the Thyroid Gland in Radiations Environment. Indian Journal of Science and Technology. 2016;9(25):1–6.
6. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation induced fatal cancer from pediatric CT. AJR American Journal of Roentgenology. 2001; 176(2):289–296.
7. BEIR VII Biological Effects of Ionizing Radiation. Health risks from exposure to low levels of ionizing radiation–phase 2. Washington, DC: The National Academies Press 2006.
8. Brenner D J, Hall E J. Computed tomography an increasing source of radiation exposure, New England Journal of Medicine. 2007; 357(22):2277–2284.
9. U.S. Food and Drug Administration. Safety investigation of CT brain perfusion scans: http://www.fda.gov/MedicalDevices/Safety/Alertsand Notices/ucm185898.htm. Date accessed: 11/09/2010.
10. Yoo S J, Han M S, Lee S Y, Jeon M C, Lee H K, Seo S Y, Yang I M. The Analysis of Exposure Dose Related Factors in Abdominal CT of General Hospitals in Daejeon Area. Indian Journal of Science and Technology. 2015; 8(S1):493–496.
11. Qi L, Lv F, Li Y, Li K, Luo T, Xie P. Suntraction CT angiography for evaluation of intracranial aneurysms: comparison with conventional CT angiography. Neuro European Radiology. 2009; 19(9):2261–2267.