A Study on the Dose and Image Quality for Reduction of the Patient's Lens Dose Using Nano Tungsten Shield in Brain Perfusion CT

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Abstract

Background/Objectives*: Brain Perfusion CT is an important examination for diagnosing cerebral infarction. However, doses of the lens of the patient in Brain Perfusion CT are very high. Therefore, purpose of this study is to reduce the dose received by the lens of a patient without affecting the image quality.*

Methods/Statistical analysis*: To evaluate the exposure dose of the lens of the patient during Brain Perfusion CT, brain perfusion CT was taken at 100 ± 20 kVp and 360 ± 20 mAs. PLD was inserted at each lens position of the Rando phantom composed of human equivalents, and the dose was repeated five times at the same position, depending on the presence or absence of a tungsten shield composed of nano-sized particles. Image quality evaluation in this study is based on the RMSE, CC, MSSIM, PSNR was used.*

Findings: *In comparison with the case of using a self-made shield and no use, the lens showed a difference of minimum 39.7 and maximum 85.9 mGy in Brain Perfusion CT. As a result of evaluating the difference of images according to the application of nano-sized tungsten shield, the mean square root error (RMSE) was 35.1 ± 0.3, the correlation coefficient (CC) was 0.93 ± 0.03 in Brain perfusion CT, and the average structural similarity (MSSIM) was 0.91 ± 0.01, the maximum signal-to-noise ratio (PSNR) was 27.0 ± 1.*

Improvements/Applications: *In conclusion, use of self-produced nanotungsten shielding is believed to solve the problem of exposure of high doses to the patient's lens during a brain perfusion CT examination, which does not affect the image.*

Keywords*: CT, nanoparticles, tungsten, shield, absorbed dose, image evaluation*

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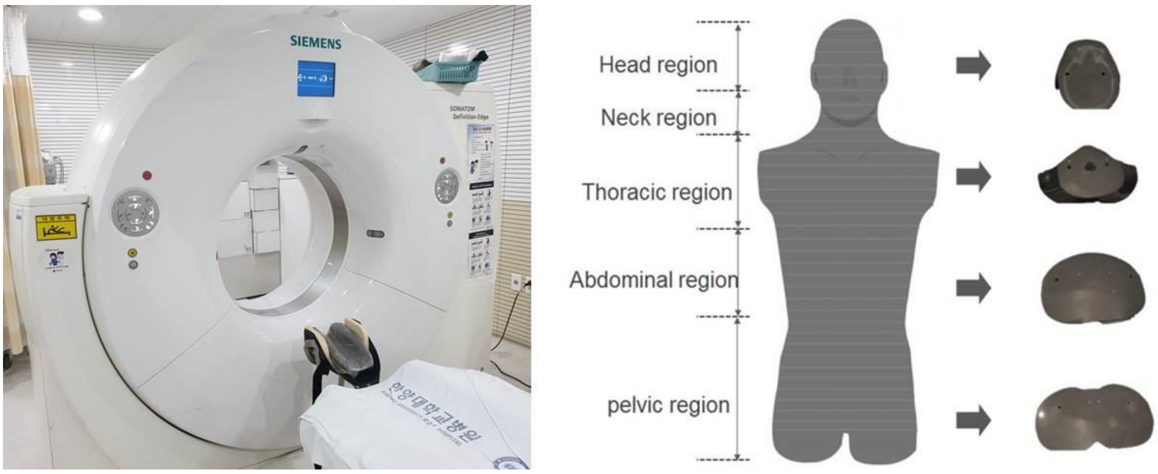
1. Introduction

Patients with severe cerebral infarction should be diagnosed at the same time as soon as possible, and the infarct site should be checked to minimize the sequelae after treatment. For rapid diagnosis, examination using computed tomography (CT) equipment are being conducted, providing 3D imaging and fast scanning speed. Brain Perfusion CT, together with Brain Diffusion MRI, is a very important test for diagnosing cerebral infarction. Brain Perfusion CT scans repeatedly scan the brain area to diagnose the cerebral infarction area. Due to this scanning method, the radiation dose received by the patient is about 50 times that of normal imaging general radiography Skull PA and 3 times that of Brain CT [1, 2]. Excessive dose to patients can cause many side effects such as hair loss as well as cancer. Especially, radiation-sensitive organs can cause cataracts due to excessive dose [3, 4]. For this reason, studies are being conducted to reduce the exposure dose of the lens due to the excessive dose [5-7]. Materials for shielding X-rays are materials that have high atomic number, are not harmful to the human body, and are light and economical. In addition, recent research has been conducted using tungsten (W, 74) composed of nano-particle size with excellent shielding efficiency at low energy [8]. Therefore, in this study, we tried to find a method for reducing the dose of lens in patients without affecting the image quality by applying tungsten shield composed of nanoparticle size for the purpose of reducing excessive dose of lens in Bain Perfusion CT.

2. Materials And Methods

2.1. *Used equipment in experiment*

The CT used to measure the absorbed dose received by the lens is the SOMATOM Definition (Siemens, Germany) and is a dual energy CT. The phantom used in this study was Rando phantom (Churchin Associate LTD. USA) and consists of dried bone, lung, airway, and tissue equivalents [Figure 1].



(a) (b)

Figure 1. Photo of the equipment used in the experiment: (a) Computed tomography (Definition) (b) Rando phantom.

Dose measuring equipment is glass dosimeter (Dose ACE FDG -1000, Asahi Techno, Shizuoka, Japan) and can be measured from 0.01 mGy to 10 Gy and 15 keV to 20 MeV [Figure 2].

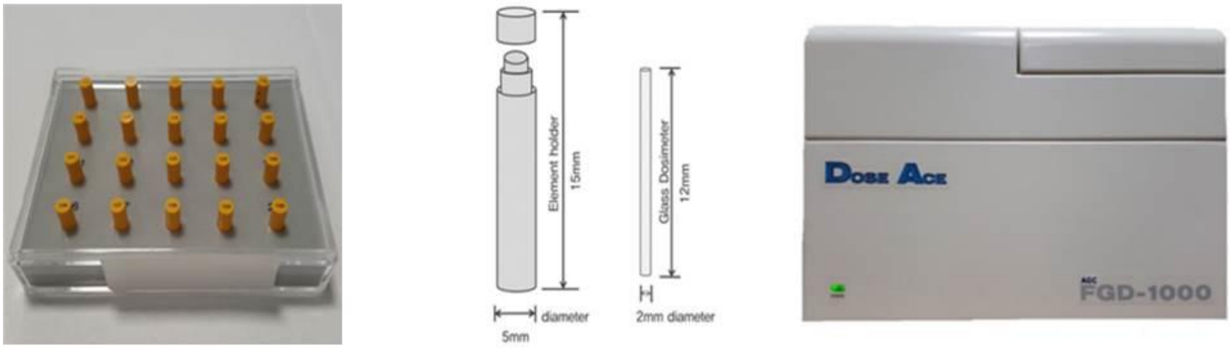


Figure 2. Photo of the equipment used for dose measurement: (a) glass dosimeter (b) Reade

2.2. *Self-produced Nanoparticle-sized Tungsten Shields*

A tungsten shield sheet consisting of nanoparticles was fabricated for the purpose of reducing excessive dose of lens in Bain Perfusion CT. the fabrication of the shielding sheet is a dry milling process with a milling ball to make the tungsten (W) powder into nano-sized particles. It was manufactured in the form of a sheet through the process of melt molding with a polymer substrate using high polymer hot mixing machine and then compression molding. The shielding sheet was manufactured in a form that can be applied to the lens in consideration of the shape to be applied to each organ sensitive to radiation sensitivity. In addition, a 5 mm thick sponge material was attached in consideration of infection, discomfort felt by the patient, and artifacts due to shielding [Figure 3].

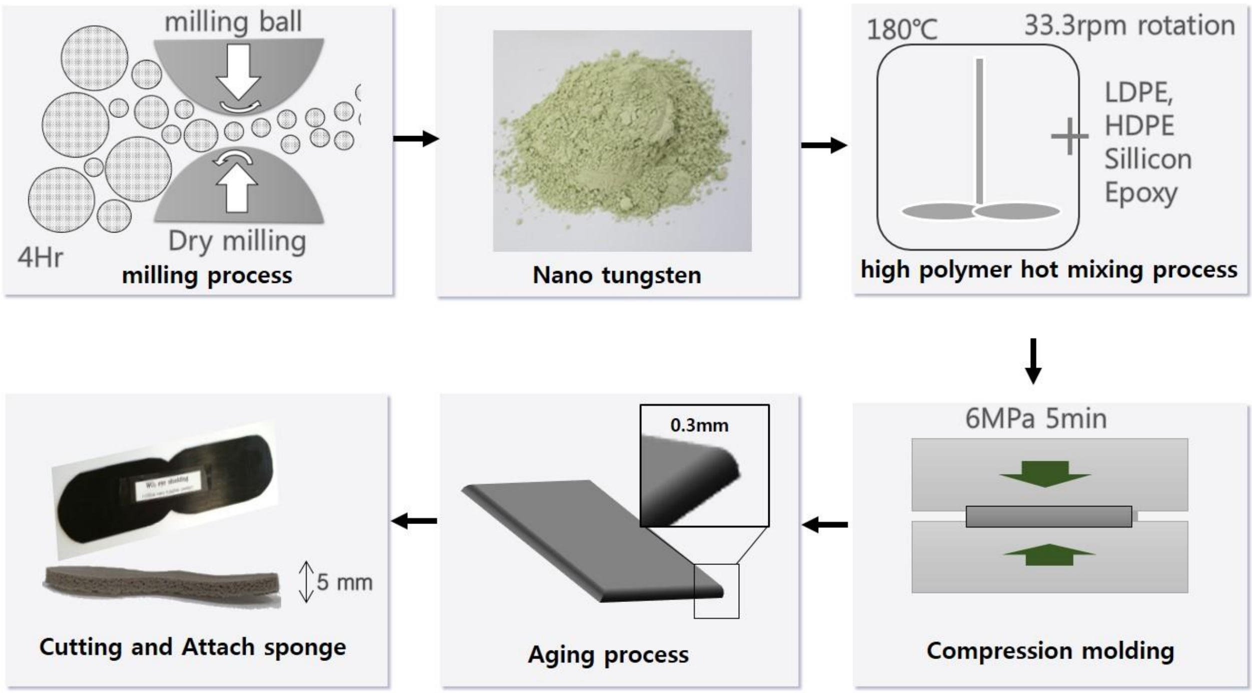
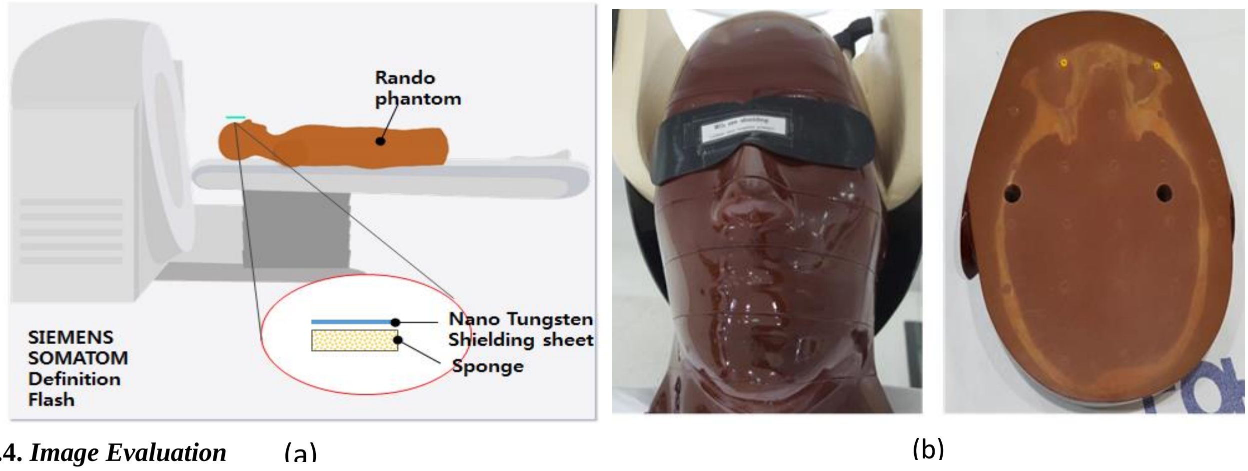


Figure 3. Schematic diagram showing the production process of Nano sized Tungsten Shields

2.3. *Dose measurement*

To evaluate the exposure dose of the lens of the patient during Brain Perfusion CT, brain perfusion CT was taken at 100 ± 20 kVp and 360 ± 20 mAs. PLD was inserted at each lens position of the Rando phantom composed of human equivalents, and the dose was repeated five times at the same position, depending on the presence or absence of a tungsten shield composed of nano-sized particles [Figure 4].



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2.4. *Image Evaluation*

Brain Perfusion CT was used to evaluate images according to the presence or absence of tungsten shields composed of nano-sized particles. The software used for DICOM image processing was the Image J (v.1.48v) program developed by the National Institutes of Health (NIH) and the ICY program, a free open source open source software. Image quality evaluation in this study is based on the root mean square error (RMSE), correlation coefficient (CC), mean structural similarity (MSSIM), and maximum signal Peak signal to noise ratio (PSNR) was used. RMSE is the square root of the average of the squared difference of pixel values between two comparative images x and y, indicating the degree of error between two images. Therefore, the lower the result, the smaller the error between the two images. CC is a factor that linearly evaluates the similarity between two images by calculating Pearson autocorrelation coefficients. The equation is as follows. The closer to 1, the more similar the two images. MSSIM is an average value of structural similarity (SSIM) of two images, and is an image quality evaluation factor indicating the degree of distortion of the images. The closer to 1, the higher the structural similarity between two images. PSNR is a numerical value so that the difference between the two images can be quantitatively expressed, which is expressed as follows. Ideally, if there is no difference between the two images, the PSNR value will be infinite, and if it is 11 dB or more, it will be regarded as a very similar image.

3. Results And Discussion

3.1. *Dose measurement*

In comparison with the case of using a self-made shield and no use, the lens showed a difference of minimum 39.7 and maximum 85.9 mGy in Brain Perfusion CT [Table 1].

Table 1. Absorbed dose values of Eye ball with and without Nano sized tungsten shield in Brain Perfusion CT.

kV	mAs	None (Mean ± SD)	Nano W (Mean ± SD)	p-value
80	350	144.9±3.2	105.2±2.3	p < 0.05
	360	157.2±4.1	119.7±4.4	
	370	164.5±1.2	130.6±5.4	
100	350	294.2±4.2	241.8±3.2	
	360	313.8±2.4	266.2±5.8	
	370	336.8±3.1	280.7±4.3	
120	350	482.7±8.7	390.4±2.4	
	360	513.6±2.9	412.4±5.4	
	370	547.6±6.1	461.7±4.2	

* Statistically significant < 0.05, by Willcoxson test.
SD: standard deviation

3.2. *Image Evaluation*

As a result of evaluating the difference of images according to the application of nano-sized tungsten shield, the mean square root error (RMSE) was 35.1 ± 0.3, the correlation coefficient (CC) was 0.93 ± 0.03 in Brain perfusion CT, and the average structural similarity (MSSIM) was 0.91 ± 0.01, the maximum signal-to-noise ratio (PSNR) was 27.0 ± 1 [Figure 5].

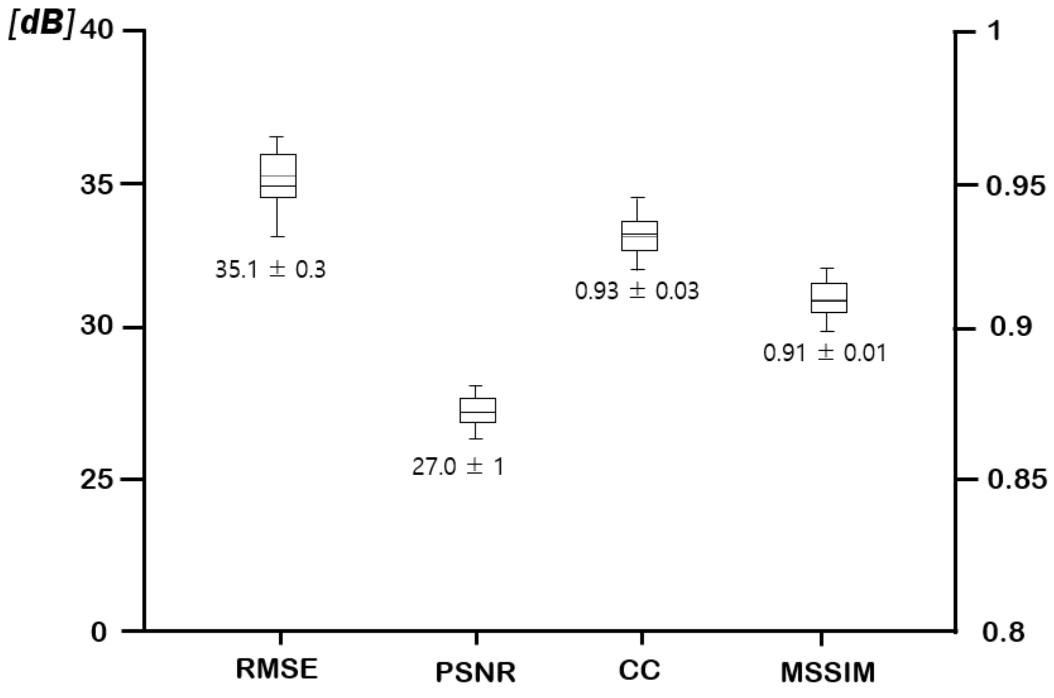

Figure 5. A graph showing results of evaluating the difference of images according to the application of nano-sized

3.3. *Discussion*

This study used a nano sized tungsten shielding designed to protect the patient's sensitive organ, the lens, from radiation. The Brain Perfusion CT examination measured the dose before and after the use of the shielding of the lens, compared it to each other and quantitatively evaluated the image quality. Lead was mostly used as a radiation shielding material because of its high weight, it was cheaper economically, its medical radiation shielding was very good, and its processing was excellent. However, the harmfulness to lead is already well known and expensive to dispose of. This trend is accelerating in advanced countries such as the United States and Japan to develop and use radiation shielding materials rather than lead. Therefore, research on other substances that can replace lead is required [9, 10]. To solve this problem of lead, this study wanted to find shielding materials that would prevent exposure to radiation, make it easy to process, and make it lighter by maintaining radiation shielding without using lead that is harmful to the human body. Tungsten was selected as a shielding material to replace these lead. Tungsten is known to have excellent physical properties and is harmless to the human body due to its high weight. Tungsten shows a better linear attenuation factor than lead, and tungsten shows a value very similar to lead in terms of mass attenuation factor. Tungsten has the advantage of being so dense that it can increase X-ray shielding efficiency. The study also applied nano sized tungsten to maximize physical characteristics. Shielding with distributed nano sized shielding can increase the probability of radiation interacting with shielding material compared to a shielding consisting of particles larger than micro-sized, thus increasing the efficiency of radiation shielding effects. The shielding sheet was constructed to minimize exposure to radiation during CT examinations, taking into account the form of the human body for each sensitive organ, the lens. And dose was measured using PLD device and Rando phantom to prove shielding performance during CT examinations. The results of this study show that tungsten sheets composed of nano sized particles could statistically reduce the average dose in a lens by about 25.1% without compromising image quality. Therefore, it is believed that the use of shielding in the eye during Brain Perfusion CT examinations can be properly examined to minimize unnecessary radiation exposure doses.

4. Conclusion

In this study, the quality of the image with and without shield was quantitatively analyzed, which proved that the degradation of image quality due to the use of the shield was small. In conclusion, use of self-produced nano tungsten shielding is believed to solve the problem of exposure of high doses to the patient's lens during a brain perfusion CT examination, which does not affect the image. In addition, when using a tungsten shield made of nanoparticles, it may be an alternative solution to the harmful effects on the human body and the environment of the lead shield. In the future, research is needed to reduce the dose received by patients by applying nano tungsten shields to the thyroid, breast, and other organs sensitive to radiation as well as the lens.

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