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Evaluating Of Usefulness According To The Use Of Cylinder Cone In Pananasal Sinus Examination In Digital Radiography

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Abstract

In a digital radiography system, the irradiation range acts as an important factor that greatly affects the quality of the image, the radiation dose of the patient, and the radiation dose of the adjacent site, so the need to set and manage the irradiation range is required. In this study, SNR and CNR were measured by an image quality evaluation method according to whether the cylinder cone was used/not used when the Water's method, Caldwell method, and Lateral method were performed in the sinus examination method of the head using a cranial phantom, and measured and compared and evaluated the radiation dose of the adjoining cranial region and the thyroid gland. The measurement results showed that the irradiation field area was smaller when the cylinder cone was used than when the cylinder cone was not used. In the quantitative evaluation of the quality of radiographic images, SNR and CNR were measured at higher values when used when compared to when not using a cylinder cone. It was found that the radiation dose of the adjacent site was measured lower when used as a result of comparison with when silicon cone was not used, and was statistically significant. Such result was evaluated as a factor that affects the image quality and the radiation dose due to use / no use of a cylinder cone that can set the irradiation field range in the radiography of the digital radiology system.

Keywords: Digtal Radiography, Paranasal sinuses(PNS), Signal to noise ratio(SNR), Contrast to noise ratio(CNR),
Cylinder Cone, Radiation Field Size, Radiation dose

Ⅰ. Introduction

The equipment used to obtain medical images is selected according to the type of disease and the cause of the occurrence, etc., and is being tested, but the most frequent test performed on patients receiving medical treatment can be said to be an examination using an X-ray generator system. The medical image acquisition system that can determine the diagnosis and treatment of patients using X-rays has evolved with the development of science. In particular, the field of general radiography is pursuing convenience as it evolves into a digital radiography (DR) environment where images can be acquired in real time, but it can be said that management of the patient's radiation dose and image quality is insufficient. [1-2].

Prior research has shown that in general radiography of digital systems, it is important to ensure that the photographing site exactly matches the image receiving area with irradiation restriction as a factor affecting the radiation dose and image quality [3-5]. Therefore, it can be said that it is necessary to adjust the distance (soure-image distance; SID) between the focus and the image receiving part and to limit the radiation field size [6].

The cylinder cone used in general radiography is used to remove unnecessary X-rays that occur outside the irradiation field range by limiting the irradiation field. Therefore, when using the Water's method, Caldwell method, and Lateral method to diagnose sinus disease in various age groups from children to the elderly in digital radiography, the use/non-use of the cylinder cone is evaluated as a factor affecting the quality of radiography because it can regulate the distance between the focus-image receiving part and limit the irradiation field [7-8]. In addition, the radiation dose includes the brain and thyroid gland in the cranial region, which is adjacent to the irradiation field during sinus examination and is defined as a highly radiation sensitive area by the International Commission Radiological Protection (ICRP) [9] .

Accordingly, this study can be utilized as a method to reduce the exposure dose affecting the test site and adjacent organs with high sensitivity by limiting the irradiation field using a cylinder cone in digital radiography. And it is considered to be the purpose and necessity of the study to provide guidelines on the quality and importance of influencing the radiation dose.

Ⅱ. Materials and Methods

1. Devices and measuring tools

A digital system (Dong Kang Medical, Accu ray 525R, (R-500-125), Korea) was used as the X-ray generator used in this study. In a ddition, a cylinder cone (length 30 cm, diam eter 11 cm) and a head sectional phantom were used for the examination of the parana sal sinuses. For measurement of the radiation dose, the dosimeter (The Unfors, PSD-4, Swe den) with four sensors were used.

2. Research methods

In this study, images of the Water's method, Caldwell method, and Lateral method of sinus examination according to the use/non-use of a cylinder cone were obtained for a skull pha ntom in digital radiography.

The radiation dose was compared and evaluated by measuring the dose of the brain and thyroid gland adjacent to the irradiation si te using a dosimeter, and the analysis of the obtained image was quantitatively evaluated, c ompared and analyzed by measuring (Signal t o Noise Ratio; SNR) and (Contrast to Noise Ratio; CNR) using the Image J program [10].

1) Image measurement method

As for the imaging conditions in the sinus ex amination, the Water's method and Caldwell method were set to 77 kVp, 30 mAs (250 m A, 0.12 sec), and the Lateral method to 72 k Vp, 25 mAs (250 mA, 0.10 sec), and a cylin der cone Image quality and radiation dose to surrounding areas were measured according to use/non-use [11]. When the cylinder cone was not used, the distance between the focus and t he image receiving part was set to 100 cm, th e irradiation field area was set to 20 × 20 cm (400 cm^2), and when the cylinder cone was u sed, the SID was 70 cm, and the diameter wa s 11 cm, and the irradiation field area was set to 94.985 cm^2 (Fig. 1).

(a) (b) (c)

Fig. 1. Cylinder cone
(a) Cylinder cone unused (b) Cylinder cone used (c) Cylinder cone

2) Measurement method for Radiation dose

Radiation dose measurement was measured simultaneously by attaching 4 sensors to the parietal, occipital, bilateral parietal and thyroid glands of the head as defined by the adjacent ICRP in the sinus examination.

The dose measurement was compared and analyzed with the average value through a total of 5 measurements according to the use/non-use of the cylinder cone on the phantom with the measuring instrument attached.

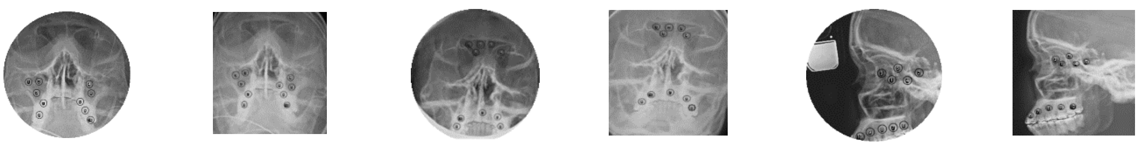
3) Evaluation method for image quality

To evaluate the quality of the image, SNR and CNR values were measured by setting the region of interest (ROI) using the Image J. Ver.1.50 program on the images obtained by the inspection method. The ROI (Region of Interest; ROI) setting of the signal area was analyzed by setting maxillary in the Water's method video, frontal sinus in the caldwell method image, Signal in the sphenoid in the lateral method image, and 5 ROI settings for the noise area (mandible) (Fig. 2).

For the measurements of SNR and CNR, the (Equation 1) and (Equation 2) were applied [12].

$$SNR = \frac{Background\,SI_{Avg} - ROI_{Avg}}{ROI\ SD} \quad \text{--- (Eq. 1)}$$

$$CNR = \frac{Background\ SI_{Avg} - ROI\ SI_{Avg}}{\sqrt{Background\,SD^2 + ROI\ SD^2}} \quad \text{--- (Eq. 2)}$$



(a) (b) (c) (d (e) (f)

Fig. 2. ROI measurement region
(a) Water's cone used method (b) Water's cone unused method (c) Caldwell coned used method (d) Caldwell cone unused method (e) Lateral cone used method (f) Lateral cone unused method

3. Statistical analysis

The statistical analysis used SPSS (version 22.0, SPSS, Chicago, IL, USA), and technical statistics were conducted to calculate the measurement value of the image quality evaluation, the average, standard deviations and the minimum and maximum values of the dose. In order to compare and analyze the difference between the use and non-use of the cylinder cone, a Paired t-test was conducted, and the statistical significance level was evaluated as significant if it was p<0.05 or less.

Ⅲ. Results

1. Image evaluation

1) Warer's method

In the image evaluation of Water's method, SNR was measured at a value of 8.43 when using a cylinder cone and 7.87 when a cylinder cone was not used, and the CNR was measured at 6.64 when a cylinder cone was used and 6.50 when a cylinder cone was not used (Table 1). This has been shown to be statistically insignificant (p>.05).

Table 1. SNR and CNR of Water's method

Direction	Division	Max	Min	AVE	S.D	SNR	CNR	t-value	p-value
cone used	Signal	10096.68	6939.72	8455.31	518.64	8.43	6.64	1.620	0.181
	Noise	14064.20	11219.96	12829.47	406.49				
cone unused	Signal	10962.56	8270.92	9542.11	416.83	7.87	6.50		
	Noise	13738.24	11779.72	12822.01	284.49				

* Max: maximum, Min: minimum AVE: Average, S.D: Standard Devision, ***p<.000, **p<0.01, *p<0.05

2) Caldwell method

According to the image evaluation of Caldwell method, the SNR was measured to be 17.09 when the cylinder cone was used and 9.25 when the cylinder cone was not used, and the CNR was measured to be 10.87 when the cylinder cone was used and 7.60 when the cylinder cone was not used (Table 2). This has been shown to be statistically significant (p<.05).

Table 2. SNR and CNR of Caldwell method

Direction	Division	Max	Min	AVE	S.D	SNR	CNR	t-value	p-value
Cone used	Signal	6163.88	3575.00	4742.28	454.25	17.09	10.87	9.582	0.001**
	Noise	14146.44	10825.68	12506.41	551.24				
Cone unused	Signal	9574.28	6820.20	8047.46	460.69	9.25	7.60		
	Noise	13284.16	11159.92	12307.95	318.82				

* Max: maximum, Min: minimum AVE: Average, S.D: Standard Devision, ***p<.000, **p<0.01, *p<0.05

3) Lateral method

In the image evaluation of the lateral method, the SNR was measured at 1.73 when the cylinder cone was used and 0.94 when the cylinder cone was not used, and the CNR was measured at 1.37 when the cylinder cone was used and 0.76 when the cylinder cone was not used (Table 3). This has been shown to be statistically significant (p<.05).

Table 3. SNR and CNR of Lateral method

Direction	Division	Max	Min	AVE	S.D	SNR	CNR	t-value	p-value
Cone used	Signal	10763.48	5276.96	7571.98	1115.89	1.73	1.37	7.335	0.002*
	Noise	11625.96	7249.40	9500.26	863.19				
Cone unused	Signal	12602.92	7163.12	9587.71	1133.91	0.94	0.76		
	Noise	12966.12	7699.92	10653.28	827.61				

* Max: maximum, Min: minimum AVE: Average, S.D: Standard Devision, ***p<.000, **p<0.01, *p<0.05

2. Measurement of Exposure dose

For the measurement of radiation dose, four sensors were attached to the parietal and bilateral temporal and thyroid glands of the cranial region as a sensitive area stipulated by the ICRP, included in the sinus examination, and measured at the same time.

1) Warer's method

In the Water's method, the radiation dose of the right temporal region was measured at 2.571 mGy when the cylinder cone was not used and 0.552 mGy when the cylinder cone was used. The radiation dose of the left temporal region was measured at 2.884 mGy when the cylinder cone was not used and 0.020 mGy when the cylinder cone was used. The radiation dose of the Perietal region was measured at 1.356 mGy without the cylinder cone and 0.313 mGy when the cylinder cone was used. The radiation dose of the thyroid gland was measured at 0.199 mGy when the cylinder cone was not used and 0.030 mGy when the cylinder cone was used (Table 4). This has been shown to be statistically significant (p<.05).

Table 4. Radiation dose of Water's method (unit: mGy)

Division		Direction	Max	Min	AVE	S.D	t-value	p-value
Temporal bone	Rt.	Cone unused	2.667	2.481	2.571	0.075	-56.14	0.00**
		Cone used	0.558	0.536	0.552	0.009		
	Lt.	Cone unused	2.993	2.694	2.884	0.117	-51.38	0.00**
		Cone used	0.020	0.020	0.020	0.000		
Parietal bone		Cone unused	1.395	1.281	1.356	0.044	-66.61	0.00**
		Cone used	0.317	0.306	0.313	0.004		
Thyroid gland		Cone unused	0.205	0.184	0.199	0.009	-65.70	0.00**
		Cone used	0.032	0.285	0.030	0.002		

* Max: maximum, Min: minimum, AVE: Average, S.D: Standard Devision, ***p<.000, **p<.001, *p<0.05

2) Caldwell method

In the Caldwell method, the radiation dose of the right temporal region was measured at 4.425 mGy without the cylinder cone and 0.248 mGy when the cylinder cone was used. The radiation dose of the left temporal region was measured at 2.558 mGy when the cylinder cone was not used and 0.450 mGy when the cylinder cone was used. The radiation dose of the Parietal region was measured at 2.765 mGy without the cylinder cone and 0.522 mGy when the cylinder cone was used. The radiation dose of the thyroid gland was measured at 0.467 mGy wen the cylinder cone was not used and 0.012 mGy when the cylinder cone was used (Table 5). It was found to be statistically significant (p<.05).

Table 5. Radiation dose of Caldwell method
(unit: mGy)

Division		Direction	Max	Min	AVE	S.D	t-value	p-value
Temporal bone	Rt.	Cone unused	4.45	4.399	4.425	0.027	-560.81	0.00*
		Cone used	0.259	0.218	0.248	0.017		
	Lt.	Cone unused	2.567	2.552	2.558	0.006	-141.87	0.00*
		Cone used	0.512	0.426	0.450	0.035		
Parietal bone		Cone unused	2.789	2.684	2.765	0.005	-4.84	0.01*
		Cone used	0.603	0.339	0.522	0.111		
Thyroid gland		Cone unused	0.473	0.463	0.467	0.004	-173.53	0.00*
		Cone used	0.018	0.007	0.012	0.004		

* Max: maximum, Min: minimum, AVE: Average, S.D: Standard Devision, ***p<.000, **p<.001, *p<0.05

3) Lateral method

In the lateral method, the radiation dose of the occipital part was 0.104 mGy when the cylinder cone was not used, and 0.016 mGy when the cylinder cone was used. The radiation dose of the Perietal region was measured at 0.236 mGy without the cylinder cone and 0.047 mGy when the cylinder cone was used. The radiation dose of the thyroid gland was measured at 0.748 mGy when the cylinder cone was not used and 0.098 mGy when the cylinder cone was used (Table 6). It was found to be statistically significant (p<.05).

Table 6. Radiation dose of Lateral method
(Unit: mGy)

Division	Direction	Max	Min	AVE	S.D	t-value	p-value
Occipital bone	Cone unused	0.109	0.099	0.104	0.004	-49.76	0.000***
	Cone used	0.019	0.014	0.016	0.002		
Parietal bone	Cone unused	0.239	0.232	0.236	0.003	-182.77	0.000***
	Cone used	0.049	0.045	0.047	0.002		
Thyroid gland	Cone unused	0.752	0.745	0.748	0.004	-192.96	0.000***
	Cone used	0.104	0.091	0.098		0.006	

* Max: maximum, Min: minimum, AVE: Average, S.D: Standard Devision, ***p<.000, **p<.001, *p<0.05

Ⅳ. Discussion

As X-ray generators develop into digital radiography systems, it can be said that image quality and radiation dose management, including the irradiation field range, have become relatively inadequate. In radiological examination, the irradiation field range acts as a factor affecting the patient's radiation dose and the scattering ray dose, so it is necessary to set and manage the irradiation range [13].

In this study, SNR and CNR were measured by evaluating the quality of images according to the presence or absence of the use of cylinder cones in the field of general radiography performed to diagnose sinus diseases, and quantitatively measured and evaluated the exposure dose of the highly sensitive cranial and thyroid glands.

In the quantitative evaluation of the quality of radiographic images, the SNR when using the cylinder cone was measured at 8.43 for the Water's method, 17.09 for the Caldwell method, and 1.73 for the Lateral method, the CNR was measured at 6.64 for the Water's method, 10.87 for the Caldwell method, and 1.37 for the Lateral method. When the cylinder cone was not used, the SNR was measured at 7.84 for the Water's method, 9.25 for the Caldwell method, 0.94 for the Lateral method, and the CNR was measured at 6.50 for the Water's method, 7.60 for the Caldwell method, and 0.76 for the Lateral method. This is the same result as Jung's (2021) report that SNR and CNR were measured high when using cones in mastoid tests [14] and Kang (2018)'s IRIS collimator reduced the radiation dose of patients and increased SNR, CNR, sharpness, and spatial resolution [6]. It can be said that it is the same as the result of this study.

The radiation dose of the surrounding area included in the sinus test is measured by the Water's method (0.020 to 0.552 mGy), Caldwell method (0.012 to 0.552 mGy), and the Lateral method (0.016 to 0.098 mGy) when using a cylinder cone, and the Water's method (0.199 to 2.884 mGy) without using a cylinder cone, and the Caldwell method (0.046 to 0.046 mGy) 4.425 mGy) and the lateral method (0.104 to 0.748 mGy) were compared. According to this, the overall measurement was lower when a cylinder cone was used. This is the case in Choi (2013)'s study in which the scattering radiation around the subject was reduced by about 6 to 7 times compared to when the field size was maximized when optimizing the field size of X-ray imaging [15], and in Jung (2021)'s mastoid examination and study in which the exposure dose to major organs including cones was measured low when cones were used [14], and Jeon (2020) in the study [16] that the dose was reduced by 42.75~70.08% when the radiation field was restricted using cones. As a factor influencing the generation of scattered rays, when the irradiance field decreases when a cylinder cone is used, the scattered radiation dose decreases.

The limitations of this study are that it used only a single X-ray generator and dosimeter, and the use of cylinder cones was not applied in the general radiological examination in various environments.

Ⅴ. Conclusion

In the sinus examination conducted with the digital radiography system of this study, the evaluation of image quality according to the use/non-use of cylinder cones and quantitative measurement of radiation doses to the highly sensitive head and thyroid gland adjacent to the irradiation field are as follows.

First, the area of the survey field was measured and evaluated as 4.21 times the difference between the irradiation area when the cylinder cone was not used (400 cm2) and when the cylinder cone was used (94.985 cm2).

Second, in the evaluation of image quality, SNR and CNR were highly measured and evaluated when silicon cone was used.

Third, the sinus test showed that the radiation dose of the main adjacent area differed depending on the test method and site, but it was measured lower when the cylinder cone was used (0.012 to 0.552 mGy) than when the cylinder cone was not used (0.046 to 4.425 mGy).

This study evaluated the quality of the image and the radiation dose quantitatively according to use / no use of cylinder cone in the radiography of the digital radiation system. This result provides guidelines on the importance of the irradiation field range in general photography, and is expected to be used as a basic data for providing images of high diagnostic value while minimizing the radiation dose.

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