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<원저>

Patient Radiation Dose Values During Interventional Cardiology Examinations in University Hospital, Korea

- 심장혈관 조영술과 심장혈관 인터벤션의 환자 선량 평가 -

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— Abstract —

The use of cardiac angiography (CA) and the interventional procedures is rapidly increasing due to the increase in modern adult diseases. Cardiovascular intervention (CI) is an examination method where radiation is applied to the same area for a long period, and thus may cause skin injury. In this study, we investigate the diagnostic reference level (DRL) of the cardiovascular intervention (CI) carried out by medical institutions and use it as a tool to reduce patient exposure dose. In this study, the DRL was set by acquiring information about the cumulative fluoroscopy time, cumulative fluoroscopy dose-area product (DAP), radiography DAP, cumulative DAP, air kerma, number of video clips, and the total number of images from the cardiac angiography and interventional procedures performed on 147 patients. The DAPs corresponding to the DRL of cardiac angiography(CA) and that of the interventional procedures were shown to be 44.4Gy · cm2 and 298.6Gy · cm2, respectively; the corresponding DRLs of fluoroscopy time were shown to be 191.5s and 1935.3s, respectively. A DRL is not a strict upper bound for radiation exposure. However, the process of setting, enacting, and reviewing the DRLs for the dose by medical institutions will contribute to a reduction in the unnecessary exposure dose of patients.

Key words: Cardiac Angiography (CA), Patient dose, Dose-area product (DAP), Diagnostic reference level (DRL), Radiation exposure

I. INTRODUCTION

Cardiac angiography (CA) is one of the major examination methods applied to the detection of cardiovascular diseases using X-rays. As an interventional procedures, cardiac angiography (CA) can diagnose

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cardiac blood flow insufficiency and ischemic myocardial infarction, and treat vascular abnormalities. During cardiac angiography (CA), the same area is exposed to radiation for a long period, and therefore a radiation injury to skin is highly likely to occur[1)2)]. Damage to skin caused by radiation during an interventional procedures has already been reported many times. The International Commission on Radiological Protection (ICRP) has published a report that discussed the importance of radiation protection in the cardiovascular field[3)]. Cardiac angiography (CA) includes angiography for disease diagnosis and the interventional procedures for treatment. Interventional procedures may increase the likelihood of skin injury or cancer incidence, which result from a large amount of radiation, as the treatment procedures are carried out in series after the diagnosis of the disease[4)]. Accordingly, when using cardiac angiography (CA) and interventional procedures, radiation protection should be justified and optimized without fail, and the as low as reasonably achievable (ALARA) principle should be followed to minimize the patient dose. In the ICRP Publication 103 (2008), the diagnostic reference level (DRL) is recommended to be set for the optimization of medical radiation[5)]. In Korea, although the DRLs for the interventional procedures in radiology have been enacted by the Ministry of Food and Drug Safety, studies on the DRLs for the interventional procedures in the cardiovascular field are still limited.

In this study, we aim to set the DRLs by evaluating the exposure doses of cardiac angiography (CA) and the interventional procedures, and use them as a tool to reduce patient exposure to radiation.

II. MATERIALS AND METHODS

The subjects in this study are 147 patients on whom cardiac angiography (CA) and cardiovascular interventions (CI) have been carried out between September 2015 and January 2016 in the cardiovascular center of a university hospital located in Gangwon-do, Korea. The objects comprised 67 male patients and 80 female patients, with ages between 35 and 95 and an average age of 68. The frequency distribution of age is shown in Figure 1. The weights of the patients, distributed between 40 kg and 103 kg, showed an average of 63.1 kg, and the heights distributed between 140 cm and 176 cm showed an average of 159 cm. For the evaluation of the patient dose, the objects were divided into two groups: for one group, only cardiac angiography (CA) was carried out; for the other, the interventional procedures was carried out along with cardiac angiography (CA). The dose information provided by the angiographic device was analyzed. To acquire the dose information, the examination report saved in the control computer of the angiographic device was retrieved. For each examination, information was acquired about the cumulative fluoroscopy time, cumulative fluoroscopy dose-area product (DAP), cumulative radiography DAP, total cumulative DAP, air kerma, number of video clips, and total number of images. The angiographic device used for this study was Allura CV20 (Philips N.V). The X-ray tube used for the angiographic device used 0.4 mm and 0.7 mm focuses, and the X-ray target angle was 11°. The detector used was an amorphous silicon (aSi) detector with a CsI scintillator. The size of the detector was 40 cm x 20 cm, with a pixel size of 154 mm x 154 mm and a bit depth of 14.

Frequency and bivariate correlation analyses were performed using SPSS Version 22 (IBM Corporation,

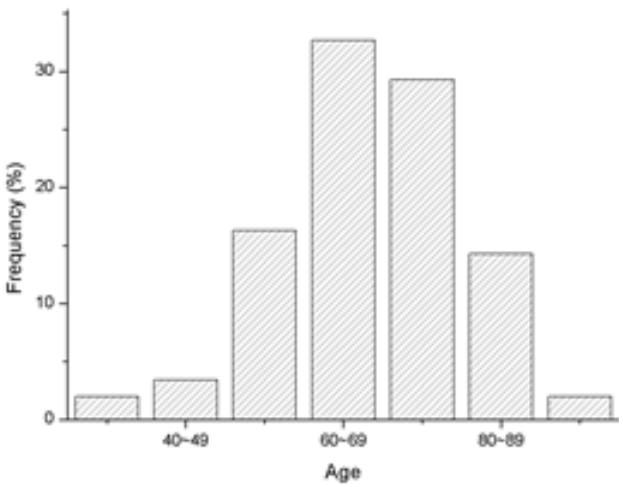

Figure 1 Age Groups of Patients(year)

USA) to set the DRL, using the third quadrant value of the dose information. The data used in this study passed a review by the Institutional Review Board.

III. RESULTS

Cardiac angiography (CA) was carried out on 113 patients, which accounted for 76.9% of the total; both cardiac angiography and the interventional procedures were carried out at the same time on 34 patients, which accounted for the remaining 23.1% of the total. To examine each patient, the tube of the cardiac angiography (CA) was inserted into a wrist artery. According to the frequency analysis of the cardiac angiography (CA) examinations, 40.7% patients were male and 59.3% patients were female, with an age distribution between 35 and 92 and an average age of 67.9. The heights of the patients, distributed between 140 cm and 176 cm, showed an average of 158 cm, and the average weight was 62.2 kg. The exposure dose statistics for the cardiac angiography is shown in Table 1. The maximum, minimum and average values of the total cumulative DAP are 131.9 Gy·cm^2, 0.6 Gy·cm^2, and 37.1 Gy·cm^2, respectively. On average, 454.7 sheets of images were examined, and the average fluoroscopy time was 165.9 s.

For 88.2% of the patients on whom both cardiac angiography (CA) and the interventional procedures were carried out at the same time, the tube was inserted into a wrist artery; for the remaining 11.8%, it was inserted into a femoral artery. The heights of these patients, distributed between 147 cm and 175 cm, showed an average of 162 cm. The weights distributed between 51 kg and 89 kg showed an average of 66.9 kg. The exposure doses are shown in Table 2 for the patients on whom both cardiac angiography and the interventional procedures were

Table 1 Frequency analysis results of the patient radiation dose at the cardiac angiography (CA) examinations

	Fluoro Time (s)	Cum DAP Fluoro (mGy · cm^2)	Cum DAP Expo (mGy · cm^2)	Total DAP (mGy · cm^2)	Cum Air Kerma (mGy)	Total Run	Total Image
Mean±SD	165.9±111.0	19642.3±16036.5	17674.7±8825.3	37130.3±22178.4	650.5±323.2	8.7±2.5	454.7±202.7
Range	51.0-713.0	43.2-89431.0	16.9-49601.0	60.1-131911.0	21.0-1971.0	5.0-19.0	238.0-1371.0
Median	136.0	15478.0	16298.0	32612.0	586.0	8.0	398.0
25%	98.0	10004.0	12414.0	22855.5	442.0	7.0	328.5
50%	136.0	15478.0	16298.0	32612.0	586.0	8.0	398.0
75%	191.5	21198.0	21455.0	44489.0	791.5	10.0	506.5

Cum DAP Fluoro: cumulated dose-area product of fluorography, Cum DAP Expo: cumulated dose-area product of exposure, Cum Air Kerma: cumulated air kerma

Table 2 Frequency analysis results of the patient radiation dose at the cardiac angiography (CA) and percutaneous coronary intervention (CI) examinations

	Fluoro Time (s)	Cum DAP Fluoro (mGy · cm^2)	Cum DAP Expo (mGy · cm^2)	Total DAP (mGy · cm^2)	Cum Air Kerma (mGy)	Total Run	Total Image
Mean±SD	1200.0±773.8	131389.2±92586.0	57743.7±31880.9	213312.6±161594.2	3486.6±2410.8	31.2±11.4	1613.7±897.6
Range	117.0-2711.0	16936.0-368009.0	8564.0-140670.0	39940.0-796880.0	618.0-8801.0	13.0-63.0	612.0-4707.0
Median	926.5	97758.0	52595.5	165911.5	2604.0	29.5	1401.0
25%	637.8	63208.0	31534.3	99730.5	1716.3	22.8	960.3
50%	926.5	97758.0	52595.5	165911.5	2604.0	29.5	1401.0
75%	1935.3	161636.5	68094.0	298627.8	5254.8	39.3	2201.3

Cum DAP Fluoro: cumulated dose-area product of fluorography, Cum DAP Expo: cumulated dose-area product of exposure, Cum Air Kerma: cumulated air kerma

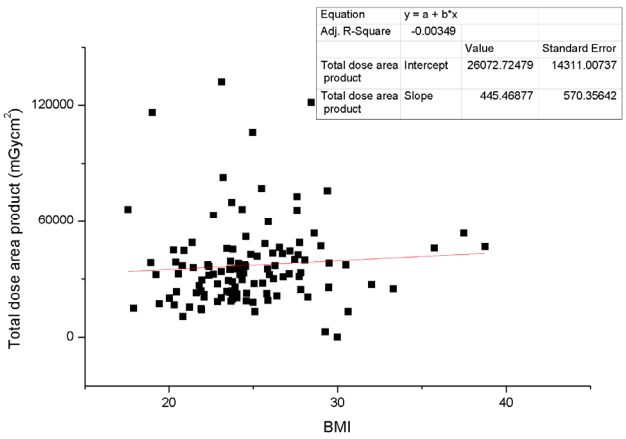

Figure 2 Total dose-area product of each body mass index at the cardiac angiography (CA) examinations

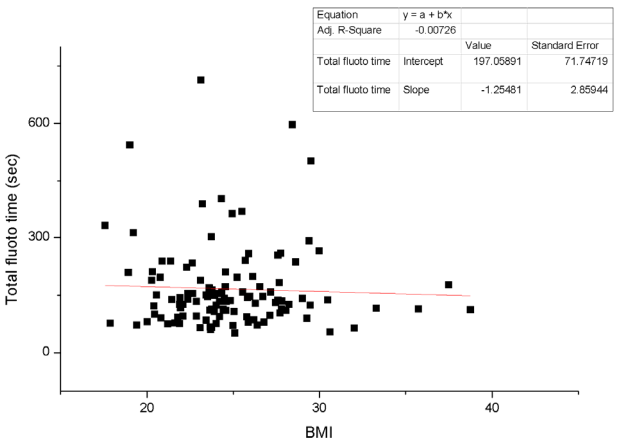

Figure 3 Total fluoro time of each body mass index at the cardiac angiography (CA) examinations

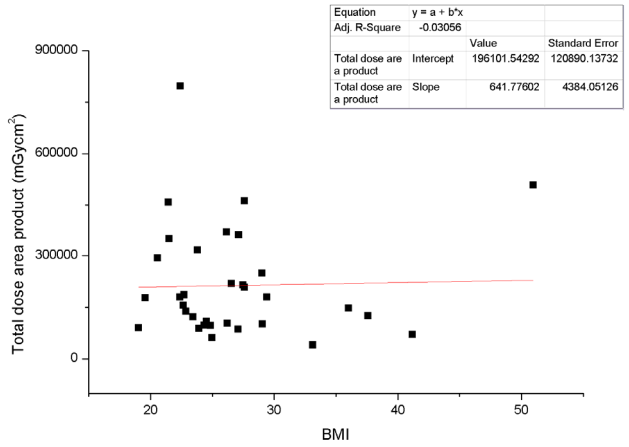

Figure 4 Total dose-area product of each body mass index at the percutaneous coronary intervention (CI) examinations

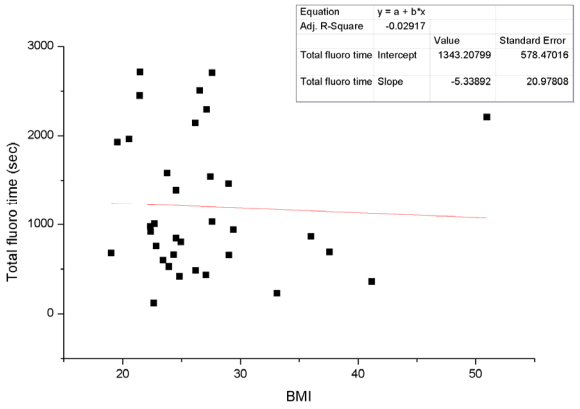

Figure 5 Total fluoro time of each body mass index at the percutaneous coronary intervention (CI) examinations

carried out at the same time. The maximum, minimum, and average values of the total cumulative DAP were 796.3 Gy·cm^2, 39.9 Gy·cm^2, and 213.3 Gy·cm^2, respectively. On average, 1613.7 sheets of images were examined, and the average fluoroscopy time was 1200 s.

The average body mass index (BMI) of the patients on whom cardiac angiography (CA) was carried out was found to be 24.8, with a distribution between 17.6 and 38.8. According to the correlation analysis for the BMI and the cumulative DAP, the Pearson correlation coefficient showed a correlation between the two with a significance level of 0.073 ($p = 0.01$); the Pearson correlation coefficient between the cumulative DAP and the cumulative fluoroscopy DAP showed a correlation with a significance of 0.935 ($p = 0.001$). The R-squared value of the BMI and the cumulative DAP showed a negative value of 0.00349 (Figure 2), and that of the BMI and the fluoroscopy time showed a negative value of 0.00726 (Figure 3).

The average BMI of the patients on whom both cardiac angiography (CA) and the interventional procedures were carried out at the same time was found to be 26.8, with a distribution between 19 and 51. According to the correlation analysis for the BMI and the cumulative DAP, the Pearson correlation coefficient showed a correlation between the two with a significance level of 0.027 ($p = 0.01$). The Pearson correlation coefficient between the BMI and the cumulative fluoroscopy time showed a correlation with

a significance of 0.043 (p = 0.01), and that between the fluoroscopy time and the cumulative DAP showed a high correlation with a significance of 0.621 (p = 0.01). The R-squared value of the BMI and the cumulative DAP showed a negative value of 0.03056 (Figure 5), and that of the BMI and the fluoroscopy time showed a negative value of 0.02917 (Figure 6).

IV. DISCUSSION AND CONCLUSION

Although the patient exposure dose in cardiac angiography (CA) can be directly measured using a thermo-luminescence dosimeter, a glass dosimeter, or a film dosimeter, a trace of the dosimeter may be left on the image. Therefore, an indirect method such as a DAP meter is preferable for measuring the exposure dose. The US Food & Drug Administration requires the attachment of a DAP meter to the X-ray system for fluoroscopes produced from 2006 onwards[6]. The DAPs corresponding to the DRL of cardiac angiography and the DRL of the interventional procedures investigated in this study were shown to be 44.4 Gy·cm2 and 298.6 Gy·cm^2, respectively; the corresponding DRLs of fluoroscopy time were found to be 191.5 s and 1935.3 s, respectively. In the case where both cardiac angiography and the interventional procedures were carried out at the same time, the DRL was close to 300 Gy·cm^2, consistent with the DAP for the first patient presented in the study by Stecker et al[7]. Besides, the DRL of the present study is higher than the DRL of cardiac angiography (30 Gy·cm^2) as well as than that of the interventional procedures (60 Gy·cm^2) presented by A. I. Stratis et al[8]. A comparison between the results of this study and the DRLs presented in previous studies is shown in Table 3.

The DRL of the cardiovascular intervention (CI) presented in this study is much higher than that in the preceding studies, probably due to the increase of the lesion complexity. Another contributing factor is the fact that lesions that required invasive surgery in the past are now treated by the interventional procedures, due to the advancement in the interventional procedures apparatus. A DRL is not a value that should never be exceeded . However, the process of setting the reference values for the dose, used by medical institutions by enacting and reviewing the DRLs, will contribute to a reduction in

Table 3 Comparison with other studies Dose-area product (DAP) for coronary angiography (CA) and percutaneous coronary intervention (CI)

Reference	Parameter	Procedure	Dose	Number of Patient
This study	DAP (Gy · cm^2)	CA	44.4 (DRL)	113
		CI	298.6 (DRL)	34
Bouzarjomehri et al (2009)[9]	DAP (Gy · cm^2)	CA	41 (DRL)	168
		CI	107.4 (DRL)	84
A. I. STRATIS et al (2009)[8]	DAP (Gy · cm^2)	CA	30 (DRL)	108
		CI	60 (DRL)	101
M. G. Delichas et al (2003)[10]	DAP (Gy · cm^2)	CA	81.8 (Mean)	106
		CI	105.9 (Mean)	55
Bakalyar et al (1997)[11]	DAP (Gy · cm^2)	CA	94.5 (Mean)	173
		CI	141.6 (Mean)	337
V Tsapaki et al (2014)[12]	DAP (Gy · cm^2)	CA (FPF)	27.7 (Mean)	200
		CI (FPF)	51.1 (Mean)	
		CA (Conventional)	39.3 (Mean)	
		CI (Conventional)	44.3 (Mean)	

DAP: dose-area product, CA: cardiac angiography, CI: percutaneous coronary intervention, DRL: Diagnostic reference levels

the unnecessary exposure dose of patients. Accordingly, the enactment of the DRL in the cardiovascular intervention (CI) will be utilized as an important tool for medical institutions to justify examinations by reducing the exposure dose of both patients and practitioners.

In this study, the fluoroscopy time and patient exposure dose are found to be closely related to each other. Accordingly, reducing the fluoroscopy time is likely to have an effect on the reduction of the patient exposu

re dose. However, as the cardiovascular intervention (CI) is carried out for a long period and is different from a general radiography, the correlation between the BMI of patients and the exposure dose is low. Therefore, the BMI of patients does not have much effect on the dose increase. As a limitation of this study, it is required to take into consideration that the DAP is more highly evaluated than the actual dose irradiated on the patients.

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•국문초록

심장혈관 조영술과 심장혈관 인터벤션의 환자 선량 평가

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심장혈관 조영술과 인터벤션은 현대 성인병의 증가로 급격히 증가하고 있다. 심장혈관 인터벤션은 장시간 동일 부위에 방사선을 조사하는 검사로 방사선으로 인한 피부상해를 일으킬 수 있다. 본 연구에서는 의료기관의 심장혈관 인터벤션의 진단참조준위를 조사하여 환자의 피폭선량을 감소시키는 도구로 사용하고자 한다. 본 연구는 147명의 환자에서 심장혈관 조영술과 인터벤션을 대상으로 누적 투시시간, 누적 투시면적선량, 영상촬영을 위한 면적선량, 누적 면적선량, 공기커마, 동영상 수, 총 영상 수에 대한 정보를 획득하여 진단참조준위를 설정하였다. 심장혈관 조영술의 진단참조준위와 인터벤션의 진단참조준위에 해당하는 면적선량 값은 각각 44.4 Gy · cm^2와 298.6 Gy · cm^2로 나타났고 투시시간에 대한 진단참조준위는 각각 191.5 sec와 1935.3 sec로 나타났다. 진단참조준위는 반드시 넘으면 안 되는 값은 아니다. 하지만 진단참조준위를 제정하여 의료기관에서 사용하고 있는 선량의 참조 값을 설정하고 이를 검토하는 과정은 환자의 불필요한 피폭선량을 감소시키는데 기여할 것이다.

중심 단어: 심장혈관 조영술, 환자선량, 면적선량, 진단참조준위, 방사선피폭