Measurement And Analysis of Environmental Radiation in The Extracorporeal Shock Wave Lithotripsy Laboratory

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Abstract

Background/Objectives: Extracorporeal shock wave lithotripsy is a non-invasive procedure in which high energy from outside the body is focused on the stones to break them gradually. However, this procedure risks increasing the exposure dose of the patient's guardian or related workers.

Methods/Statistical analysis: In the extracorporeal shock wave lithotripsy laboratory and general fluoroscopy laboratory, an environmental glass dosimeter was installed at the same height as the X-ray tube on the radiation barrier, patient entrance, the staff entrance, and the patient view window to measure and analyze the cumulative dose for 3 months.

Findings: The cumulative 1 cm dose equivalent measured with the glass dosimeter for 3 months outside the barrier at the entrance and outside the barrier at the control room of the extracorporeal shock wave lithotripsy laboratory was measured to be less than the natural radiation dose. The cumulative 1cm dose equivalent value measured with the glass dosimeter for 3 months at the entrance of the control room of the extracorporeal shock wave lithotripsy laboratory was measured to be a maximum of 0.21mSv and an average of 0.07mSv. The cumulative 1cm dose equivalent measured with the glass dosimeter for 3 months at the entrance of the patient caregivers' waiting room and the patient view window was measured to be less than the natural radiation dose. The cumulative 1 cm dose equivalent measured with the glass dosimeter for 3 months outside the barrier of the general fluoroscopic X-ray room was measured to be 0.86mSV, and the cumulative 1 cm dose equivalent for 3 months at outside the barrier of the control room was measured to be less than the natural radiation dose. The cumulative 1 cm dose equivalent measured with the glass dosimeter for 3 months at the entrance of the patient caregivers' waiting room of the general fluoroscopic X-ray laboratory was measured to be an average of 3.41mSV, and the same at the control room's entrance was measured to be an average of 0.96mSv

Improvements/Applications: The results of this research is expected to be usefully utilized in the safe management of medical radiation. In addition, the measurement management of the leakage and scattered radiation for diagnosis requires continuous monitoring at the nation's dimension. Active support for research and development of the associated fields is deemed necessary.

Keywords: Lithotripsy, radiation, fluoroscopy, safety management, shielding performance

1. Introduction

Extracorporeal shock wave lithotripsy (ESWL) is a treatment that focuses a high-energy shock wave from outside the body to gallstones (stones in the gallbladder or liver), pancreatic stones, kidney stones or ureter stones, so that the stones are gradually broken and discharged naturally. This is a non-invasive procedure that does not injure the body [1-3].

Recently, extracorporeal shock wave lithotripsy is frequently used in the kidneys and ureteric stones. This is because the broken stones are naturally excreted with the urine to cure the disease.

Extracorporeal shock wave lithotripsy began in 1969 when Dornier conducted a study on "the effect of shock waves on tissue." In 1972, Dornier Medical Systems developed a clinically applicable lithotripsy, and in February 1980, shock wave lithotripsy (SWL) was applied to humans and treated for the first time. The development and dissemination of the crusher developed by Dornier started at the end of 1983, and shock wave lithotripsy was approved by the US Food and Drug Administration in 1984 and is still used today [4].

The crusher uses high-density sound pulses from the outside to attempt crushing while minimizing the risk to the human body. Anesthesia is administered to the patient to keep the patient's posture stable and to reduce discomfort [5].

In a position in which the patient is lying, digital X-rays are used to determine the location of the stone through digital X-rays. A shock wave is emitted from the outside in the direction of the stone to remove the stone.

Although extracorporeal shock wave lithotripsy has the advantage of being minimally invasive for stone treatment, it has a lower stone removal rate than other invasive treatment methods such as retrogade intrarenal surgery (RIRS), percutaneous nephrolithography, and ureteroscopy with laser lithotripsy. It has a characteristic [6].

In addition, it may take several days to a week for the stone fragments crushed by the external shock wave to escape from the body part, which may cause pain to the patient. During this time, it is helpful for the patient to drink as much water as possible.

There is a risk of side effects that may cause capillary damage, renal parenchyma, and subcapsular hemorrhage during extracorporeal shock wave lithotripsy

In order to perform extracorporeal shock wave lithotripsy, X-ray fluoroscopy is used to determine the location of the stone in advance and deliver the shock wave accurately. Fluoroscopy uses the voltage same as the tube voltage (80-100kV) and very low tube current (<10mA) as in general imaging, and prolonged exposure is inevitable due to delay in examination time, magnification, and extensive selection of examination sites [7, 8].

In fluoroscopy, X-rays are used to conduct the examination, but there is a risk of increasing the patient's cumulative dose depending on imaging factors such as the examiner's skill, examination time, the use of contrast medium, and the patient's position change [9,10].

The number of annual diagnostic medical radiological examinations for Koreans increased from about 312 million in 2016 to about 374 million in 2019, increasing at an average annual rate of about 6.2%, and increased by about 20% in 2019 compared to 2016 [11-16].

Korea's radiation safety management standards for facilities using extracorporeal shock wave lithotripsy using X-rays require installing radiation barriers on the ceiling, floor, and walls, and the sum of the radiation leakage and scattered dose measured from the outside of the barrier shall be less than 100 mR per week.

However, safety management of medical radiation depending on the leakage dose per week has limitations in management. This is because the leakage dose and scattered dose change every moment according to the device's weekly operation amount and energy. Such an environment may lead to an increase in medical radiation dose. Accordingly, there is a need to develop a new medical radiation safety management method to reduce the exposure dose of medical radiation-related workers and patient caregivers.

Therefore, in this study, using a glass dosimeter that can measure the cumulative dose, the 3-month cumulative dose of the radiation barrier of the facility using extracorporeal shock wave lithotripsy was measured and compared to evaluate the method and improve the safety management standard for radiation safety management for diagnosis.

2. Research subjects and methods

2.1. *Evaluation of Leakage Dose to Barrier in X-ray-using Extracorporeal Shock Wave Lithotripsy Laboratory*

In this study, COMED SDS-5000PLUS was used to measure the dose to the barrier of the extracorporeal shock wave lithotripsy laboratory using X-rays [Figure 1]. COMED SDS-5000PLUS extracorporeal shock wave lithotripsy device can remove urolithiasis without anesthesia, skin incision, and pain, causing no aftereffect and does not affect other organs. So, this device is widely used in clinical practice.

In 3 hospitals that use extracorporeal shock wave lithotripsy, glass dosimeters for environmental measurement were installed outside the laboratory's barrier, and the leakage radiation dose was measured for one month from May 17 to June 17, 2021.

As a radiation leakage dose and scattered dose-measuring device, the glass dosimeter (Glassbadge: GB) RS type manufactured by Chiyoda Technology of Japan, which is highly sensitive to medical X-ray measurement, was used. For the location of diagnostic radiation and environmental radiation measurement, taking into account the location of the radiation generator, the measurement equipment was installed in a space where the leakage dose is expected to be high [Figure 2]. In order to secure the reliability of the measurement data, the author requested the measurement and management center of Chiyoda Technology, Japan to read the dosimeter, performed the analysis and evaluated the results.

Figure 1. Extracorporeal shock wave lithotripsy device

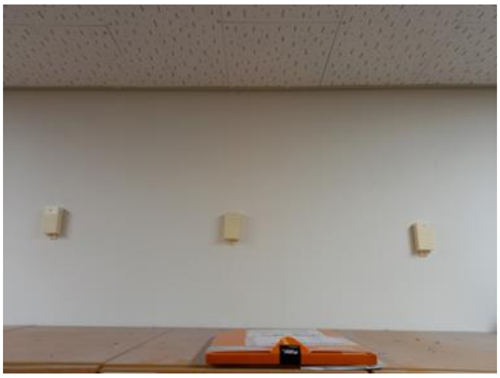

Figure 2. Glass dosimeter for measuring radiation installed on a barrier wall

2.2. *Dose analysis of entrance and patient view window of extracorporeal shock wave lithotripsy laboratory*

The effectiveness of radiation safety for radiation workers and patient caregivers was evaluated by measuring and evaluating the leakage dose at the examination room entrance and patient view window of the extracorporeal shock wave lithotripsy using X-rays.

The glass dosimeter was installed at the patient's entrance door, which is expected to have the highest leakage dose based on the X-ray generator, at the entrance door of the control room, the shielding wall, and the patient view window of the extracorporeal shock wave lithotripsy laboratory [Figure 3].

To measure and evaluate the shielding efficiency of the patient view window, glass dosimeters were installed inside and outside the laboratory to measure the environmental radiation dose and verify the statistical significance.

Measurement analysis was carried out by sending the glass dosimeter to Chiyoda Technology, Japan. The value calculated by multiplying the value measured for one month by 3 was used to compare the final dose analysis.

Figure 3. Glass dosimeter installed in the patient view window

2.3. *Statistical processing and analysis*

The data analysis was performed using the statistical program SPSSWIN (Ver 22.0). The significance of measurement of the average value of the exposure dose for the control and test groups was verified through t-test. The significance level of all statistics was set to $p<0.05$.

3. Research result and considerations

3.1. *Evaluation result of leakage dose of barrier wall in the extracorporeal shock wave lithotripsy laboratory using X-ray*

It is important for the extracorporeal shock wave lithotripsy device to accurately identify the body part where the stone is located and appropriately apply shock wave energy to the center of the stone. In this process, to accurately identify the location of the stone and use the device effectively, the human body is viewed through an X-ray generator. Scattered and leakage rays are generated by seeing the human body through an X-ray generator. At this time, radiation barriers are needed to reduce radiation exposure to workers or patient caregivers and control shielding.

In Korea, the standard for shielding facilities for leakage and scattered dose in the laboratory using medical radiation should be less than 100mR per week in total radiation measured from the outside.

As mentioned earlier, in Korea, the dose management of medical radiation exposure for leaky and scattered radiation is managed based on the radiation dose.

In Japan, the cumulative dose of radiation leaked for 3 months should not exceed 1.30 mSv according to medical radiation dose management standards for leaky and scattered radiation. Unlike Korea's concept of safety management, Japan conducts radiation safety management based on cumulative dose rather than temporary dose based on absorbed dose.

As a result of the operation of the medical radiation safety management system in Japan, as of 2019, the average annual dose of radiation-related workers is maintained at 0.30 mSv. This is less than one-third of the average annual exposure dose of 0.45 mSv for radiation-related workers as of 2019 in Korea.

In this experiment, glass dosimeters were installed in 5 extracorporeal shock wave lithotripsy laboratories of hospitals that passed the “barrier” standard for medical radiation safety management in Korea, and the accumulated dose was measured and analyzed.

The glass dosimeters were installed at the same height as the position of the X-ray tube, which has a high frequency of leakage and scattered rays. The dosimetry using a glass dosimeter was carried out for one month, and the result was compared and analyzed with Japan's 1cm dose equivalent standard by multiplying the result value measured by the reading system by 3.

Table 1 shows the cumulative dose values measured for 3 months by installing a glass dosimeter on the barrier wall at the control room side and the barrier wall at the extracorporeal shock wave lithotripsy laboratory's entrance, the boundary of the radiation area.

To compare the degree of radiation leakage dose in the extracorporeal shock wave lithotripsy laboratory, the cumulative dose in the general fluoroscopy laboratory of the same hospital was also measured, and the results are shown in [Table 1].

Table 1: Results of 3-month cumulative dose analysis for the barrier of the extracorporeal shock wave laboratory using X-rays (Unit: mSv)

Laboratory	Barrier wall at the entrance		Barrier wall at the control room	
	General fluoroscopy laboratory	Extracorporeal shock wave laboratory	General fluoroscopy laboratory	Extracorporeal shock wave laboratory
1	1.35	-	-	-
2	0.96	-	-	-
3	-	-	-	-
4	0.79	-	-	-

5	**1.21**	**-**	**-**	**-**
Average	**0.86**	**-**	**-**	**-**

The cumulative 1 cm dose equivalent measured with a glass dosimeter for 3 months outside the barrier installed at the entrance of the extracorporeal shock wave lithotripsy laboratory was measured to be less than the natural radiation dose. The cumulative 1 cm dose equivalent measured with a glass dosimeter for 3 months outside the barrier installed at the entrance of the general fluoroscopy laboratory showed a maximum of 1.35 mSv and an average of 0.86 mSv. One of the five laboratories that performed the test showed a result value higher than the Japanese standard.

The cumulative 1 cm dose equivalent measured with a glass dosimeter for 3 months outside the barrier installed in the control room of the extracorporeal shock wave lithotripsy laboratory was measured to be less than the natural radiation. The cumulative dose measured with a glass dosimeter for 3 months outside the barrier installed in the control room of the general fluoroscopy laboratory was measured to be less than the natural radiation.

The cumulative dose measured with a glass dosimeter outside the barrier installed in the control room was below the Japanese standard in all 5 test laboratories.

The fact that the cumulative 1 cm dose equivalent measured with a glass dosimeter for 3 months outside the barrier wall installed on the entrance of the general fluoroscopy laboratory exceeds the Japanese leakage dose safety standards is judged to be caused by the poor construction of the barrier wall, deterioration of building materials such as concrete, construction and shielding materials and/or their increased fatigue [7-9, 17].

The reason the leakage dose varies by hospital is the difference in the laboratory's operation during the measurement period.

As shown in the above analysis results, the cumulative leakage and scattered dose is not a problem in view of Korea's safety management standards, but in view of Japan's safety management standards, it was identified that the dose exceeded the regulation at the barrier of the entrance of the general fluoroscopy laboratory.

According to these results, it is expected that if Korea adopts Japan's safety management standards and methods, insufficient safety management can be supplemented, and the exposure to radiation-related workers can be minimized.

3.2. *Dose analysis at the entrance and patient view window of the extracorporeal shock wave lithotripsy laboratory*

The structure of the barrier and the patient view window of the extracorporeal shock wave lithotripsy laboratory or general fluoroscopy laboratory differs according to the maximum tube voltage of the diagnostic radiation generating device.

If the maximum tube voltage exceeds 100KV, the barrier should be 1.5mm lead equivalent or more, and the patient view window should be 1.5mm lead equivalent or more. If the maximum tube voltage is less than 100KV, the barrier should be 1mm lead equivalent or more, and the patient view window should be 1mm lead equivalent or more.

In the extracorporeal shock wave lithotripsy laboratory or general fluoroscopy laboratory, the maximum tube voltage used is about 80-100kV, so the barrier and the patient viewing window must be at least 1.0mm lead equivalent. Therefore, all medical institutions that use extracorporeal shock wave lithotripsy using X-rays and general fluoroscopy devices must install a barrier and a patient view window of 1.0mm lead equivalent or higher.

In this paper, to verify the shielding performance of barriers and patient view windows used in extracorporeal shock wave lithotripsy laboratory and general fluoroscopy laboratory and to use them as the basis for safety management, The cumulative dose of leakage and scattered radiations were measured and analyzed [Table 2].

Table 2: Leakage dose analysis result at the entrance and patient view window of the extracorporeal shock wave lithotripsy laboratory (Unit: mSv)

Hospital	Entrance of the waiting room		Entrance of the control room		Patient view window	
	General fluoroscopy laboratory	Extracorporeal shock wave laboratory	General fluoroscopy laboratory	Extracorporeal shock wave laboratory	General fluoroscopy laboratory	Extracorporeal shock wave laboratory
A	2.73	-	-	-	-	-
B	8.31	-	4.56	0.21	-	-
C	1.79	-	-	-	-	-
D	-	-	-	-	-	-
E	4.23	-	1.23	0.13	-	-
평균	3.41	-	0.96	0.07	-	-

1cm dose equivalent measured with a glass dosimeter for 3 months at the control room entrance in the extracorporeal shock wave lithotripsy laboratory was a maximum of 0.21 mSv and an average of 0.07 mSv. 1cm dose equivalent measured with a glass dosimeter for 3 months at the patient's waiting room entrance, and the patient view window was measured to be less than the natural radiation dose.

1cm dose equivalent measured with a glass dosimeter for 3 months at the entrance of the patient's waiting room in the general fluoroscopy laboratory was a maximum of 8.31 mSv and an average of 3.41 mSv. 1 cm dose equivalent measured with a glass dosimeter for 3 months at the control room entrance was a maximum of 4.56 mSv and an average of 0.96 mSv. 1 cm dose equivalent measured with a glass dosimeter for 3 months at the patient view window was measured to be less than the natural radiation dose.

In the above experimental results, the cumulative dose of leakage at the entrance and the patient view window differed depending on the radiation energy and frequency of use of the extracorporeal shock wave lithotripsy device and the general fluoroscopy device. A relatively lower leakage dose was measured in the extracorporeal shock wave lithotripsy laboratory than in the general fluoroscopy laboratory, which is thought to be due to the difference in frequency of use and range of X-ray irradiation.

This study has limitations in that it is limited to medical institutions located in specific regions due to problems such as supply limitations and the cost of measuring glass dosimeters. In the future, the researcher thinks that continuous research on the entire radiation barrier facilities for diagnosis in medical institutions is necessary to supplement these problems.

4. Conclusion

Using a glass dosimeter, the 3-month cumulative dose of the radiation barrier in the extracorporeal shock wave lithotripsy laboratory and the general fluoroscopy laboratory was measured, compared, evaluated, and analyzed.

The cumulative 1 cm dose equivalent value measured with a glass dosimeter for 3 months outside the barrier at the extracorporeal shock wave lithotripsy laboratory's entrance and outside the control room's barrier was measured to be less than the natural radiation dose.

At the entrance of the control room of the extracorporeal shock wave lithotripsy laboratory, the cumulative 1 cm dose equivalent value measured with a glass dosimeter for 3 months was measured to be a maximum of 0.21 mSv and an average of 0.07 mSv. The cumulative 1cm dose equivalent value measured with a glass dosimeter for 3 months at the entrance of the patient caregivers' waiting room and patient view window was measured to be less than the natural radiation dose.

The cumulative 1 cm dose equivalent value measured with a glass dosimeter for 3 months outside the barrier on the entrance side of the general fluoroscopy laboratory was measured to be 0.86 mSv on average. The cumulative 1 cm dose equivalent value measured with a glass dosimeter for 3 months outside the barrier in the control room was measured to be less than the natural radiation.

The average cumulative 1cm dose equivalent value measured with a glass dosimeter for 3 months at the entrance of the patient caregivers' waiting room in the general fluoroscopy laboratory was 3.41mSv. The cumulative 1cm dose equivalent value measured with a glass dosimeter at the control room's entrance for 3 months was measured to be an average of 0.96mSv.

It is expected that the results of this research will be widely used as reference data for the safety management of radiation for diagnosis in the future. In addition, it is proposed to carry out continuous research and policy establishment at the national level for institutions that use medical radiation.

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References

1. Abe. T., Akakura. K., Kawaguchi. M., Ueda. T., Ichikawa. T., Ito. H. Outcomes of shockwave lithotripsy for upper urinary-tract stones: a large-scale study at a single institution. J. Endourol. 2005 19 (7): 768–73. doi:10.1089/end.2005.19.768.
2. Albala. D. M., Assimos. D.G., Clayman. R.V., Denstedt. J.D., Grasso. M., Gutierrez-Aceves. J., Kahn. R. I., Leveillee. R. J., Lingeman. J. E., Macaluso. J. N., Munch. L. C., Nakada. S. Y., Newman. R. C., Pearle. M. S., Preminger. G. M., Teichman. J., Woods. J. R. Lower pole I: a prospective randomized trial of extracorporeal shock wave lithotripsy and percutaneous nephrostolithotomy for lower pole nephrolithiasis-initial results. The Journal of Urology 2001 166 (6): 2072–80. doi:10.1016/s0022-5347(05)65508-5.
3. Anagnostou. T., Tolley. D. Management of ureteric stones. Eur. Urol. 2004 45 (6): 714–21. doi:10.1016/j.eururo.2003.10.018. PMC 3180306.
4. Auge B. K., Preminger G. M. Update on shock wave lithotripsy technology. Curr. Opin. Urol. 2002 12 (4): 287–90. doi:10.1097/00042307-200207000-00005.
5. Chacko J., Moore M., Sankey N., Chandhoke P. S. Does a slower treatment rate impact the efficacy of extracorporeal shock wave lithotripsy for solitary kidney or ureteral stones?. J. Urol. 2006 175 (4): 1370–3. doi:10.1016/s0022-5347(05)00683-x.
6. Y. H. Seoung. Effects of Tube Voltage and Tube Current on Exposure Index: Focused on Radiographic Images of Cone Pyramid Phantom. J. Korean Soc. Radiol. 2019 Vol. 13, No. 5, October pp 749-755. https://doi.org/10.7742/jksr.2019.13.5.749
7. C. G. Kim. Development of a Medical Phantom to Evaluate the Function of Low Dose 3D MDCT. Medico Legal Update. 2020 January-March; 20(1): 2025-2030. DOI: https://doi.org/10.37506/mlu.v20i1.677
8. C. G. Kim. Development of a Phantom for Low Dose Mammography. Medico Legal Update. 2020 January-March; 20(1): 1887- 1892. DOI: https://doi.org/10.37506/mlu.v20i1.653
9. C. G. Kim. Evaluation of Environmental dose in Diagnostic Radiation CT (Computed Tomography) Room. International Journal of Psychosocial Rehabilitation. 2020 Vol. 24, Issue 7, 1611-1617. DOI: 10.37200/IJPR/V24I7/PR270143
10. Jae Hoon Jeong, Chung Wun Lee, Yeon Wook You, Yeong Deok Seo, Ho Yong Choi, Yun Cheol Kim, Yong Geun Kim and Woo Jae Won. Evaluation of Radiation Exposure to Nurse on Nuclear Medicine Examination by Use Radioisotope. J Nucl Med Technol. 2017 May Vol. 21, No. 1: 44-49.
11. Jong-Won Gil. Comparing of the Administered Activities and the Effective Dose of the Various Pediatric Dose Formulas of Nuclear Medicine. Journal of the Korea Convergence Society. 2017 Vol. 8. No. 8: 147-154. DOI: https://doi.org/10.15207/JKCS.2017.8.8.147
12. Jong-Ryul Seon, Jong-Won Gil. Study on Development of Patient Effective Dose Calculation Program of Nuclear Medicine Examination. Journal of the Korea Academia-Industrial cooperation Society. 2017 March; Vol. 18, No. 3: 657-665,DOI:https://doi.org/10.5762/KAIS.2017.18.3.657

13. Chaerim Song, Wanghui Lee, Sungmin Ahn. A Measurement of Exposure Dose for Patient Transporter. "J. Korean Soc. Radiol.. 2019 June; Vol. 13, No. 3: 433-438. DOI: https://doi.org/10.7742/jksr.2019.13.3.433
14. Han S. C., Hong D. H. Measurement of Spatial Dose Distribution for evaluation operator dose during Neuro-interventional Procedures. Journal of Radiological Science and Technology. 2016 March; Vol. 39, No. 3: 323-328. DOI: 10.17946/JRST.39.3.04
15. Yoon H. J., Lee Y. K., Lee I. J. Measurement of the Spatial Scattering Dose by Opening, Closing Door and Installing Shielding: A Study on the Reduction of Exposure Dose in Radiography. Journal of Radiological Science and Technology. 2019 42(6): 477-482. DOI: 10.17946/JRST.42.6.477
16. Park C. W., Cho P. K. Dose Reduction According to Geometric Parameters of Digital Cerebral Angiography. J. Korean Soc. Radiol. 2019 June; Vol. 13, No. 3: 399-406. DOI: http://dx.doi.org/10.7742/jksr.13.3.399
17. Kim D.H., Kim S.H., Lee Y.J., Lim J.C., Han D. K. Study on Exposure Dose and Image Quality of Operator Using Shielding. J. Korean Soc. Radiol. 2017 December; Vol. 11, No. 7: 579-587. DOI: http://dx.doi.org/10.7742/jksr.11.7.579