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Study on Radiation Exposure Dose According to Operating Conditions of Radiation Generator

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1. Introduction

Overexposure to radiation is very rare however, in such a case, it may have acute and long-lasting consequences in life. There have been cases of radiation injuries recorded over the years in various sectors [1] . The major factors of ionizing radiation accidents identified by the International Atomic Energy Agency include inadequate routine monitoring, violations of operating procedures, inadequate training, poor maintenance, human error, malfunction or defects in equipment, and intentional violations [2].

There was a worrying example of a certain company in Korea. The accident involved an X-ray generator that was used to inspect the defects of products. Out of negligence while handling the equipment, several workers were exposed to radiation. This was because, the safety interlock device was intentionally disabled, allowing the door to be opened while operating [3].

This paper discusses the dose changes accumulated in organs due to exposure to direct or scattered radiation beams in accident conditions. It gives insight into making operation procedures safer and more protective against radiation in an industrial setup.

2. Method And Material

To assess the radiation dose of the x-ray generator in the accident conditions, computational dosimetry was performed using the mesh-type ICRP adult male reference phantom described in the ICRP 145 [4] together with a Geant4 toolkit(ver.10.04) [5]. As shown in Figure 1, the dimensions of the X-ray generator were determined by referring to the equipment from where the actual radiation accident occurred, and the X-ray spectrum was obtained based on information provided by the manufacturer [3].

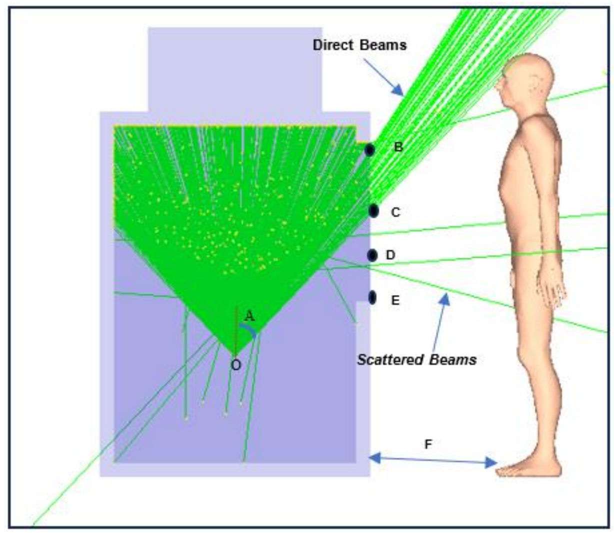

Figure 1.Simulated geometry of X-ray generator

Figure 1 shows the setup of the simulated geometry of the X-ray generator with a point X-ray source and the abnormally opened door through which the radiation beam emerges. The angle A may be adjusted to about 32°, 43°, 54°, or 65° so that direct beams emerge through the door at segments not beyond boundary lines (o-B, o-C, o-D, or o-E) respectively. Two angles (32° and 65°) were calculated from the door dimensions, and the others (43° and 54°) were determined by equally dividing the angles. Distance F is the distance from the X-ray generator to the phantom, it changes from 0cm to 250cm. The physics library of the Geant4 (G4EmLivermorePhysics) was used to transport electron particles as well as photons. The statistical errors of the calculated values were all less than 10%.

3. Results and discussion

Results revealed two types of exposure: direct beam exposure and scattered beam exposure. Both types of exposure were well controlled by angle A and distance F, as shown in the figure1.

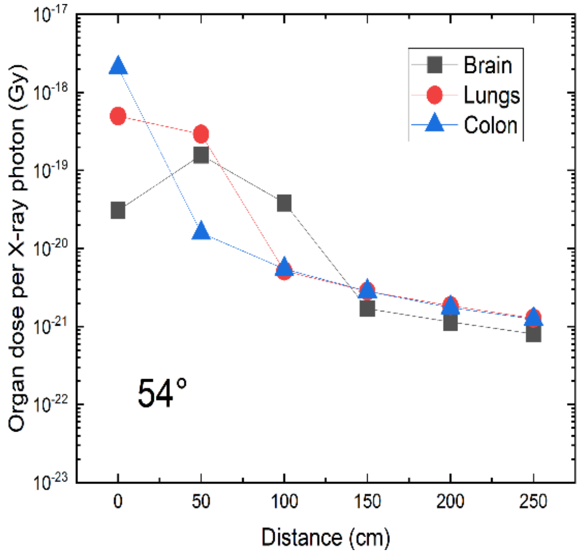

Figure 2. Dose pattern in a human body at angle A equal to 54°

Figure 2 shows that the lungs have almost 10 times higher doses than the brain at 0cm. That means the brain is not fully exposed to direct beams as other organs are. However, the brain shows a significant dose increase of about 7 times at 50cm, confirming that it has become fully exposed to direct beams. At long distances beyond 125cm, the dose pattern starts to overlap with a little bit of differences for all organs, this is due to almost the same exposure condition in the scattered beams.

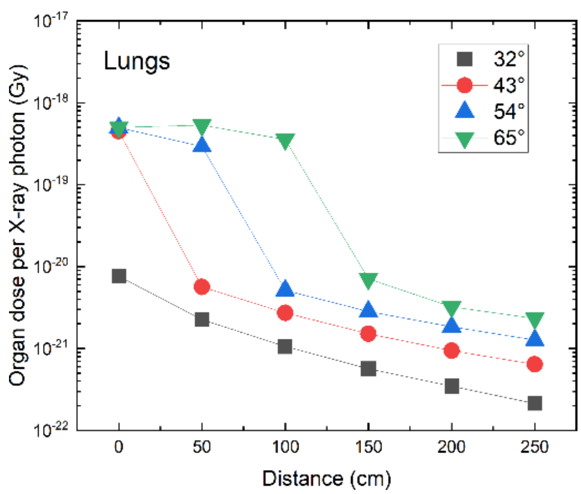

Figure 3. Dose pattern of lungs

Figure 3 shows that at short distances, significant dose exposure has been delivered to the lungs at all angles except the smallest angle, which is the result of enabling the propagation of the direct beams toward the lungs' location. A similar pattern appeared in the effective dose calculation result since the lungs have a high tissue weighting factor of 0.12 and they are the main organs surrounded by the direct beams. Therefore, the lungs' position is the best choice for wearing a personal dosimeter. Out of the direct beam range, the dose of the other positions exposed to the scattered beams are insignificant.

4. Conclusion

The use of X-ray generators shall be necessary, but radiation protection should be prioritized, and the exposure dose should be kept at an absolute minimum. In addition, the door must be closed for shielding, and the narrow-angle X-ray generator is recommended for safety against abnormal accident conditions.

The workers shall strictly adhere to the fundamentals of radiation protection by minimizing the exposure time, keeping the maximum possible distance from sources, and using protective equipment correctly. Furthermore, remember to locate a personal dosimeter at a lung position so that it can measure effective doses completely.

5. References

[1] K. Coeytaux, E. Bey, D. Christensen, E. S. Glassman, B. Murdock, and C. Doucet, "Reported radiation overexposure accidents worldwide, 1980-2013: a systematic review," PloS one, vol. 10, p. e0118709, 2015.

[2] N. Abd Razak, S. A. Othman and A. M. A. Halim, "Safety in Industrial Radiography: A Short Review," Emerging Advances in Integrated Technology, vol. 3, p. 60–64, 2022.

[3] KINS, "Investigation of Radiological Event(2019)," Daejeon, 2019.

[4] ICRP, "Adult Mesh-type reference computation phantoms," publication145, 2020.

[5] S. Agostinelli, J. Allison, K. a. Amako, J. Apostolakis, H. Araujo, P. Arce, M. Asai, D. Axen, S. Banerjee, G. J. N. I. Barrand and others, "GEANT4—a simulation toolkit," Nuclear instruments and methods in physics research section A: Accelerators, Spectrometers, Detectors and Associated Equipment, vol. 506, p. 250–303, 2003.