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

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Introduction

Overexposure to radiation is very rare. However, when it happens, 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, malfunctions or defects in equipment, and intentional violations [2].

There was a worrying example of a certain company in South 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.

Methods and Materials

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]. 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].

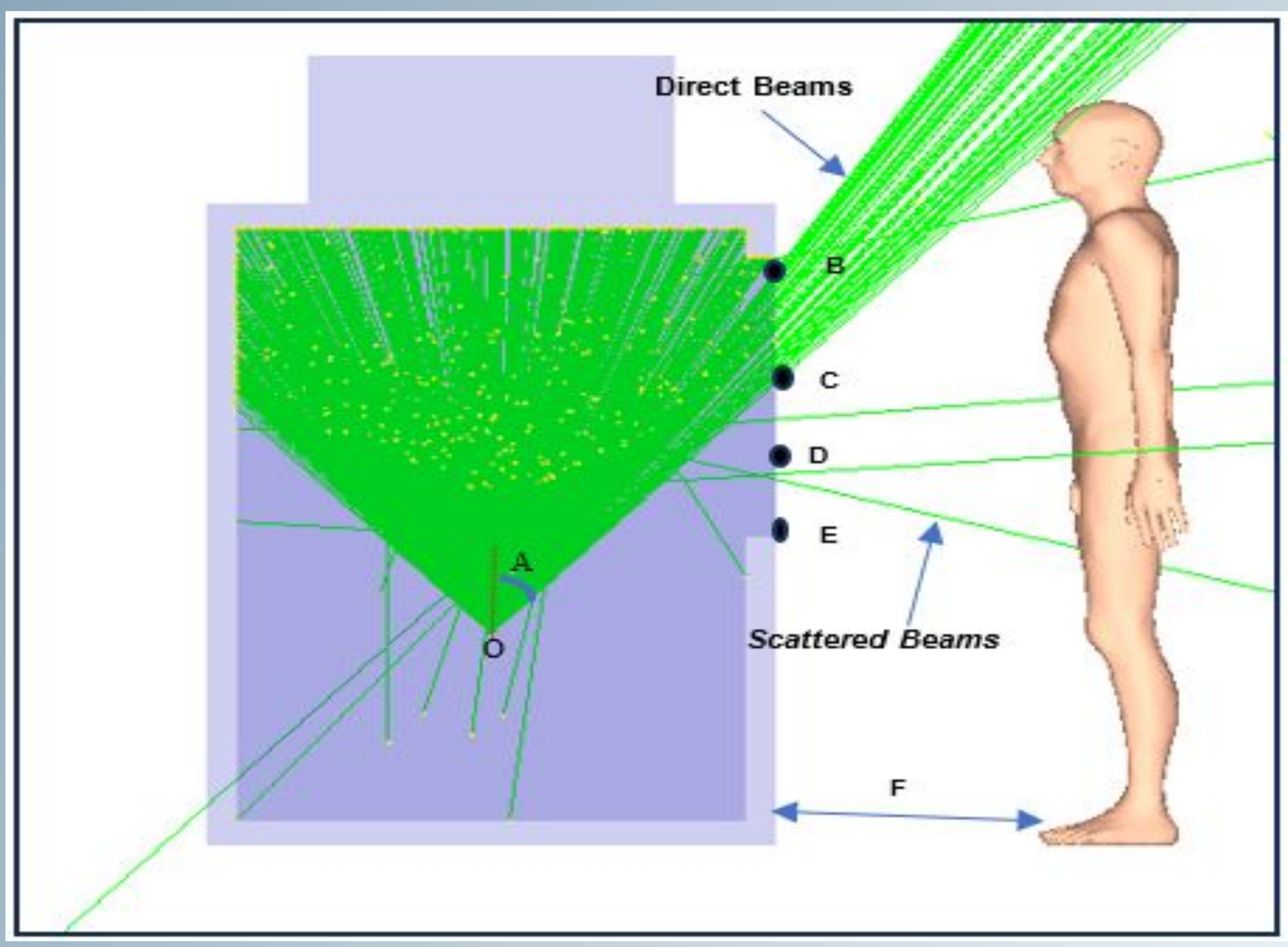

Figure 1. Simulated geometry of X-ray generator

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. F is the distance from the X-ray generator to the phantom; it changes from 0 cm to 250 cm. The physics library of the Geant4 (G4EmLivermorePhysics) was used to transport electron particles and photons. The statistical errors of the calculated values were all less than 10%.

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 previously presented in Figure 1.

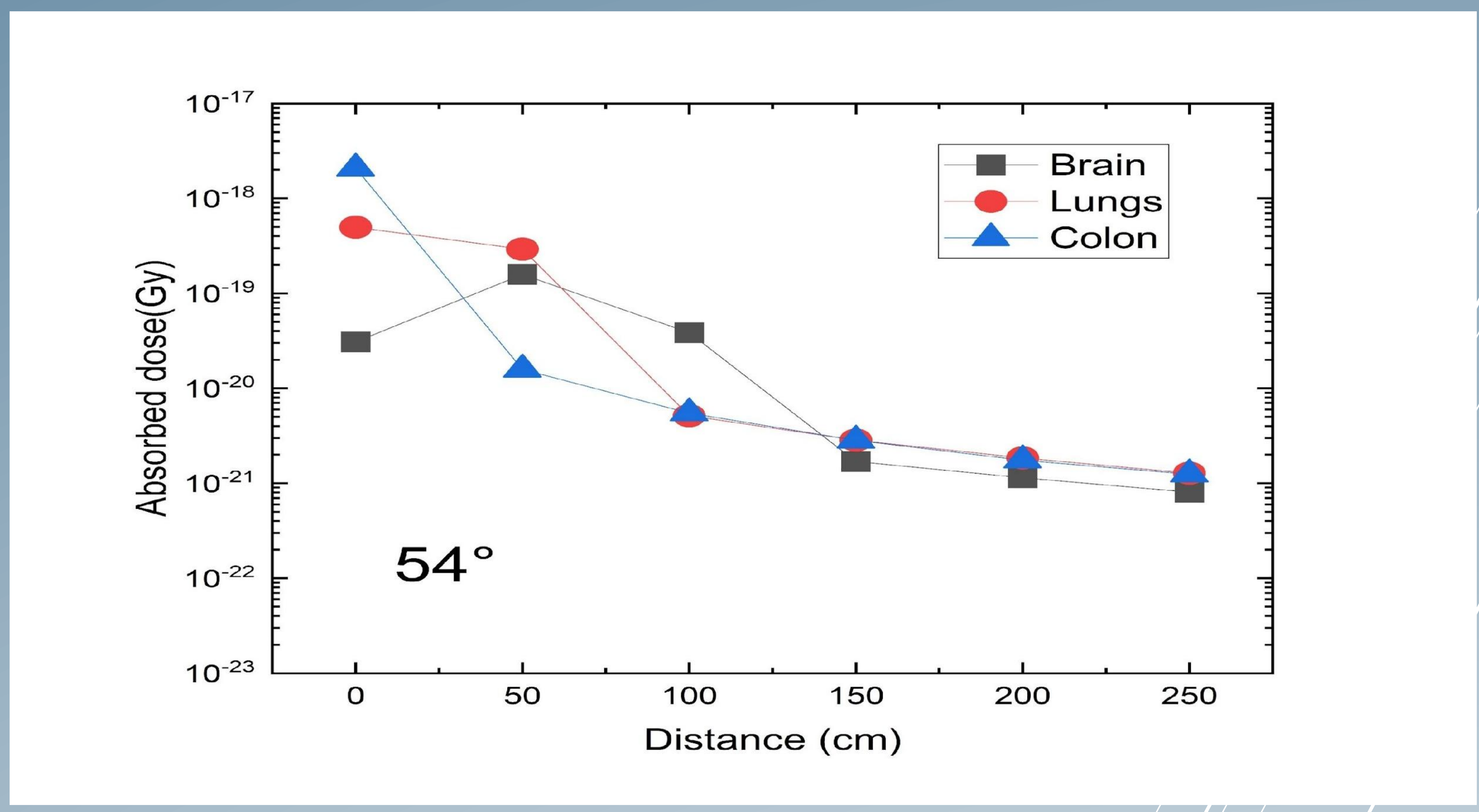

Figure 2. Dose pattern in a human body at angle A equal to 54°

Figures 2, and 3 illustrate that the lungs receive almost 10 times higher doses than the brain at 0 cm. This implies that the brain may not fully be exposed to X-ray propagations from the direct beam, unlike the colon, and the lungs.

However, the brain receives a significant dose increase of about 7 times than the lungs at 50 cm, confirming that it becomes fully exposed to direct beams by the beam propagation as presented in Figures 2, and 4.

Notably, at longer distances beyond 125 cm, the dose pattern starts to overlap with a little bit of differences for all selected organs, due to almost similar exposure conditions for the scattered beams.

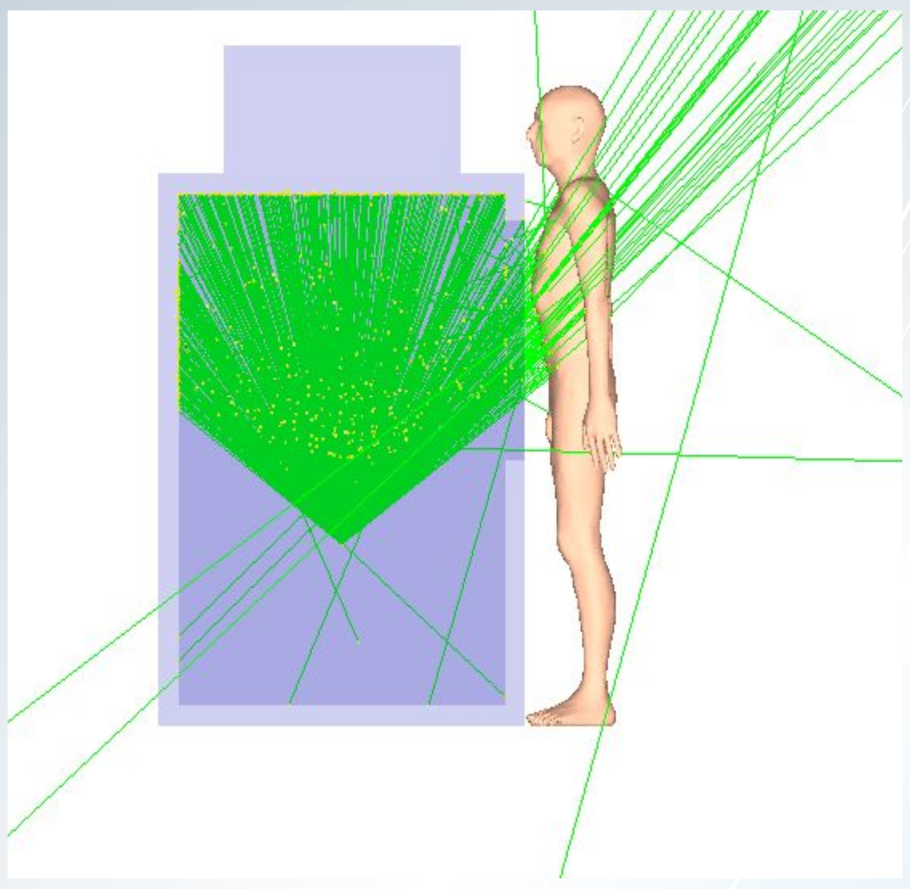

Figure 3. Propagation of direct beam through phantom at 0 cm distance

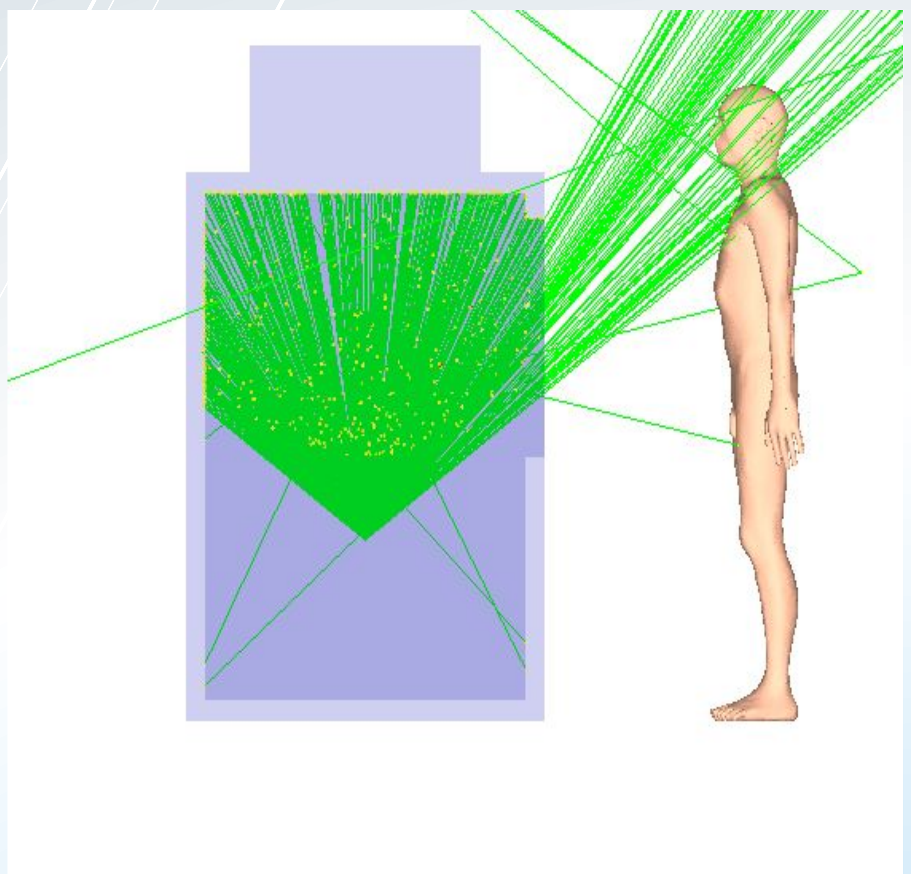

Figure 4. Propagation of direct beam through phantom at 50 cm distance

Conclusion and recommendation

X-ray generators are 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 focused x-ray generator (narrow-angle x-ray generator) is recommended for safety against abnormal accident conditions.

The workers should strictly adhere to the fundamentals of radiation protection by minimizing the exposure time, keeping the maximum possible distance from X-ray sources, and using protective equipment correctly.

Furthermore, workers must wear a personal dosimeter, preferably in a lung position, so that it can accurately measure the effective dose.

References

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