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Effect of X-ray Room Size on Patient Dose

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1. Introduction

During medical radiography the primary X-ray beam is directed towards a patient's body and collimated to a specific area of anatomic interest. The patient's body scatters the X-ray radiation through-out the room and to the X-ray room walls. The radiation scattered by the patient is the most significant source of radiation dose to workers [1]. Consequently, considerable research has been done on scatter radiation in medical practice since 1921 [2]. The objective of a significant number of research papers on scatter radiation dose distribution in Diagnostic, and Interventional Radiology (IR) rooms is to minimize operator and public doses. Therefore, conventional wisdom is that it is acceptable to mitigate the high scatter radiation due to small X-ray rooms by thicker shielding to protect members of the public and occupationally exposed workers [3].

However, research has not covered the effect of radiation scattered from the walls on patient dose. For radiation protection purposes, optimization of patient dose in diagnostic radiography requires that unnecessary and avoidable dose to patients be eliminated in order to achieve high diagnostic gains while minimizing possible harm from radiation [4]. It is thus important to determine whether the X-ray room size has a significant effect on patient dose. Consequently, the objective of this study is to use Monte Carlo simulation to compute the total dose received by a patient undergoing diagnostic radiography examinations in order to determine the effect of X-ray room size on patient dose.

2. Materials and methods

The investigation of the effect of X-ray room size on patient dose requires that all conditions in the X-ray room be kept constant except the room size. This was achieved by implementation of the Particle and Heavy Ion Transport code System (PHITS) version 3.10 Monte Carlo method [5]. PHITS simulations were implemented on a computer with Intel® Core™ i7-6700 CPU @ 3.40 GHz quad-core and eight threads processor, 16.0 GB RAM, and 64-bit Windows 7 Enterprise.

The PHITS model used for the transport of photons electrons and, positrons was based on the Electron Gamma Shower Version 5 (EGS5) [6]. The cut-off energy for electrons, positrons and photons were all set at 0.001MeV. The maximum energy for photons electrons and positrons was set at 0.120 MeV.

This study simulated six diagnostic radiography rooms with different floor dimensions as shown on Table I. However other geometry aspects of the simulation were kept constant. The rooms had a floor to roof height of 3 m and 30 cm concrete walls. The floor and roof of the rooms were also made of 30 cm of concrete.

Table I: X-ray room floor dimensions

	Length (m) along z-axis	Length (m) along x-axis	Height (m) along y-axis
1	3	4	3
2	4	3	3
3	4	4	3
4	4	5	3
5	5	4	3
6	5	5	3

The patient's body was simulated with an IAEA 30 cm cubic water phantom. The bottom surface of the phantom was placed 70 cm above the floor and located at the center of the X-ray room walls.

The X-ray spectrum used in the simulation was generated with SRS-78 software. A tungsten target was used to generate an X-ray beam at a tube voltage of 120 kVp with sinusoidal waveform ripple value of 0%. The target angle was set at 12°. The filtration used was 2.5 mm Al. Fig. 1 shows the photon spectra calculated by SRS-78. The photon spectrum was calculated at a distance of 700 mm in air from the anode focal spot and centered about the central ray. A data set of the energy bins and their probability value calculated as a normalized value of the x-ray intensity was imported into PHITS. The tally results were normalized for an exposure of 0.7 mAs.

The X-ray source was placed 70 cm above the top surface of the phantom. A 3 cm thick rectangular shaped collimator made of lead was used to control the radiation projection on the phantom. The collimator was positioned 2cm below the X-ray source and set at 2.1428 cm x 2.1428 cm.

The time required to stabilize the dose results to a relative error of 0.0001 was about 5 hours and 42 minutes.

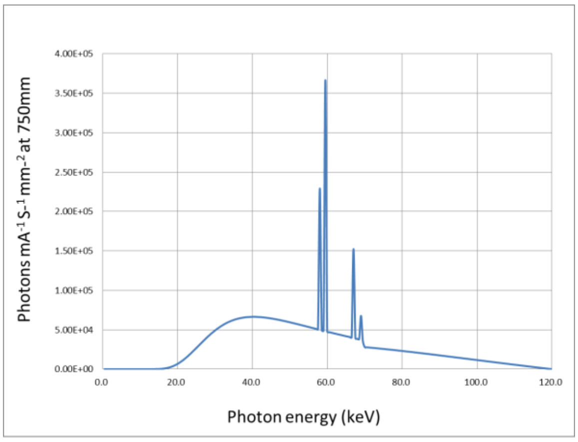

Fig. 1. Calculated photon spectra: 120 kVp with 0% ripple, 12 degrees tungsten target, 2.5 mm Al filtration, 700mm air

3. Results and Discussion

Table II shows the effective dose received by a patient in six different x-ray rooms calculated by PHITS code. The Table also shows the absolute change in patient dose in comparison to that received in the smallest room of 3m x 4m floor area. The percentage relative change in patient dose is also shown on Table II.

Table 2: Calculated effective dose to the patient in X-ray rooms of different sizes

Room size (m)	Effective dose (mSv)	Absolute change (mSv)	Relative change (%)
3x4	7.4910E-02	0.0E+00	0.0000
4x3	7.4910E-02	0.0E+00	0.0000
4x4	7.4906E-02	-4.0E-06	-0.0053
4x5	7.4904E-02	-6.0E-06	-0.0080
5x4	7.4906E-02	-4.0E-06	-0.0053
5x5	7.4905E-02	-5.0E-06	-0.0067

The results show that an in increase in room size result in a small non-significant decrease in patient dose. The decrease in dose is not significant relative to the large dose that the patient receives due to the primary beam for diagnostic purposes.

4. Conclusions

The research shows that X-ray room size has an insignificant effect on patient effective dose in x-ray rooms of floor areas ranging from 12 m^2 to 25m^2 at standard chest exposures of 120 kVp and 0.7 mAs.

This research will be used as a basis for future studies on the effects of x-ray room size on patient dose. Further future research includes using the ICRP adult phantom as the patient, investigating the effects of room size in Interventional radiology, and radiotherapy.

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