# Estimation of Patient and Physician Doses in Interventional Cardiology Using ICRP Male Phantom and Hybrid Phantom VOXMAT

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## INTRODUCTION

In interventional radiology, both the patient and the physician are exposed to radiation. The patient is exposed to radiation from the primary beam, and the cardiologist, performing the procedure on a regular basis, is mostly exposed to scattered radiation from the patient or the operation table. The dose to the patient and the physician has been investigated previously using either scaled VIP-man voxel phantom [1] or mathematical phantom models [2, 3]. In all these previous studies, the physician was assumed to be in the vertical-upright position.

In this study, the patient and physician doses are estimated simultaneously. First, the physician and patient are modeled using the International Commission on Radiation Protection (ICRP) standard male phantom models [4]. To determine the impact of the physician's posture on the estimated dose values, the VOXMAT phantom model is used to generate a more realistic posture. VOXMAT, which was recently developed at Oak Ridge National Laboratory (ORNL), uses a combination of voxelized geometry for the head and torso and stylized geometry for the arms and legs [5]. This phantom is based on the ICRP's male phantom model.

In this paper, the comparative computational results for the estimated dose values are presented.

## DESCRIPTION OF THE ACTUAL WORK

For the analysis, three different configurations were considered. In all these cases, the patient model is based on ICRP's male phantom. The phantom model for the physician is varied and the cases include:

1. ICRP's male phantom model in vertical-upright position, as depicted in Fig. 1 (left),
2. VOXMAT phantom model in vertical-upright position, to ensure that the results agree with the previous case, and
3. VOXMAT phantom model in a more realistic posture, as illustrated in Fig. 1 (right).

In all the computational models, the patient lies down on the table in supine position. The dimensions of the table, which is made of Bakelite, are 200 × 60 × 10 cm. The table is 60 cm above the floor. A 1 cm thick air cell, with an area of 10 x 10 $cm^2$, was placed between the patient and operation table to calculate the dose-area product (DAP). The PA (Posterior-Anterior) source exposure geometry with three tube potentials (80, 100, and 120 kVp) [1] was used. The beam was chosen to have a 10×10 $cm^2$ field of view centered at the heart of the patient.

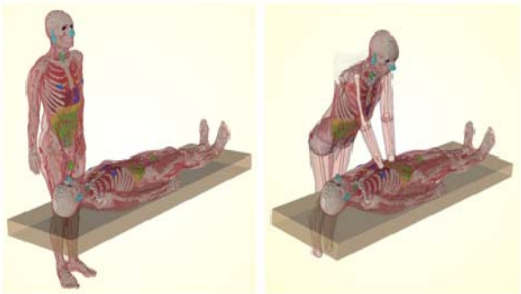

Fig. 1 The geometrical setting for patient-physician modeling. The physician model is based on the ICRP male model (left) and VOXMAT with a more realistic posture (right).

Although not shown in the figures, in the simulations, the physician is placed behind a 0.5 mm thick lead apron from below the jaw line to knee level. For the effective dose calculations, 1 cm diameter spheres were placed at thyroid, chest, and waist levels, on and under the lead apron. The organ dose values for all configurations were computed using the MCNPX [6] Monte Carlo radiation transport code on a Linux cluster.

## RESULTS

The computations were performed using $2x10^9$ particles, and the relative errors in organ dose values for these source energies are less than 5% for all cases. The absorbed dose in major organs was determined using the energy deposition (F6) tally of MCNPX. The organ equivalent doses are equal to corresponding absorbed doses since the radiation-weighting factor ($w_R$) for photons is equal to 1. The computed organ absorbed dose values were divided by DAP (Gy-$cm^2$).

The computed organ dose values for the physician for Cases 1 and 2 were in good agreement with each other within statistical fluctuations.

The equivalent dose values for the physician for the vertical-upright position (V) and the realistic position (R) using VOXMAT are presented in Fig. 2. In the following figures, "Remainder" refers to the average organ dose values of adrenals, gall bladder wall, heart wall, kidneys, lymph nodes, pancreas, prostate, spleen, and thymus. As evident from this figure, the estimated dose values are higher for the realistic posture for the majority of the organs. Further, to show the effect more clearly, the ratios of organ dose values using the realistic posture against the vertical-upright position are presented in the inset of Fig. 2. As apparent from the ratios, the impact of posture is most pronounced for the brain (ratio > 15) followed by the eye lenses (ratio > 7). With the exception of the testes (ratio < ~0.7), the estimated dose values are higher in the realistic posture for all of the critical organs.

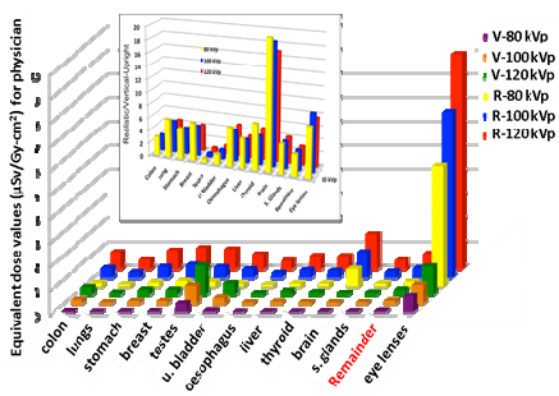


Fig 2. Equivalent dose values, in µSv/Gy-cm$^2$, as a function of tube voltage for critical organs of the physician for vertical-upright position (V) and realistic posture (R). The ratios of the computed organ dose values using realistic posture vs vertical-upright position are shown in the inset.

The equivalent organ dose values for the patient are shown in Fig. 3. As expected, the patient organ dose values are significantly higher than the physician dose values. Moreover, there is no statistically significant change in the patient organ dose values with the change in the physician's posture.

The preliminary computational results demonstrated that the estimated organ dose values for the physician vary significantly with the posture. Furthermore, the impact on the estimated dose values depends on the organ location and source energy. In this summary, only the results for the PA geometry for a few tube voltages are presented. In the full paper, other source configurations and energies will be investigated as well.

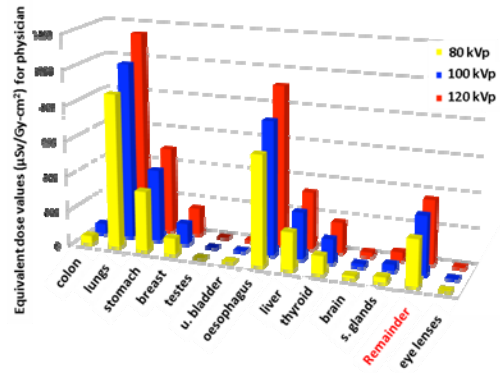


Fig. 3. Equivalent dose values, in µSv/Gy-cm$^2$, as a function of tube voltage for critical organs of the patient.


## ACKNOWLEDGEMENTS

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