LOCAL RADIATION DOSIMETRY OF WORKERS USING OPTICALLY STIMULATED PULSED LUMINESCENCE AND MONTE CARLO SIMULATION

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1. Background and Goal of the present work

A total of 54 radiation workers at TEMARA Regional Hospital were monitored from October 2021 to July 2022.

Optically stimulated luminescence (OSL) dosimeters are used to measure radiation doses of personnel working in conventional and interventional radiology departments (the departments involved radiology, traumatology, pediatric surgery, cardiology and urology).

The average annual individual dose in the different categories is less than 1 mSv/year and no individual approached the ICRP recommended dose limit of 20 mSv.

a monte carlo simulation study was conducted to investigate the dose received by workers in all categories and compare them with the results of dosimetry monitoring.

2. Method and material

Two hospitals belonging to the regional hospital center of Temara were included in this study.

A workstation study before the beginning of this study was conducted using a STEP- OD-02 radiation meter, to verify the shielding of the rooms and their tightness.

Each worker has two detectors (dosimeters) that ensure the continuity of collection of radiation doses of OSL type (OSL optically stimulated luminescence based on aluminum oxide (Al_2O_3: C) of small type (nanoDot)) according to the IAEA guidelines.

The dosimeter is worn at chest level to estimate the personal dose equivalents Hp(10) and Hp(0.07). Hp(10) was used as the best estimate of effective dose.

The GATE code, in this work, was used to perform the particle transport included in the dosimetric monitoring. Due to the different interactions with the target material, the transport of photons generated by these interactions is followed until it is completely absorbed or leaves the region of interest. For photon transport, the code uses photoelectric and Compton cross sections for electromagnetic radiation and for electrons, fluorescence and Bremsstrahlung emission are simulated by the code using the differential cross section. The energy loss model of the continuous slowing approach is used for the electron transport. In order to track all particles through a large energy loss, the GATE code chops the electron path into several phases [19]. [20] Except for the calculation of energy loss and scattering, the simulation of the electron history takesplace during the sampling of the substeps; a cutoff energy value for inelastic collisions and Bremsstrahlung emission has been defined at 250 eV. [15]

For all activated interactions, the PENELOPE and STANDARD cross sections are chosen as they are considered more accurate at low energies [21]. The phase space was used to collect information about all particles created at the exit of the X-ray tube. The phase space calculation takes approximately 160 hours of CPU time on an Intel Core i5 computer at 2.71 GHz. The phase space collects information on about 10^{11} transported particles. Due to the low probability of photon emission in the diagnostic energies, Bremsstrahlung splitting is used as a variance reduction technique for the phase space calculation. Thus, we began by defining the source of electrons ($4*10^{8}$ electrons are simulated, the use of a large number of particles in the sources, allowed us to obtain a relative statistical uncertainty due to the number of photons at each energybin was less than 3%).

3. Results

To validate the developed Monte Carlo code, the results were compared with the results of dosimetric monitoring (via OSL dosimeters). The Monte Carlo method uses energy deposition to determine the absorbed dose at the points of interest. That is, by simulating the complete history of each particle.

Comparison between measured and simulated values of H*p*(10) and H*p*(0.07) are shown in Tables 1 and 2 respectively.

Table 1. Comparison between measured and simulated values of Hp(10).

Categories ofworkers	Number	Average annual individual dose (OSL)	SD	Average annual individual dose MC GATE	SD	Difference (%)
conventional radiology	15	0.28 mSv	0.13	0.43 mSv	1.8	34
interventional radiology	39	0.65 mSv	0.11	0.73 mSv	1.4	10

Table 2. Comparison between measured and simulated values of Hp(0.07).

Categories ofworkers	Number	Average annual individual dose (OSL)	SD	Average annual individual dose MC GATE	SD	Difference (%)
conventional radiology	15	0.21 mSv	0.23	0.35 mSv	1.1	4
interventional radiology	39	0.44 mSv	0.1	0.79 mSv	1.2	4.5

Table 1 and 2 show the simulated H*p*(10) and Hp(0.07) compared to the OSL dosimeter measurements and the associated standard deviations. For the Monte Carlo data, the uncertainty takes into account the statistical uncertainty and an uncertainty associated with the air kerma value due to normalization. As for the uncertainties associated with the measurements, they are related to the random and systematic errors of the measurement conditions and the way the dosimeters are worn.

Several main approaches were adopted to speed up the simulation process, use of a variance reduction technique to calculate the operator doses; simplification of the geometry, application of the kerma approximation method. This approximation is valid for the energy range of radiology, and finally the cut-off energies for electrons and positrons have been set to maximum values so that the transport of these charged particles is not taken into account and the simulation times are therefore reduced.

CONCLUSION

The study consisted in validating the Monte Carlo simulation code GATE in dosimetric monitoring by comparing the results with results obtained by OSL dosimeters of workers in the regional hospital of TEMARA in Morocco. An agreement was observed between the Monte Carlo simulation results and the experimental values.

The average individual annual doses for different workers were less than 1 mSv per year. The maximum doses of all occupationally exposed workers were well below the national dose limit of 20 mSv per year. Furthermore, all doses during the last fourteen years were below the annual investigation level for workers in interventional radiology which is equal to 6 mSv.