Abstract. In this paper the general purpose Monte Carlo code MCNP5 was used to study the effects of medical linear accelerators positioned in unusual conditions in the calculation methods for shielding design of radiotherapy facilities. It was found that these unusual conditions should be taken into account when projecting the treatment rooms. Photon doses at the door can reach values up to 20 times higher than those obtained at standard condition, depending on the energy of the primary beam.

KEYWORDS: shielding techniques; medical physics, MCNP

1. Introduction

Shielding requirements for medical linear accelerators rooms are based, besides other factors, on the photons energies, yield of the equipment and field sizes that can produce high dose rates outside the vault. One of the choices to be made when projecting such a room is the use of a maze or a direct-shielded door. The maze is the most common alternative since it reduces the radiation levels at the entrance of the room, due to scattering of photons, avoiding doors that have to be hydraulically driven [1].

Since the advent of teletherapy, both equipment and treatment techniques have improved significantly, as have regulatory rules for radiation exposure to the workers and public. Numerous publications have become available over the years to elucidate the effects of these changes on shielding techniques. For example, most radiation therapy facilities are designed with the gantry rotation plane orthogonal to the primary barriers, as illustrated in Figure 1.

There are occasions, specially when a room has to be re-shielded to receive a machine, such as $^{60}$Co equipment or a low energy medical linear accelerator (< 10 MV), that it is desired to place the machine in the room with its axis of gantry rotation at, for example, 45 degrees with respect to the walls of the room, as illustrated in Figure 2.
In order to evaluate the dose rates at the maze entrance, the calculational methods described in NCRP 151 [1] should be used. These methods take into consideration that the radiation reaching the maze door is due to scattering of photons from the room surfaces and patient, in addition to direct penetration of head-leakage radiation in the inner maze wall. These components are:

i) Dose equivalent per week due to scatter of the primary beam from the room surfaces ($H_s$);

ii) Dose equivalent per week due to head-leakage photons scattered by the room surfaces ($H_{ls}$);

iii) Dose equivalent per week due to primary beam scattered from the patient ($H_{ps}$) and

iv) Dose equivalent per week due to leakage radiation which is transmitted through the inner maze wall ($H_{lt}$).
Nonetheless, the calculational methods described in NCRP 151 take into account some parameters, as wall areas and reflection coefficients, which are not easy to assess in some conditions, like the 45 degrees condition described in Figure 2. In order to study problems like that, Monte Carlo simulations are very useful and have been applied to solve lots of complex problems related to shielding calculations [2-4].

In order to study the photon streaming inside the maze of treatment rooms, for typical bunkers, the general purpose Monte Carlo code MCNP5 has been used [5]. MCNP is a well-known general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron or coupled neutron/photon/electron transport within an arbitrary three-dimensional configuration of materials in geometric cells; relating the created geometries with various classes of materials. A variety of sources can be defined by the user, from where electron, photon and neutron emission is simulated, with probability distributions for energy and direction defined by the user. Subsequently, interactions are simulated according to the type of particle and material properties, as well as the production of secondary particles, which can be assessed for both particle fluence and energy deposition.

In this work the general purpose Monte Carlo code MCNP5 has been used to study the effects produced to the dose rates at the maze door, for medical linear accelerators positioned in 45 degrees with respect to the walls of the room, considering $^{60}$Co photon energies, 4, 6 and 10 MV beams.

2. Materials and Methods

In the simulations performed in this work, besides the $^{60}$Co energies, the radiotherapy beams of 4, 6 and 10 MV given by Daryoush and Rogers [6] were used. Daryoush and Rogers (2002) did wide-ranging simulations of nine beams from three major medical linac manufacturers, from 4 MV to 25 MV equipments. The barriers of the simulated room are composed by ordinary concrete with density 2.35 g/cm³ and the divergence of the simulated beam was set to limit the primary spectra to a field size of 40 cm X 40 cm at 1 m from the target, corresponding to the maximum field size at the isocenter for some common linacs. The F5 MCNP tally was used in this work to provide photon fluences at the treatment room doors. Following, conversion coefficients were applied in order to convert the simulated fluences in the operational quantity ambient dose equivalent (H*).

The results of the simulations were compared with the data obtained by using the NCRP 151 calculational methodology, for the cases where the linear accelerators are at usual condition, as illustrated in Figure 1. For the 45 degree condition (Figure 2), only the Monte Carlo simulations are able to give reasonable results, due to the difficulties related to the solution of the empirical methods for these situations, as described before. However, for these situations, results from the NCRP 151 calculational methods were not provided.

3. Results

The results of the simulations are presented in Table 1. For the usual condition of irradiation, it was found that in all the cases studied, the NCRP 151 calculational methods give a conservative estimation of the photon doses at the door. On the other hand, for the 45 degree condition, it was observed that the simulated photon doses at the door can reach values up to 20 times higher than those obtained at standard condition.
Table 1: Comparison between photon dose rates at the door, obtained by the NCRP 151 calculational methods and Monte Carlo simulations (µ Sv).

<table>
<thead>
<tr>
<th>Type of beam</th>
<th>Standard Condition</th>
<th>45 degree condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculation</td>
<td>Monte Carlo</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>0.18</td>
<td>0.49</td>
</tr>
<tr>
<td>4 MV</td>
<td>0.78</td>
<td>0.58</td>
</tr>
<tr>
<td>6 MV</td>
<td>1.70</td>
<td>0.68</td>
</tr>
<tr>
<td>10 MV</td>
<td>4.00</td>
<td>0.91</td>
</tr>
</tbody>
</table>

4. Conclusions

When a therapeutic radiation unit, 60Co unit or linear accelerator, is placed in a treatment room in an unusual position, at 45 degrees with respect to the walls of the room, photon doses at the door can reach values up to 20 times higher than those obtained at standard condition, depending on the energy of the primary beam.

REFERENCES