Shielding evaluation for a radiotherapy bunker by NCRP 151 and Portuguese Regulation on radiation safety

CENTRO HOSPITALAR LISBOA NORTE, EPE

HOSPITAL DE SANTAMARIA

Maria Jose Rodrigues[1], Maria Esmeralda Ramos Poli[2]

[1]Institute of Biophysics and Biomedical Engineering, Faculty of Sciences of the University of Lisbon, Lisbon, Portugal
[2] Medical Physics Unit, Santa Maria Hospital, Lisbon, Portugal

1. Introduction

NCRP Report No. 151 (2005) [1] concerned with radiation safety is one of the most suitable documents for structural shielding design and evaluation in modern radiotherapy facilities. For radiation safety purposes, the barriers thicknesses must be designed to attenuate the radiation emitted directly from the equipment (primary radiation) as well, leakage and scatter radiations (secondary radiation). The current Portuguese Regulation DL 180/2002 (DL) [2], recommends the German Standard DIN-6847 (1977) [3] for a radiotherapy bunker with a linear accelerator (linac).
The purpose of this work was to establish a comparison between both norms, NCRP 151 and DL 180/2002 (following DIN-6847 method), for the primary and secondary barrier thicknesses.

2. Materials and Methods

The methods to calculate barrier thickness were carried out for a bunker (*see figure 1 and 2*) with Elekta-Synergy linac, with maximum nominal energy of 15 MV, and 3D conventional treatments (3D-CRT). The linac isocenter was located at 1 m from the radiation source and it was assumed a symmetric distribution of gantry treatment angles.

For both, NCRP 151 and DIN-6847, these calculations were based on the tenth-value layer (TVL) concept, and in this study were used the TVL values recommended in each norm for the same shielding material, the ordinary concrete. In both cases, the workload (W) of 737,18 Gy/week was used.

Two approaches were used for the input data: **1) first approach**, using the values specified in each norm for shielding design goals (P), use factor (U) and occupancy factor (T); **2) second approach**, using the P, U and T values obtained from NCRP, applied for both standards, NCRP and DL.

Figure 1. Shows the bunker design and the protected points located at 0.30 m from the barriers.

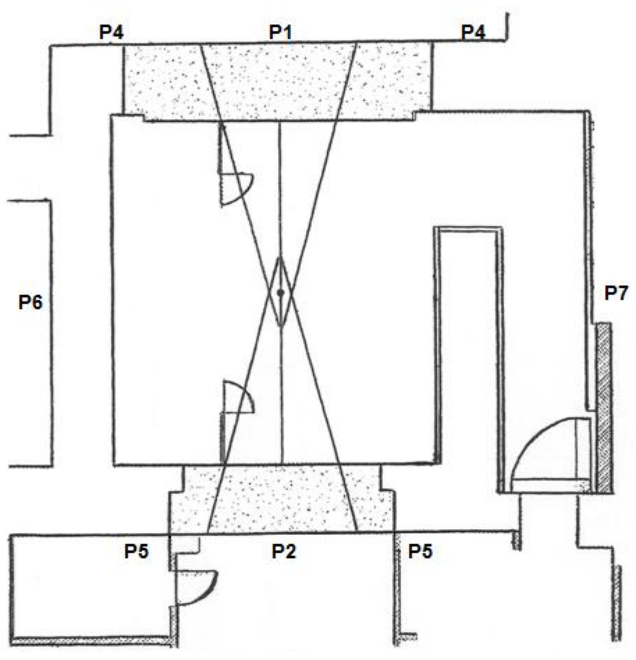

Figure 2. Vertical section of the installation and identification of the protected points located at 0.30 m from the barriers.

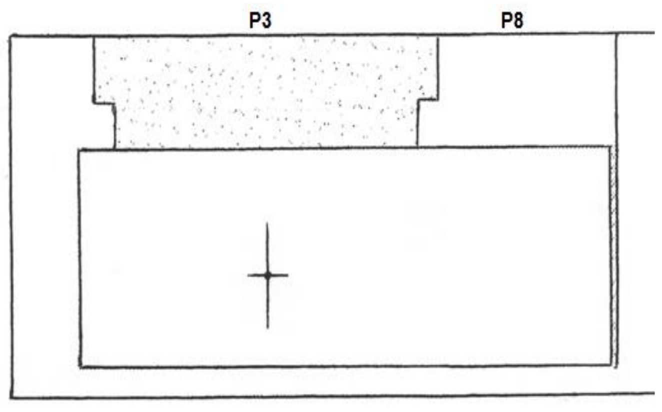

Table 1. Identification of the shielding barriers.

Protected Point	Classification of the Barriers	Area	Area Type
P1	Primary Barrier	Outdoor area	Uncontrolled
P2	Primary Barrier	Treatment control area	Controlled
P3	Primary Barrier	Ceiling - Outdoor area	Uncontrolled
P4	Secondary Barrier	Outdoor area	Uncontrolled
P5	Secondary Barrier	Treatment control area	Controlled
P6	Secondary Barrier	Brachytherapy bunker	Controlled
P7	Secondary Barrier	Adjacent treatment bunker	Controlled
P8	Secondary Barrier	Ceiling - Outdoor area	Uncontrolled

The shielding design goals, in dose equivalent, for **controlled areas** (*see table 1*) were: **0.1 mSv/week** (according to NCRP 151) and **0.4 mSv/week** (according to DL 180/2002). For **uncontrolled areas** (*see table 1*), both NCRP and DL, recommend **0.02 mSv/week**.
The use and occupancy factors are identified in table 2.

Table 2. Use (U) and occupancy (T) factors.

Protected Point	NCRP 151		DL 180/2002	
	U	T	U	T
P1	0.25	1/40	0.25	1/16
P2	0.25	1	0.25	1
P3	0.25	1/40	0.25	1/16
P4	1	1/40	1	1/16
P5	*	1	1	1
P6	1	1/2	1	1
P7	1	1/2	1	1
P8	*	1/40	1	1/16

* For P5 and P8, the use factor assumed two different values: one for leakage radiation which was 1 and the other for scattered radiation (U_{ps}) which was 0.25 (scatter angle = 30º).

3. Results and Discussion

Results obtained using both approaches, are shown in table 3. One can see that, for primary barriers, discrepancies were higher when P, U and T factors were applied following the recommendation in each norm (first approach). By using the same goals and factors, the discrepancies for primary barriers occurred because of the differences in the TVL concept for both methods.

Table 3. Difference between the barriers thicknesses calculated according to **DL 180/2002 and NCRP 151**, using the two approaches for input data.

Protected Point and Barrier	First Approach	Second Approach
	Difference (%)	Difference (%)
P1. Primary Barrier	+ 16	+ 5
P2. Primary Barrier	- 8	+ 5
P3. Primary Barrier	+ 15	+ 5
P4. Secondary Barrier	- 8	- 29
P5. Secondary Barrier	- 19	+ 1
P6. Secondary Barrier	- 4	+ 11
P7. Secondary Barrier	+ 7	+ 13
P8. Secondary Barrier	+ 16	+ 3

In order to understand the differences concerning the secondary barriers, the parameters that contribute for the discrepancies in each barrier were analyzed independently. For this analysis was necessary to take into account that DIN method considers direct neutron contribution in the calculations of the secondary barrier thickness, while NCRP considers them to the maze and door calculations. Table 4 shows the study for leakage, photon scattered, neutron radiation and time averaged dose-equivalent rate (TADR), regarding secondary barriers.

Table 4. Difference between the secondary barrier thicknesses calculated according to **DL 180/2002 and NCRP 151**, using the first approach for input data.

Points	Leakage radiation	Photon scattered radiation		DIN-6847 method without neutron consideration vs NCRP 151	DIN-6847 vs NCRP 151 without TADR consideration
	Difference (%)	Scatter angles (º)	Difference (%)	Difference (%)	Difference (%)
P4	+ 56	38	- 57	- 18	- 8
P5	- 13	30	- 61	- 28	- 19
P6	+ 9	90	- 4	- 4	+ 9
P7	+ 4	90	- 4	- 11	+ 7
P8	+ 58	30	- 39	+ 16	+ 16

According to Table 4, for **leakage radiation**, the discrepancies between two methods were mainly due to the fact that NCRP considers the equilibrium and first tenth-value layer of a shielding material and DIN method considers only the first TVL (which is the same TVL of the primary radiation). Exception was verified for P5 because of its P value and the differences related to the distances to the protected point in both norms. Regarding **photon scattered radiation**, the discrepancies were greater for small scattering angles because of the linac energy and radiation scattering angles took into account in NCRP, while the TVLs in DL depend only on the type of shielding material. So, for large angle (90º), the TVLs in both norms were similar, as can be seen for P6 and P7. The results obtained regarding **neutron radiation** contribution, show an increase of the secondary barrier thicknesses. Exception were verified for P6 and P8 because the calculated thicknesses for leakage radiation prevail over the others. **TADR** considerations in NCRP led to an increase of the barrier thickness for P6, when TADR was not considered to the calculation, the weekly dose equivalent in this point was greater than its shielding design goal.

4. Conclusion

In conclusion, when considering conventional treatment techniques and using the shielding design goals, use and occupancy factors values specified in each norm the differences for primary and secondary radiation barriers can be quite significant. Some barriers were underestimated when the calculated thicknesses were based on Portuguese Regulations. The situation can be even more critical if one consider IMRT techniques, because of the increasing leakage-radiation that is taken into account by the IMRT factor in the workload calculations for the secondary barriers in NCRP but not in DL.

5. References

[1] NCRP Report No. 151. Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities, National Council on Radiation Protection and Measurements. 2005.
[2] Decree-law 180/2002 of 8 August 2002. Diário da República – I Série – A.
[3] DIN-6847. Medizinische Elektronenbeschleuniger-Anlagen; Teil 2: Strahlenschutzregeln für die Errichtung, (Medical electron accelerators; Part 2: Radiation Protection rules for installation), DIN Deutsches Institut für Normung e.V.1977.