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COMPARISON BETWEEN STEEL AND LEAD SHIELDINGS FOR RADIOTHERAPY ROOMS REGARDING NEUTRON DOSES TO PATIENTS

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ABSTRACT

The NCRP Report No. 151, Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities, considers, in shielding calculations for radiotherapy rooms, the use of lead and/or steel to be applied on bunker walls. The NCRP Report calculations were performed foreseeing a better protection of people outside the radiotherapy room. However, contribution of lead and steel to patient dose should be taken into account for radioprotection purposes. This work presents calculations performed by MCNPX code in analyzing the Ambient Dose Equivalent due to neutron, $H^*(10)_n$, within a radiotherapy room, in the patients area, considering the use of additional shielding of 1 TVL of lead or 1 TVL of steel, positioned at the inner faces of walls and ceiling of a bunker. The head of the linear accelerator Varian 2100/2300 C/D was modeled working at 18MeV, with 5x5 cm², 10x10 cm², 20x20 cm², 30x30 cm² and 40x40 cm² openings for jaws and MLC and operating in eight gantry's angles. This study shows that the use of lead generates an average value of $H^*(10)_n$ at patients area, 8.02% higher than the expected when using steel. Further studies should be performed based on experimental data for comparison with those from MCNPX simulation.

1. INTRODUCTION

The replacement of low energy linear accelerators used in radiotherapy by high energy ones has been increasing lately. For convenience, physical space limitation or even lowering coasts, new bunkers are not built and the existing ones are being reused with shielding increments to protect the public and workers around adjacent areas. Usually, size becomes a major problem leading designers to use shielding materials of medium and high density to increase shielding, generally using either steel or lead instead of concrete. With this additional shielding, the protection of adjacent areas is reached, but involving changes in dose distributions near the patient, particularly those due to the scattered radiation or secondary radiation produced at the shielding. In 2012, our group carried out a work [1] which aimed to evaluate the contributions of steel and lead to doses on radiotherapy patients. In that study the Monte Carlo N-Particle X code, MCNPX, was used to assess the effect of Ambient Dose Equivalent due to the neutrons $H^*(10)_n$ in the patient position. The radiotherapy equipment was modeled operating at 8 angles of gantry, all with 5x5cm^2 opening field for MLC and jaws. Results indicated that the use of lead generates $H^*(10)_n$ values greater than those for steel, however it was only considered the 5x5cm^2 field. This study aims to model additional fields beyond that of 5x5cm^2 field, i.e, 10x10cm^2, 20x20cm^2, 30x30cm^2 and 40x40cm^2.

2. METHODOLOGY

In this work a standard radiotherapy room was simulated with the LINAC operating with an additional shielding of 1TVL of steel and then 1TVL of lead. The values of Ambient Dose Equivalent were calculated for each situation, at 13 points at patient position. The MCNPX code was used to calculate the radiation transport where the radiotherapy equipment, bunker and additional shielding were modeled in a standard radiotherapy room with a linear accelerator Varian 2100/2300 C/D operating in 18MeV, with an opening fields of 5x5cm^2, 10x10cm^2, 20x20cm^2, 30x30cm^2, and 40x40cm^2 for jaws and MLC [2,3].

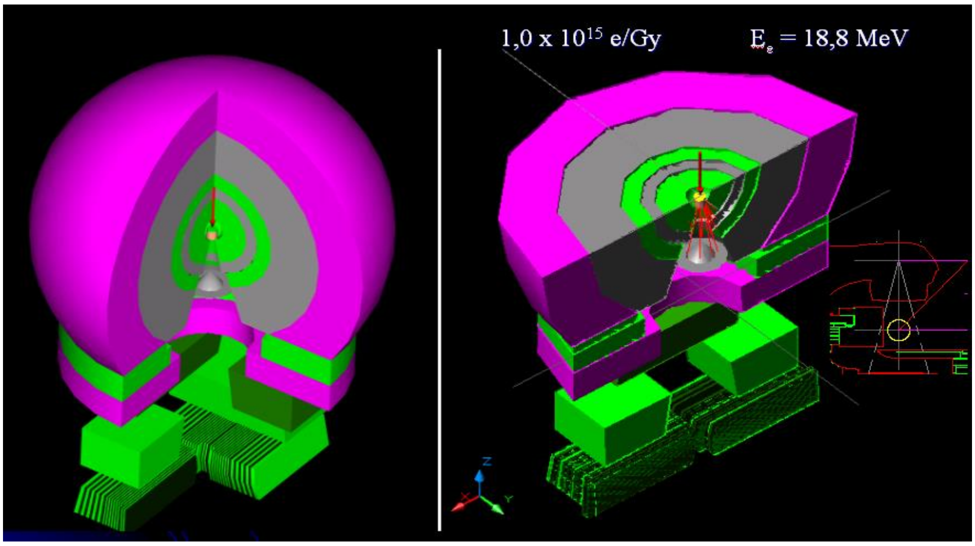

Figure 1: View of the modeled head of the linear accelerator.

It was considered an additional 1 steel TVL and, then, 1 lead TVL at the inner walls of the bunker, corresponding, respectively, to 11.0 cm and 5.7 cm thicknesses, according to the energy of 18 MeV for the equipment operation [4]. These shieldings were positioned inside the bunker, at the walls (b) and ceiling (c) at the region that receives the primary beam (Fig. 2 and 3). It wasn't considered any additional shielding on the floor (d).

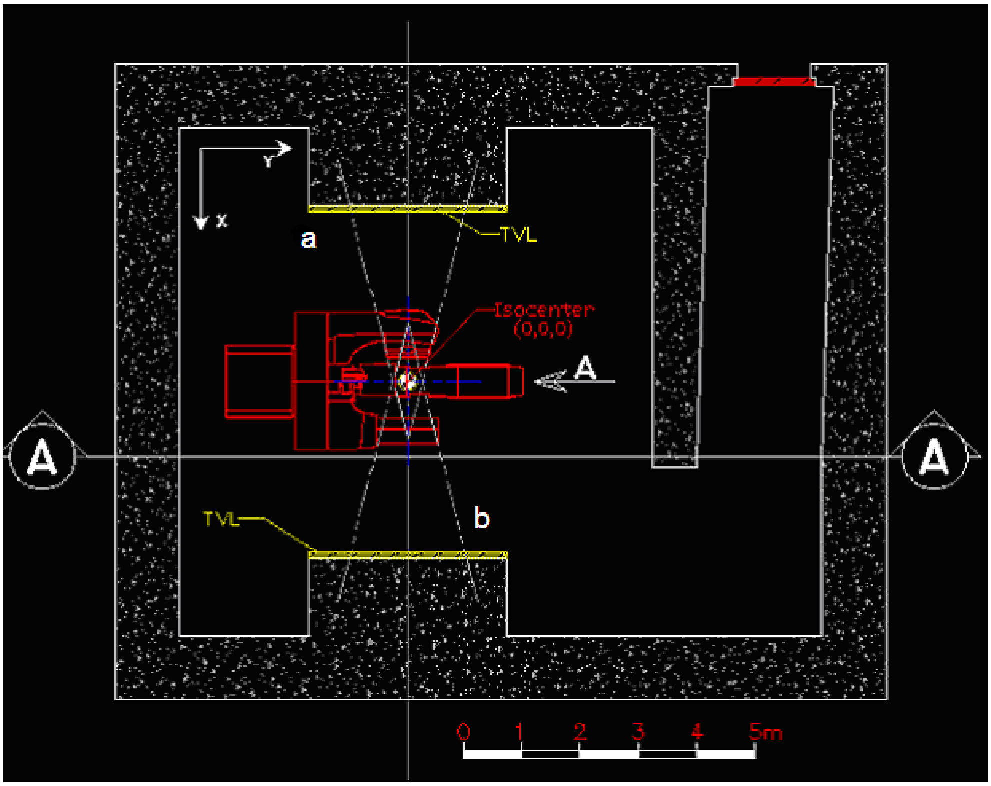

Figure 2: Plan view of the radiotherapy room, with placement of shielding at walls (a and b).

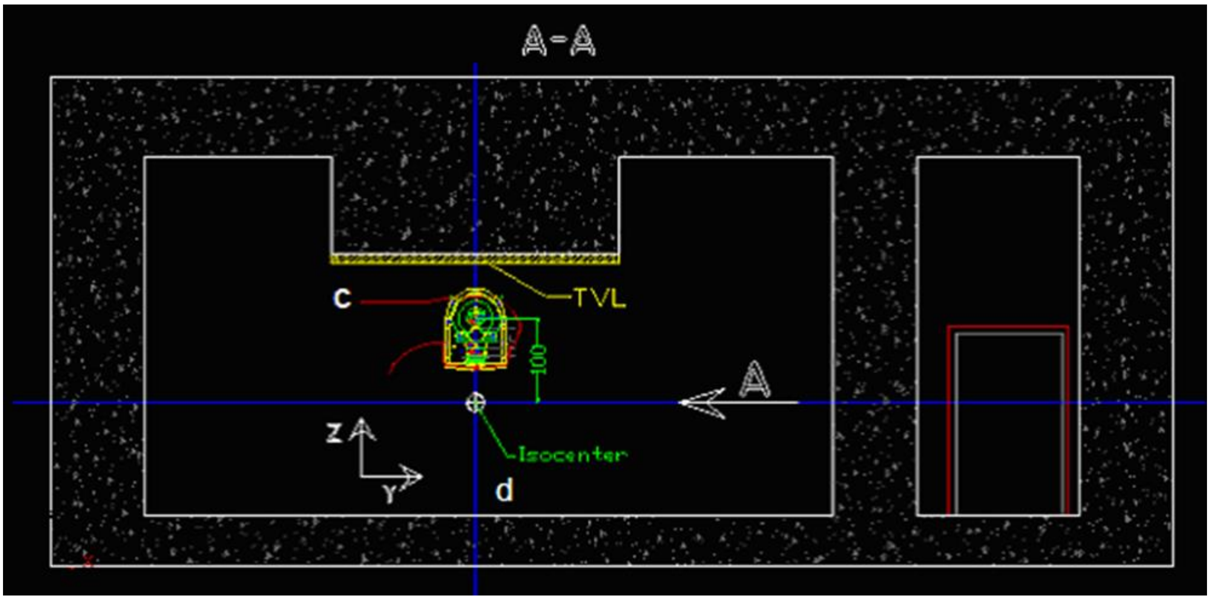

Figure 3: Cutaway view of the radiotherapy room, with placement of shielding at the ceiling of the room (c).

The accelerator was simulated considering eight angles of gantry inclination: 0º to 315° in steps of 45° [5]. The direction of each incident beam is shown in Fig. 4. For each angle, it was calculated $H^*(10)_n$ in 13 points at the patient's plane, points A to M, at Fig. 5.

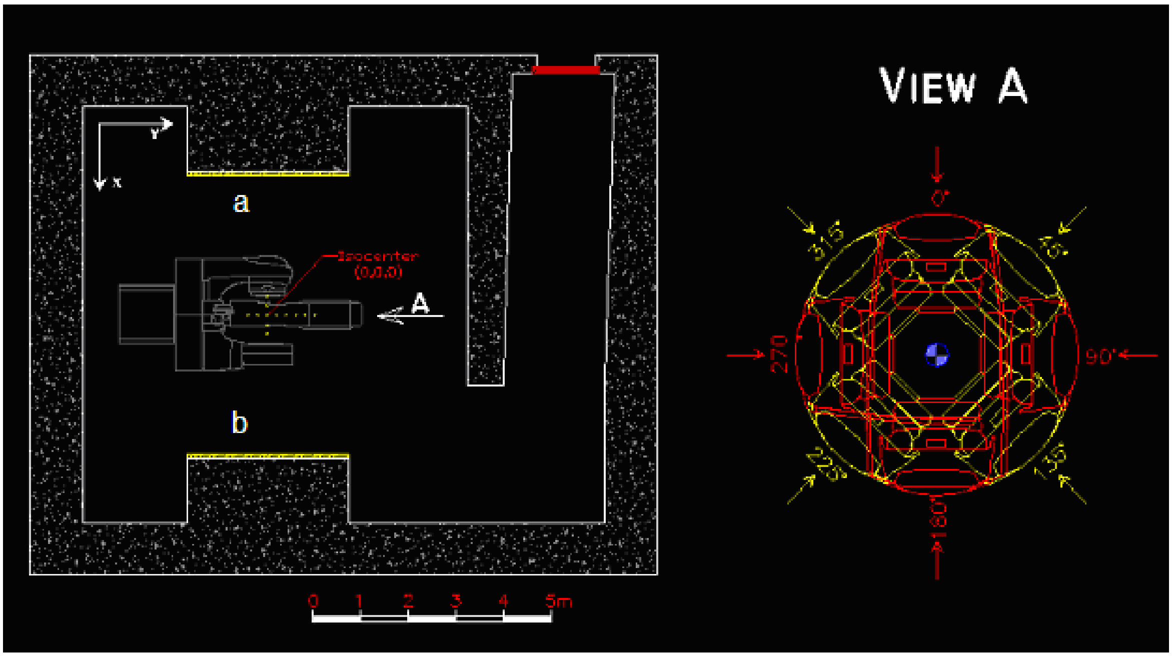

Figure 4: Plant view of the radiotherapy room, showing 8 gantry angles.

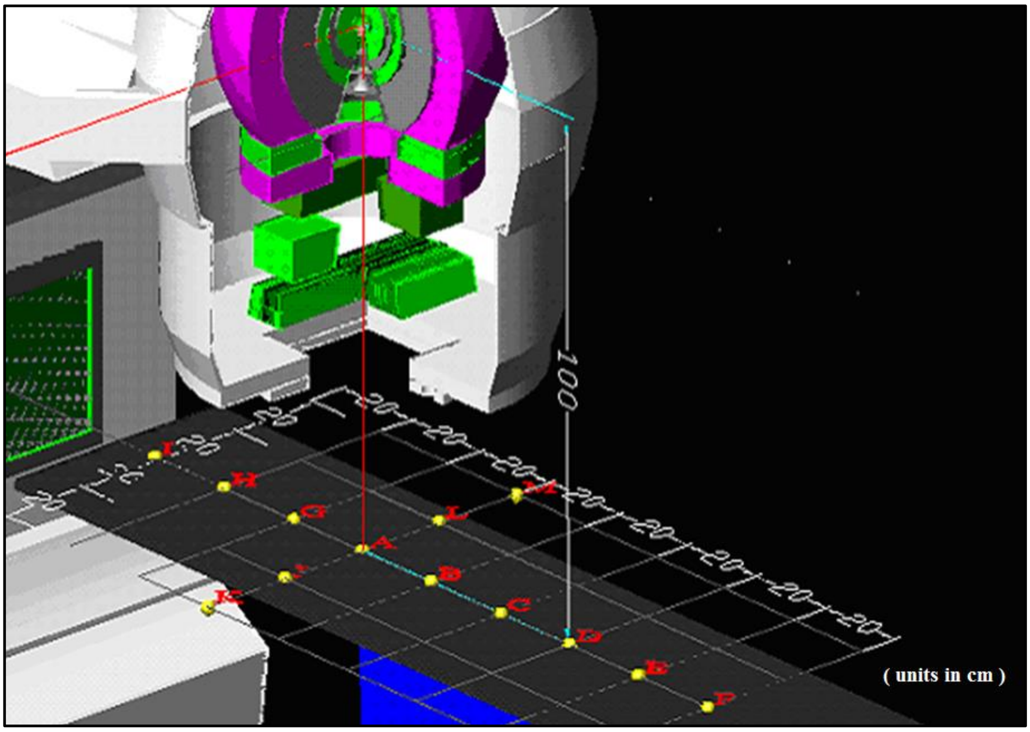

Figure 5: Details of the location of simulated point detectors. The point A (0,0,0) corresponds to the isocenter.

The conversion factors suggested by ICRP 74 [6] were used in $H^*(10)_n$ calculations. The results were normalized to 1Gy dose at the isocenter. Thus, it was considered a beam of 1.0×10^{15} electrons with 18.8 MeV each, reaching the LINAC target [2,4]. Approximately 10 million stories were used in each simulation to keep the calculation uncertainties below 5%.

3. RESULTS

Results were calculated for 8 gantry angles and presented in terms of mean values of $H^*(10)_n$ for these angles in each field, for steel and lead. Fig. 6 to 10 show these results and Table 1 summarizes them.

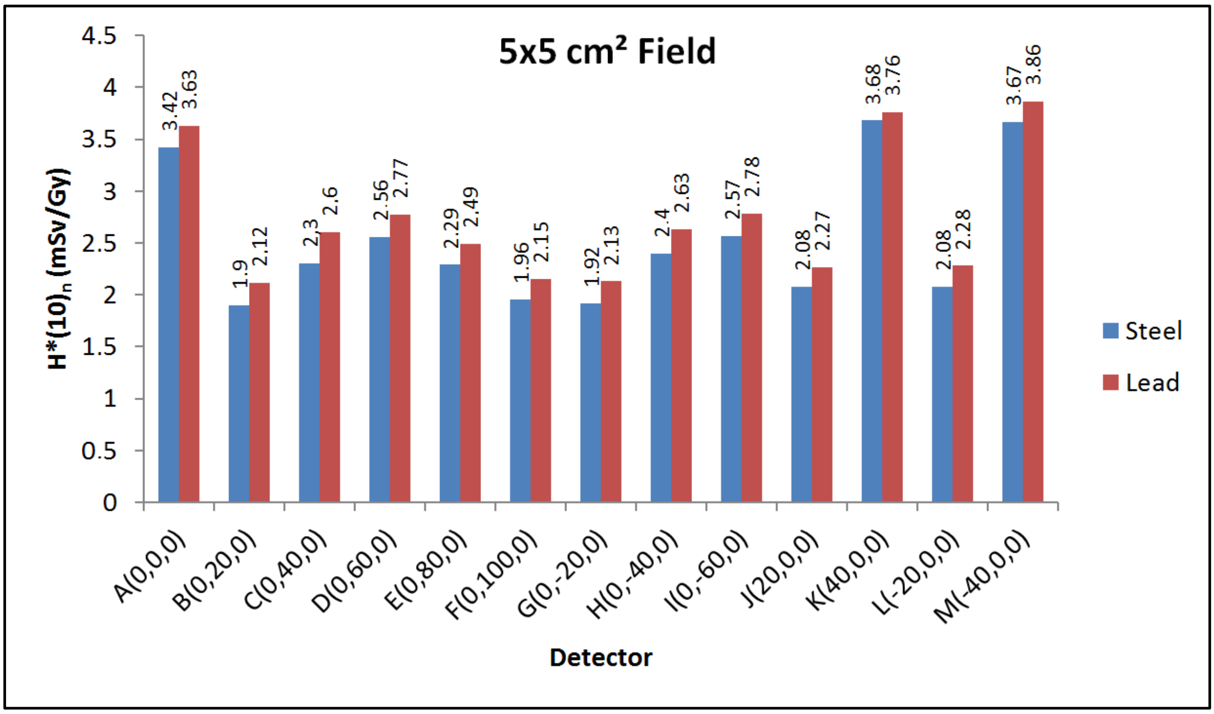

Figure 6: Mean values of $H^*(10)_n$ (mSv/Gy) for all gantry angles, 5x5cm^2 field

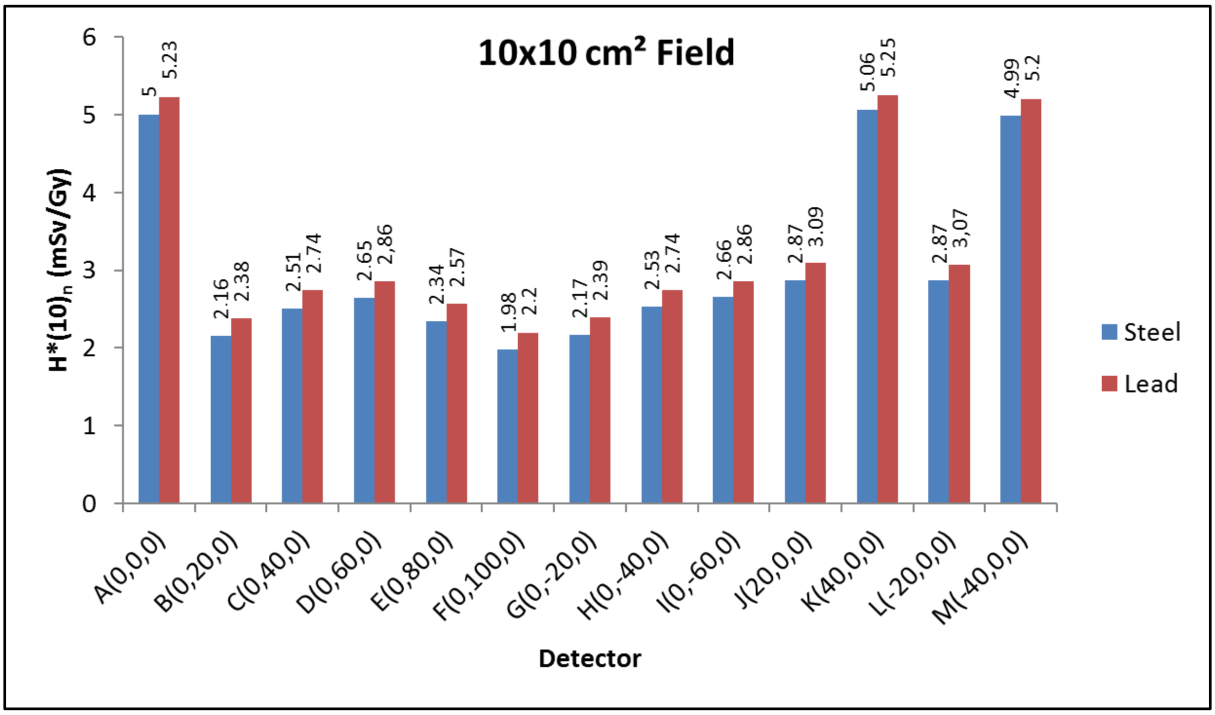

Figure 7: Mean values of *H*(10)ₙ* (mSv/Gy) for all gantry angles, 10x10cm^2 field

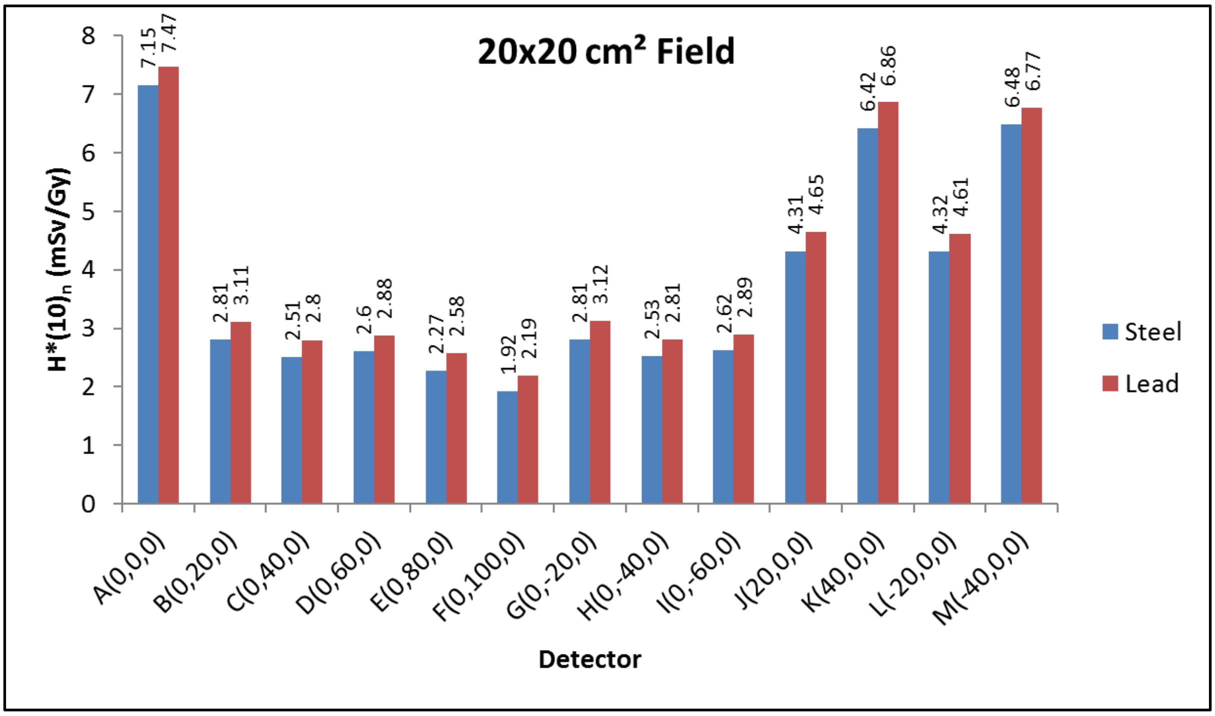

Figure 8: Mean values of *H*(10)ₙ* (mSv/Gy) for all gantry angles, 20x20cm^2 field.

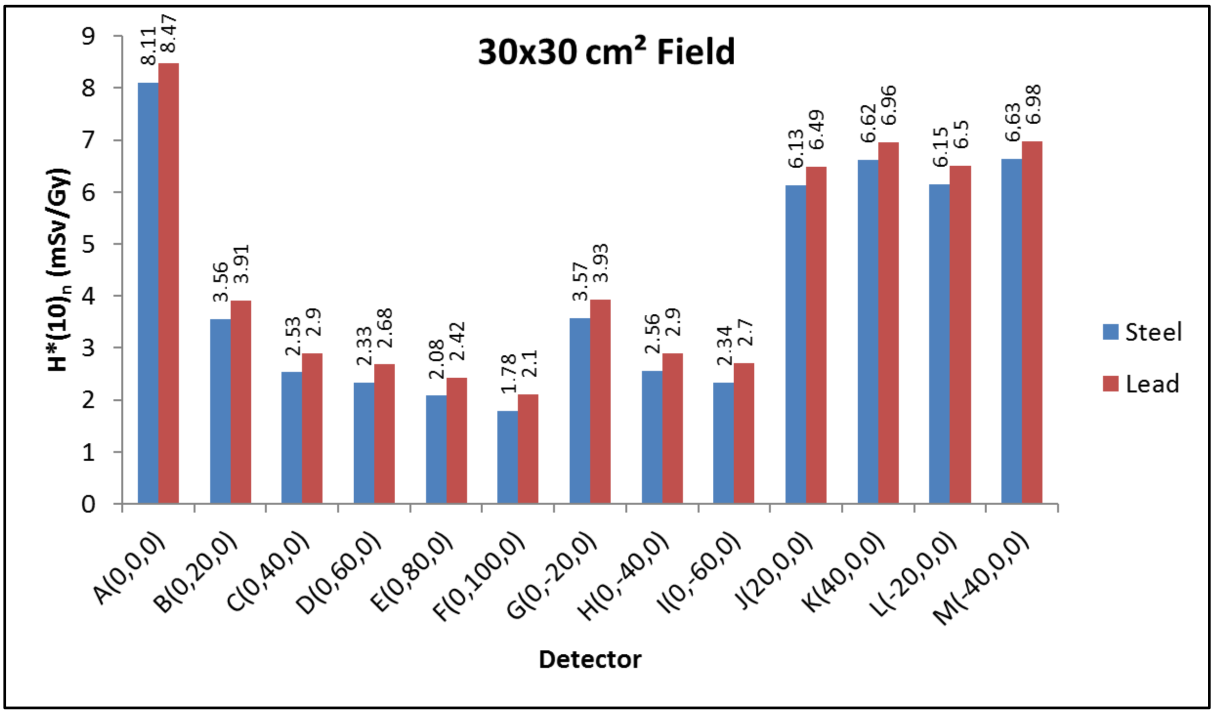

Figure 9: Mean values of *H*(10)*$_n$ (mSv/Gy) for all gantry angles, 30x30cm^2 field

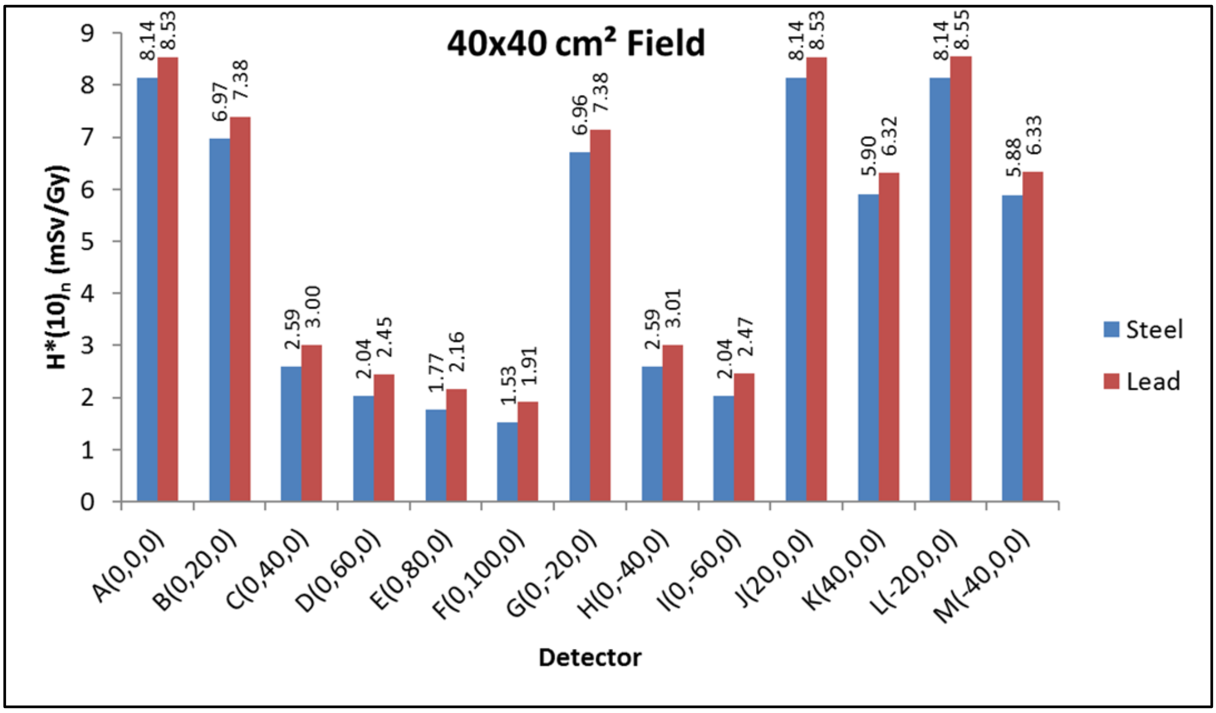

Figure 10: Mean values of *H*(10)*$_n$ (mSv/Gy) for all gantry angles, 40x40cm^2 field.

Table 1: $H^*(10)_n$ (mSv/Gy), mean values and comparison between steel and lead results.

$H^*(10)_n$ (mSv/Gy)										
Field	**5x5cm^2**		**10x10cm^2**		**20x20cm^2**		**30x30cm^2**		**40x40cm^2**	
Detector	**Stell**	**Lead**	**Stell**	**Lead**	**Stell**	**Lead**	**Stell**	**Lead**	**Stell**	**Lead**
A (0,0,0)	3.42	3.63	5.00	5.23	7.15	7.47	8.11	8.47	8.14	8.53
B (0,20,0)	1.90	2.12	2.16	2.38	2.81	3.11	3.56	3.91	6.97	7.38
C (0,40,0)	2.30	2.60	2.51	2.74	2.51	2.80	2.53	2.90	2.59	3.00
D (0,60,0)	2.56	2.77	2.65	2.86	2.60	2.88	2.33	2.68	2.04	2.45
E (0,80,0)	2.29	2.49	2.34	2.57	2.27	2.58	2.08	2.42	1.77	2.16
F (0,100,0)	1.96	2.15	1.98	2.20	1.92	2.19	1.78	2.10	1.53	1.91
G (0,-20,0)	1.92	2.13	2.17	2.39	2.81	3.12	3.57	3.93	6.96	7.38
H (0,-40,0)	2.40	2.63	2.53	2.74	2.53	2.81	2.56	2.90	2.59	3.01
I (0,-60,0)	2.57	2.78	2.66	2.86	2.62	2.89	2.34	2.70	2.04	2.47
J (20,0,0)	2.08	2.27	2.87	3.09	4.31	4.65	6.13	6.49	8.14	8.53
K (40,0,0)	3.68	3.76	5.06	5.25	6.42	6.86	6.62	6.96	5.90	6.32
J (-20,0,0)	2.08	2.28	2.87	3.07	4.32	4.61	6.15	6.50	8.14	8.55
M (-40,0,0)	3.67	3.86	4.99	5.20	6.48	6.77	6.63	6.98	5.88	6.33
Tot.	32.83	35.47	39.79	42.58	48.75	52.74	54.39	58.94	62.69	68.02
Mean	2.53	2.73	3.06	3.28	3.75	4.06	4.18	4.53	4.82	5.23
Dif. (%)	**8.04**		**7.01**		**8.18**		**8.37**		**8.50**	
Mean dif. (%)	**8.02**									

4. CONCLUSION

Results suggests that the Ambient Dose Equivalent $H^*(10)_n$ increases at patients region when lead is used instead of steel for all fields and point detectors. This increase is on average of 8.04%, 7.01%, 8.18%, 8.37% and 8.50% respectively for 5x5cm^2, 10x10cm^2, 20x20cm^2, 30x30cm^2 and 40x40cm^2 opening fields, which represents an average of 8.02% over all fields and angles studied. It can be conclude that the use of lead instead of steel, in addition to the primary shielding at walls in radiotherapy rooms, can intensify radiation doses due to neutrons at the patient location. Further studies are already underway to evaluate the effects related to X rays in addition to experimental set up for this work.

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