Letter to the Editor

"Dose Distribution Close to Metal Implants in Gamma Knife Radiosurgery: A Monte Carlo Study" [Med. Phys. 30, 1812–1815 (2003)]

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We have calculated the dose enhancements close to metal implants in Gamma Knife radiosurgery using different beam sizes, i.e., 4, 8 and 18 mm collimator helmets (in addition to the previous calculations using the 14 mm collimator helmet). For the 8 and 18 mm helmets, the obtained results were similar to those obtained using the 14 mm helmet, which can be explained by the similar beam profiles with and without the platinum implant in the region from the maximum down to the platinum–phantom interface. On the other hand, the dose enhancement for the smallest 4 mm collimator helmet is higher than those using the 8, 14 and 18 mm collimator helmets, which can be explained by the rapid falloff of the steep gradient of the dose profile without the platinum implant.

In our recent paper entitled "Dose Enhancement Close to Platinum Implants for the 4 MV, 6 MV and 10 MV Stereotactic Radiosurgery,"[1] it was found that the dose enhancement due to the foreign platinum implant increased with the beam energy but decreased as the beam size increased. Comparatively higher dose enhancements were observed when using smaller collimators. As there are similarities in the physics for the Gamma Knife and Linac based radiosurgery, these results have prompted us to extend our previous studies on the dose distribution close to metal implants in Gamma Knife radiosurgery[2] to further studies using other collimator helmets, viz., 4, 8 and 18 mm.

From our previous results on Gamma Knife radiosurgery,[2] there were dose enhancements close to some foreign metal implants when a 14 mm collimator shot was delivered at the unit center point (100, 100, 100) of a water phantom with a diameter of 160 mm (Fig. 1). The dose enhancement is defined as the percentage difference between the dose profiles with and without the platinum implant at the platinum–phantom interface. The dose enhancement is due to the generation of secondary electrons from the photoelectric effect, which is favored for higher atomic numbers. Dose enhancements as high as 10% were observed close to a platinum implant along the x and y axes, while dose enhancements as high as 20% were observed close to the platinum implant along the z axis at the superior position of the metal–phantom interface. In that study,[2] only the 14 mm collimator was studied because the order of magnitude for both the implants and the treatment area (using multiple shots) were close to the real clinical situation. Moreover, the objective of that paper[2] was to study dose enhancements for different implant materials.

In the present Letter, we focus on platinum implants with different beam sizes and we have repeated the calculations for dose enhancements close to the platinum implant using 4, 8 and 18 mm collimator helmets. In the simulations, the patient's head was modeled by a spherical water phantom 160 mm in diameter. Each one of the 201 sources located in the Gamma Knife radiation unit consists of 20 cylindrical ^{60}Co pellets 1 mm in diameter and 1 mm in length. Each source was therefore modeled by a cylinder 1 mm in diameter and 20 mm in length. The ^{60}Co sources are arranged in a sector of a hemispherical surface with a radius of about 400 mm, and are distributed along five parallel circles separated from each other by an angle of 7.5°.[3] The 201 radiation beams pass through the opening of the collimators to reach the target point. The diameters of the radiation beams at the focus are confined by the collimators, ignoring scattered photons. Single shots with all 201 gamma beams opened were delivered at the centre (unit center point: $x=100$ mm, $y=100$ mm, $z=100$ mm) of the water phantom. Scoring bins with dimensions $0.5\times0.5\times0.5$ mm^3 were set up along the three main principal axes. The platinum implant was 4 mm in diameter and placed at the unit centre point. The cutoff energies for electrons and photons were set to be 0.521 and 0.01 MeV, respectively. The absorbed dose values were obtained by dividing the energy depositions in the scoring bins by their masses. A total of 2×10^8 histories were obtained in the simulations. The standard errors for all calculations were less than 1.2%. The results are presented in Table I.

For the 8 and 18 mm helmets, the obtained results were similar to those obtained using the 14 mm helmet, which can be explained as follows. Secondary electrons are generated from the platinum implant and travel through a limited projected range when irradiated by photons from ^{60}Co. The projected range of the electrons depends on the primary photon energy and is certainly independent of the photon beam sizes. For the same photon energy, the beam profiles with

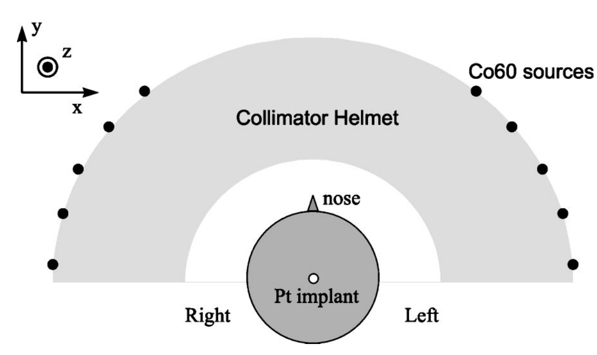

FIG. 1. Coordinate system and setup of the Gamma Knife MC simulation.

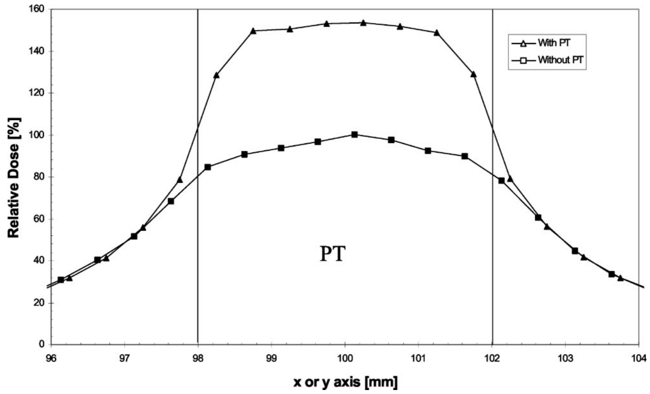

FIG. 2. A comparison of the relative doses along the x axis and y axis with and without the presence of the platinum implant for the 4 mm collimator helmet.

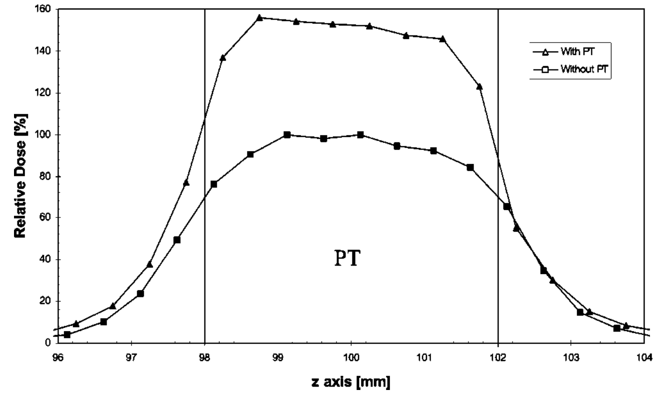

FIG. 3. A comparison of the relative doses along the z axis with and without the presence of the platinum implant for the 4 mm collimator helmet.

and without the platinum implant for the 8, 14 and 18 mm collimator helmets are similar in the region from the maximum down to the platinum–phantom interface. Therefore, the dose enhancements resulted from using the 8, 14 and 18 mm helmets are similar.

On the other hand, it is interesting to find that the dose enhancement for the smallest 4 mm collimator helmet is higher than those using the 8, 14 and 18 mm collimator helmets. In the case of the 4 mm collimator helmet, for the same limited projected range of secondary electrons, the difference between the dose profiles with and without the platinum implant at the platinum–phantom interface is larger, which is due to the rapid falloff of the steep gradient of the dose profile without the platinum implant and therefore dominates the effect of secondary electrons on the dose profile with the platinum implant. In fact, dose enhancements as high as $(104-80)/80\times 100\% = 30\%$ were observed close to the platinum implant along the $x(x=98,102\text{ mm})$ and $y(y=98,102\text{ mm})$ axes, which are shown in Fig. 2. On the other hand, dose enhancements as high as $(108-68)/68\times 100\% = 59\%$ along the z axis at the superior position ($z=98$ mm) of the metal–phantom interface and dose enhancements as high as $(88-68)/68\times 100\% = 29\%$ along the z axis at the inferior position ($z=102$ mm) were observed, as shown in Fig. 3. There were no direct gamma beams coming along the z axis and therefore small dose enhancements could be more easily observed along the z axis at the superior position than at the inferior position of the platinum–phantom interface.

TABLE I. Percentage dose enhancements at the platinum–phantom interface using different collimator helmets.

	Percentage dose enhancements at the platinum-phantom interface	
Helmet	Along the x or y axis	Along the z axis
4 mm	30% (x=98 and 102 mm)	59% (z=98 mm), 29% (z=102 mm)
8 mm	10% (x=98 and 102 mm)	20% (z=98 mm), 10% (z=102 mm)
14 mm	10% (x=98 and 102 mm)	20% (z=98 mm), 10% (z=102 mm)
18 mm	10% (x=98 and 102 mm)	20% (z=98 mm), 10% (z=102 mm)

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[3]Elekta, Leksell Gamma Unit: User's Manual 1, Elekta, 1992.

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