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# Calculation of fluence and absorbed dose in head tissues due to different photon energies

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## HIGHLIGHTS

- A Monte Carlo algorithm to simulate the passage of photons through a homogeneous material was developed.
- Two models of a patient's head, one spherical and another more realistic ellipsoidal model, were simulated using the Monte Carlo code.
- The fluence into the tumor is different for both head models, but absorbed dose in the tumor is the same.

## ARTICLE INFO

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## ABSTRACT

Calculations of fluence and absorbed dose in head tissues due to different photon energies were carried out using the MCNPX code, to simulate two models of a patient's head: one spherical and another more realistic ellipsoidal.

Both head models had concentric shells to describe the scalp skin, the cranium and the brain. The tumor was located at the center of the head and it was a 1 cm-radius sphere. The MCNPX code was run for different energies.

Results showed that the fluence decreases as the photons pass through the different head tissues.

It can be observed that, although the fluence into the tumor is different for both head models, absorbed dose is the same.

## 1. Introduction

The first report about the symptoms caused by tumors was 1500 BC in Egypt (Sudhakar, 2009). Globally, cancer kills more people than tuberculosis, human immunodeficiency virus (HIV) and malaria combined (IAEA, 2010).

Surgery, chemotherapy and radiotherapy, alone or combined, are used in the treatment of tumors. Radiation therapy with photons is used when the lesion is deep-seated and it cannot be treated by surgery (Chamberlain and Kormanik, 1998), like in the case of tumors in the brain. For these types of lesions another option is the use of Boron Neutron Capture Therapy (BNCT). Thus, several studies has been carried out to design the neutron source (Capoulat et al., 2013; Rahmani and Shahriari, 2011), and to estimate the absorbed dose in novel applications (Garnica-Garza, 2013).

In order to account for the interactions between the therapeutic radiation and the patient's body, and to study the effect of elemental concentration in healthy and tumorous tissues, the Monte Carlo methods have been used, because among the available methods only the Monte Carlo methods could provide a detailed accounting of the delivered dose (Chin and Spyrou, 2009). Also it has been pointed out that despite the required computation time, the Monte Carlo based treatment planning system is known to be more accurate than analytical methods for performing absorbed dose estimation, particularly in and near heterogeneities (Isambert et al., 2010).

With the aim to increase the accuracy in the Monte Carlo calculations for radiation dosimetry, mathematical phantoms have been developed. The first heterogeneous anthropomorphic model used for dosimetry was the Fisher–Snyder phantom (Snyder et al., 1969, 1978), devised at the Oak Ridge National Laboratory.

With the advancement of computers and medical imaging techniques, researchers have developed anatomically realistic phantoms of the human body. To date, several voxel-based models varying in age, sex, and ethnicity have been developed (Xu et al., 2000; Lee et al., 2006; Zhang et al., 2008). Also, simple models, like water phantoms, have been used (Perucha et al., 2003).

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The brain is one of the most important organs in humans. When the brain is irradiated in radiotherapy both healthy and tumorous tissues absorb certain amount of energy, with the aim to control the disease. (Pérez-López and Garnica-Garza, 2011).

The aim of this work was to use the Monte Carlo methods, using the MCNPX code (Pelowitz, 2008), to calculate the photon fluence and the absorbed dose in healthy and tumorous tissues using a simple model to describe the human head.

## 2. Experimental methods

Calculations were carried out using the MCNPX code (Pelowitz, 2008). Two simple models, spherical and ellipsoidal, were used to represent the human head.

Both head models had concentric shells to describe the scalp skin, the cranium and the brain. The scalp and the cranium were 0.5 and 1 cm-thick, respectively. In the spherical model the brain was of 7 cm-radius. In the ellipsoid model the brain modeled was of 5.75 cm-minor radius and 8.58 cm-larger radius. In both models the tumor was located at the center of the head and it was a 1 cm-radius sphere.

The elemental concentration of the head components were taken from ICRU 46 (1992).

In the calculations a unidirectional treatment beam was used collimated to the tumor cross section area. Calculations were carried out using $^{60}$Co photons and 6, 8, 10 and 15 MeV monoenergetic photons. For each case the total photon fluence and the absorbed dose in the head components were recorded. In order to reach an uncertainty less than 5%, $10^6$ histories were used.

## 3. Results and discussion

Fig. 1 shows the photon fluence per photon emitted by different sources at 5, 10 and 15 cm in air and inside the head, for the spherical head model. As can be seen, the photon fluence does not change with distance; the reason is that the photons emitted by the source are unidirectional. As the beam enters various tissues of the head it is observed that the number of photons decreases as the distance increases; this decrease is due to the fact that photons are absorbed and scattered in other directions.

In this figure it can also be seen that the photon fluence is higher for higher photon energy and lower for the source that emits photons of lower energy. One can see that about 60% of the $^{60}$Co photons reach the tumor, while in the case of a source of 15 MeV approximately 90% of photons reach the center of the tumor.

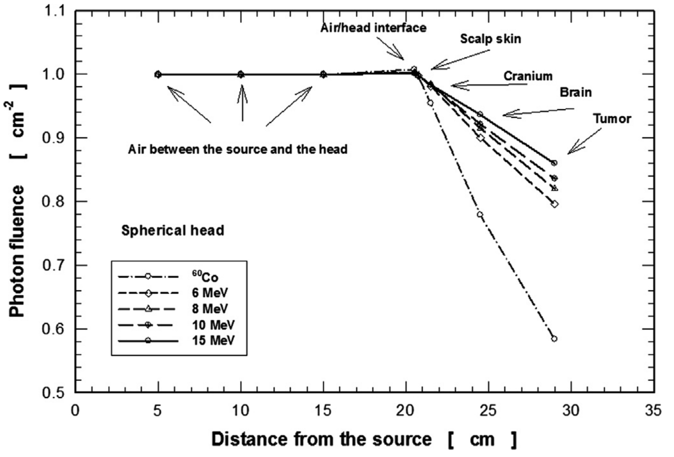

**Fig. 1.** Photon fluence at 5, 10 and 15 cm in air, and inside the head, using the spherical model.

Fig. 2 shows the photon fluence at 5, 10 and 15 cm in air as well as in the tissues of the head using the elliptic model due to different sources. In this figure one can observe that the same processes occur as observed in the spherical model.

In order to compare the impact of the geometry used in the head modeling, the relative photon fluences in the different tissues for both models are shown in Fig. 3 for $^{60}$Co. In Figs. 4, 5, 6 and 7

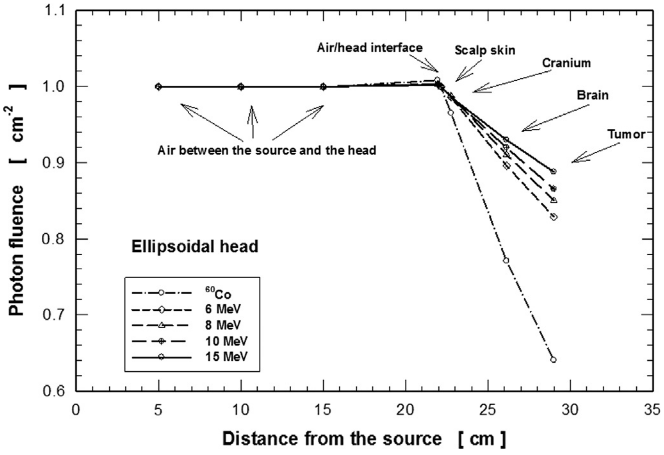

**Fig. 2.** Photon fluence at 5, 10 and 15 cm in air, and inside the head, using the spherical model.

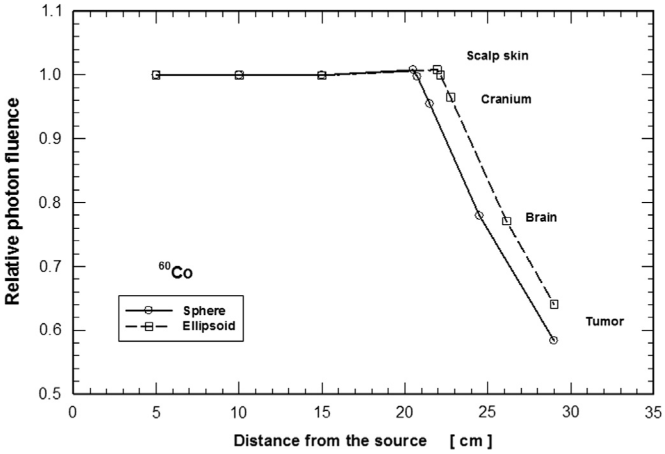

**Fig. 3.** Photon fluence in both head models at 5, 10, 15 and 20 cm in air and inside the head due to the $^{60}$Co source.

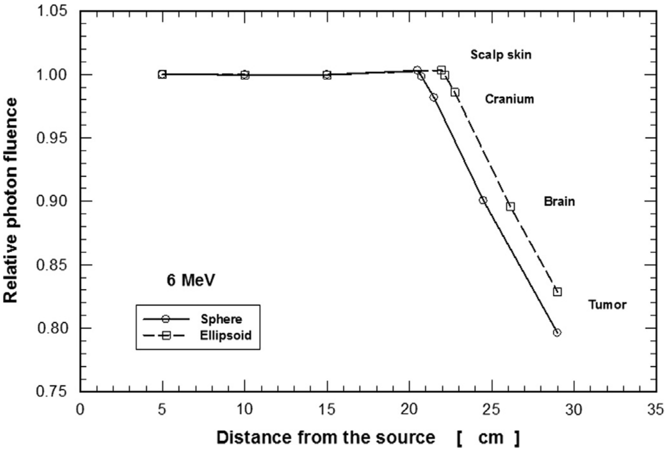

**Fig. 4.** Photon fluence in both models at 5, 10, 15 and 20 cm in air and inside the head due to the 6 MeV photon source.