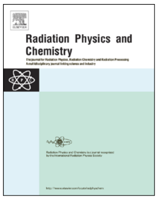
Radiation Physics and Chemistry 95 (2014) 267–270

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem



Effect of external shielding for neutrons during radiotherapy for prostate cancer, considering the 2300 CD linear accelerator and voxel phantom

J.L. Thalhofer [a],*, H.S. Roque [a], W.F. Rebello [b], S.A. Correa [c], A.X. Silva [a], E.M. Souza [d], D.V.S. Batita [e], E.S. Sandrini [b]

[a] *Programa de Engenharia Nuclear, UFRJ, 21941-914, Brazil*
[b] *Instituto Militar de Engenharia, 22290-270, Brazil*
[c] *Comissão Nacional de Energia Nuclear, 22290-040, Brazil*
[d] *Centro Universitário Estadual da Zona Oeste, 23070-200, Brazil*
[e] *Instituto Nacional de Câncer, 20230-130, Brazil*

HIGHLIGHTS

- ▸ Effect of external shielding to neutron during prostate cancer.
- ▸ Linac 2300, external shielding, radiotherapy room and MAX phantom were simulated.
- ▸ The results equivalent dose due to the photoneutrons in organs of patients decreased.
- ▸ The greatest dose reduction was verified in bone structures, approximately 75%.
- ▸ The shielding developed is effective for neutrons, decreasing the dose in patients.

ARTICLE INFO

Article history:
Received 30 September 2012
Accepted 8 February 2013
Available online 1 March 2013

Keywords:
Radiotherapy
Shield
Neutron
MCNPX and phantom

ABSTRACT

Photoneutron production occurs when high energy photons, greater than 6.7 MeV, interact with linear accelerator head structures. In Brazil, the National Cancer Institute, one of the centers of reference in cancer treatment, uses radiation at 4 angles (0°, 90°, 180° and 270°) as treatment protocol for prostate cancer. With the objective of minimizing the dose deposited in the patient due to photoneutrons, this study simulated radiotherapy treatment using MCNPX, considering the most realistic environment; simulating the radiotherapy room, the Linac 2300 head, the MAX phantom and the treatment protocol with the accelerator operating at 18 MV. In an attempt to reduce the dose deposited by photoneutrons, an external shielding was added to the Linac 2300. Results show that the equivalent dose due to photoneutrons deposited in the patient diminished. The biggest reduction was seen in bone structures, such as the tibia and fibula, and mandible, at approximately 75%. Besides that, organs such as the brain, pancreas, small intestine, lungs and thyroid revealed a reduction of approximately 60%. It can be concluded that the shielding developed by our research group is efficient in neutron shielding, reducing the dose for the patient, and thus, the risk of secondary cancer, and increasing patient survival rates.

1. Introduction

At present, radiotherapy commonly uses linear accelerators operating at high energy. And when accelerators operate above 6.7 MeV, photoneutrons are produced due to the interaction of photon beam with high atomic weight material, especially tungsten, found in the head shielding, and Jaws and Multileaf Collimators (MLC) (Facure et al., 2007). The photoneutrons increase the dose to the patient, increasing the risk of secondary cancers. Saeed et al. (2009) concluded that the neutron dose cannot be disregarded during radiotherapy treatment. Thalhofer et al. (2011), considering the most realistic environment, demonstrated that during prostate cancer treatment, the dose deposited by photoneutrons is greater than that of photons in organs (thyroid and brain) and bone structures (skull and mandible), which are farther from the tumor.

Several studies in literature demonstrate that neutrons participate in the dose deposit process in the radiotherapy room

---

* Corresponding author. Tel.: +55 21 3242 4252.
E-mail address: jardellt@yahoo.com.br (J.L. Thalhofer).

0969-806X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.radphyschem.2013.02.013

environment (Rebello et al., 2008; Roque et al., 2011). Aimed at minimizing the dose deposited by photoneutrons, our research group developed an external shielding of a linear accelerator head, developed by Roque et al. (2011). Therefore, the objective of this study was to verify the effect of external shielding compared to the values of equivalent doses deposited by photoneutrons in healthy organs of a patient undergoing radiotherapy for prostate cancer, considering the treatment protocol used at the National Cancer Institute (INCA) of Brazil.

2. Materials and methods

2.1. Computational modeling

This study simulated the head of the Varian 2300C/D linear accelerator, with the external shielding of the head, inserted in a radiotherapy room, with the MAX phantom adapted to radiotherapy for the prostate. The forearm region was replaced with a volume of air. With that, the first beam interaction structure at lateral treatment angles (90° and 270°) was the hip region, similar to real treatment (Fig. 1). The patient was positioned at a surface-source distance of 100 cm, with the isocenter at the prostate, and the Linac 2300 operating at 18 MV, thus producing photoneutrons (Rebello et al., 2008; Roque et al., 2011; Thalhofer et al., 2011). The simulation was done using MCNPX. The treatment protocol used at INCA was adopted during simulation. This study will suppress the detailed information on developing the Linac 2300 head, the external shielding of the head and the treatment protocol, since these data are referenced in the three studies described above.

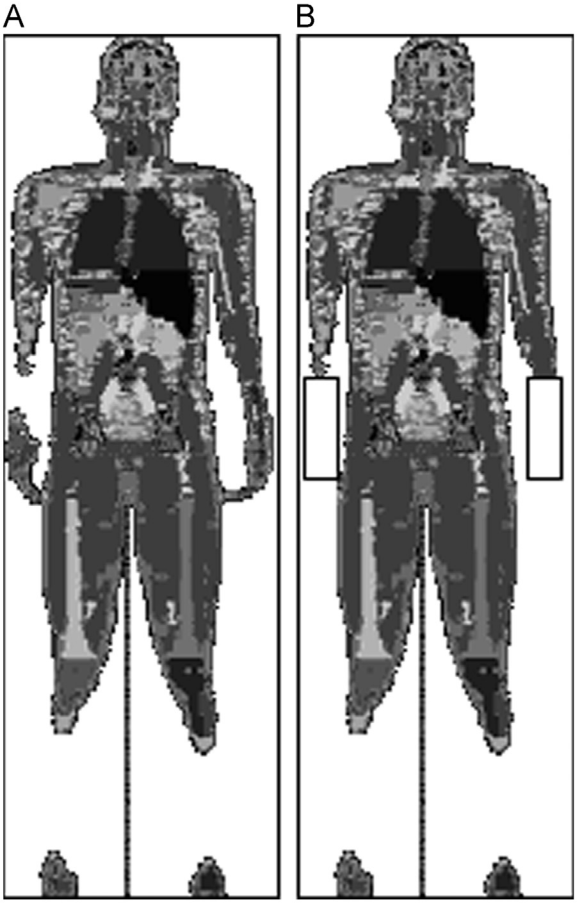


Fig. 1. MAX phantom adapted to the treatment for prostate: (A) Phantom normal (Kramer et al., 2003) and (B) Phantom adapted.

2.2. MCNPX code

The transportation of radiation by matter was simulated by the Monte Carlo MCNPX Code, version 2.5.0, with the simulation of diverse types of radiation, such as photons, electrons and neutrons, and the various types of secondary radiation stemming from interactions of the radiations with a given material (Jeraj et al., 1999; Pelowitz, 2005). In order to optimize simulation time, the cutting off of energy at 5.0 MeV was used, since photoneutrons are generated at power levels greater than that sum, with that value referenced by other authors (Bednarz et al., 2009).

2.3. Treatment for prostate cancer at INCA

The treatment protocol used in this study is similar to the one adopted in patients treated at INCA (Instituto Nacional de Câncer, 2012), one of the main centers of reference for cancer treatment in Brazil. The treatment protocol for prostate cancer uses 4 gantry inclination angles (0° and 180°—anterior–posterior) and (90° and 270—side). Due to the normal size of the prostate in the MAX phantom (Kramer et al., 2003), the sizes of fields used for each angle were “modeled” to cover the entire prostate. In other words, they are not the usually used fields in patients submitted to this treatment; however, it follows the profile as used during the treatment. These inclination angles were determined according to anatomic positioning, size and formats of the angle, thus, different opening fields are used. These openings are determined by the opening of the Jaws and MLC collimators, varying according to the gantry inclination angle.

2.4. Dose calculation

The radiation weighting factors due to neutrons vary with the energy. To consider this behavior, during the simulations to estimate the dose due to neutrons it was necessary to use the DE/DF command of the MCNPX code. Using this command, each simulation result was multiplied by the value of the DF conversion function corresponding to the DE energy of the incident radiation. Values of energies absent in the energy range defined in the DE/DF command are interpolated between the highest or lowest values of energy contained in the respective sequences. Thus, each absorbed dose obtained for each energy interval was multiplied by the corresponding w_R. At the end, adding up all the

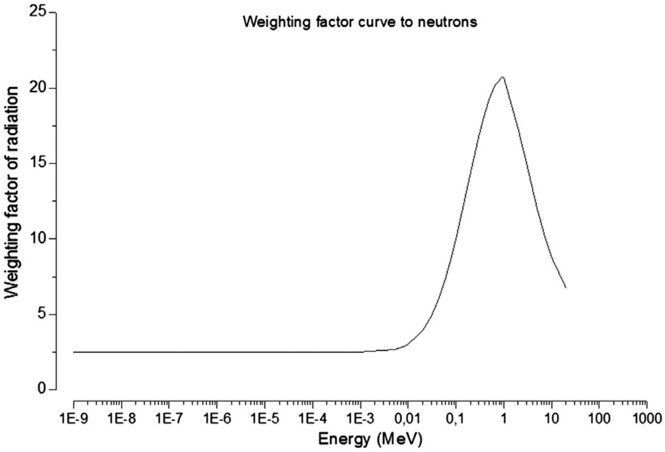


Fig. 2. Radiation weighting values used for neutrons considering ICRP, 103 (International Commission on Radiological Protection, 2008).