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Fetus absorbed dose evaluation in head and neck radiotherapy procedures of pregnant patients

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HIGHLIGHTS

- Head and neck radiotherapy simulation.
- Head and neck radiotherapy procedures for pregnant patients.
- Shielded and unshielded fetus absorbed dose evaluation.

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ABSTRACT

In this work the head and neck cancer treatment of a pregnant patient was experimentally simulated. A female anthropomorphic Alderson phantom was used and the absorbed dose to the fetus was evaluated protecting the patient's abdomen with a 7 cm lead layer and using no abdomen shielding. The target volume dose was 50 Gy. The fetus doses evaluated with and without the lead shielding were, respectively, 0.52 ± 0.039 and 0.88 ± 0.052 cGy.

1. Introduction

Therapeutic procedures causing exposures of abdomen of women likely to be pregnant should be avoided unless there are strong clinical indications (International Commission on Radiological Protection, 1991; Antypas et al., 1998). However, for many pregnant women there is no alternative and they have to be submitted to radiotherapy. When this is the case, the treatment should provide the best tumor control and reduce the dose to the fetus at levels that prevent the immediate effects of radiation and substantially reduce the probability of occurrence of its long term effects.

Each year a considerable amount of pregnant women needs to be submitted to radiotherapeutic procedures to combat malignant tumors. Annually in the United States approximately 4000 pregnant women require treatment for cancer. Radiation therapy is often a treatment of choice for these patients (Stovall et al., 1995).

In Brazil there is no information about the frequency of pregnant women that need to be submitted to radiation therapy. However, head and neck cancer is a disease that affects an important number of women in the country, including, possibly, some pregnant women. In Brazil, head and neck cancer is more common among men. Brazilian data refer only to oral cancer and estimated to the year 2008 10,380 new cases of oral cancer among men and 3780 among women, occupying this form of disease the seventh place among the more frequent types of cancers in the country (Colombo and Rahal, 2009). In Brazil, in public hospitals for the therapy of cancer, the most common treatment for women, excepting gynecological cancer therapy, is the head and neck cancer treatment. For obvious reasons of radiation protection to the fetus, gynecological treatment will not be the subject to this study. Therefore, the treatment elected to be investigated was the head and neck one, even considering that there are other possible more critical radiation therapies to the pregnant patient.

Different authors have studied the dose in distant organs outside the PTV due to secondary radiation (Fraass and van de Geijn, 1983; Greene et al., 1983, 1985; McParland, 1990; Miljanic et al.,

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2014). Data and techniques to estimate the fetal dose resulting from pregnant patients treatment with photons beams were published by the AAPM Task Group 36 (Stovall et al., 1995). Additionally, it is possible to use shielding and beam positioning such that the potential dose to the fetus can be minimized. Together, these techniques allow a treatment team to assess and, if possible, minimize the risks to the fetus (Cygler et al., 1997).

Biological effects to the fetus due to ionizing radiation exposure are noteworthy and can be divided into four categories: a) intrauterine death; b) defects; c) disorders of growth and development; d) mutagenic and carcinogenic effects (Paula and Medeiros, 2001; D' Ippolito and Medeiros, 2005).

The occurrence of these effects depends on the radiation dose absorbed and the gestational age. Generally, low doses can cause temporary cellular damage passible to be repaired by the body itself. Moreover, high doses of radiation can interrupt cellular development and maturation, leading to the fetus death or malformations (Paula and Medeiros, 2001; D' Ippolito and Medeiros, 2005).

The embryo is more sensitive to the effects of ionizing radiation during the first two weeks of gestation; during this period, the radiation exposed embryo will remain intact or will be reabsorbed or aborted (Brent, 1989; Paula and Medeiros, 2001; D' Ippolito and Medeiros, 2005). During this period, the risk of fetal death is considered when exposure exceeds 100 mGy (Paula and Medeiros, 2001; D' Ippolito and Medeiros, 2005). If the fetus is exposed between the 3rd and 15th weeks of gestation severe abnormalities may occur in the central nervous system, which is being formed. When the fetus is exposed to doses exceeding 100 mGy, mental retardation and a reduction of about 30 points can occur in the intelligence quotient (IQ) for each 100 mGy above the upper limit tolerated (D' Ippolito and Medeiros, 2005; Miller, 1990). Between the 16th and 30th weeks of gestation, the risk of mental retardation remains. After the 32nd week of gestation no significant risk to the fetus is present, excepting for a possible increased risk of developing a malignancy during childhood or maturity (D' Ippolito and Medeiros, 2005).

Cygler et al. (1997) described the fetal dose for a 23 weeks pregnant patient that underwent mantle field irradiation for supradiaphragmatic Hodgkin's disease. The fetal exposure was under 10 cGy, within the zone of fetal tolerance and a normal infant was delivered at term.

Mazonakis et al. (2003) investigated the embryo dose for radiotherapy of Hodgkin's disease in early pregnancy. They concluded that local field irradiation in the regions of neck or axilla may be safety performed even without uterus shielding. For local field irradiation in the region of neck-mediastinum and for mantle radiotherapy, the extend of the irradiated area, the distance separating the embryo from the field isocenter and the tumor dose are determining whether the reduction dose to a shielded embryo may possibly be reduced below 10 cGy.

Antypas et al. (1998) estimated the radiation dose delivered to the fetus in a pregnant patient irradiated for breast cancer. They concluded that the dose delivered to the unshielded fetus was 3.9 cGy for a 46 Gy total tumor dose. According to the authors, no deterministic biological effect of radiation on the live-born embryo would be expected and the lifetime risk for radiation-induced fatal cancer would be higher than the normal incidence, but could be considered as inconsequential.

In this work the head and neck cancer treatment of a pregnant patient was experimentally simulated. The patient was simulated by an anthropomorphic Alderson phantom and the absorbed dose to the fetus was evaluated using micro-rod TLD-100 detectors in two conditions, namely protecting the phantom's abdomen with a 7 cm lead layer and using no abdomen shielding. The aim of this experiment was to evaluate the efficiency of the abdomen protection in reducing the fetus absorbed dose.

2. Materials and methods

The pregnant patient was simulated by an Alderson anthropomorphic phantom. The phantom abdomen region was substituted by four solid water plates, forming a parallelepiped with dimensions of $30 \times 20 \times 20\ cm^3$, in order to facilitate the evaluation of the absorbed dose at the fetus position using thermoluminescent (TL) dosimeters as illustrated in Fig. 1. The fetus position was indicated by a radiotherapy expert physician. The TL dosimeters were placed in 3 acrylic supports, each support containing three samples (rod TL dosimeters). The supports were placed on a rod-shaped prism with a $3 \times 3\ cm^2$ square base (Fig. 2). This rod was placed at a depth of 10 cm from the surface of the solid water-plate arrangement simulating the abdomen of the

Fig. 1. Female Alderson anthropomorphic phantom used to simulate the pregnant patient. The phantom abdomen region was substituted by solid water plates.