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# Cancer risk coefficient for patient undergoing kyphoplasty surgery using Monte Carlo method

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ABSTRACT

Kyphoplasty surgery is widely used for pain relief in patients with vertebral compression fracture (VCF). For this surgery, an X-ray emitter that provides real-time imaging is employed to guide the medical instruments and the surgical cement used to fill and strengthen the vertebra. Equivalent and effective doses related to high temporal resolution equipment has been studied to assess the damage and more recently cancer risk. For this study, a virtual scenario was prepared using MCNPX code and a pair of UF family simulators. Two projections with seven tube voltages for each one were simulated. The organ in the abdominal region were those who had higher cancer risk because they receive the primary beam. The risk of lethal cancer is on average 20% higher in AP projection than in LL projection. This study aims at estimating the risk of cancer in organs and the risk of lethal cancer for patient submitted to kyphoplasty surgery.

## 1. Introduction

Kyphoplasty is a surgical procedure recommended for correcting the vertebral compression fracture. This surgery uses the C-Arm images to guide the surgical cement for the fractured vertebra through needles that are injected into the patient (Lieberman et al., 2001). How this surgery uses an equipment with high temporal resolution, the study of radiation doses involving the procedure is a source of many studies in the literature but, as far as we know, no study shows the cancer risk of this surgery for the patient as defined by ICRP 103 and BEIR VII (ICRP, 2007; NRC, 2006).

The concept of cancer risk at low doses has been the subject of study in diagnostic radiology procedures (Brenner et al., 2003), for example, in studies involving interventionist cardiology and computer tomography (Samara et al., 2012; Einstein et al., 2007). Brenner (2008) and Brenner and Huda (2008) questioned the use of the term effective dose commonly applied in radiation physics and proposed the calculation of cancer risk that is based on factors provided by BEIR VII. According to Brenner and Huda, this term may better represent the risk of ionizing radiation exposure.

The purpose of this study is to calculate the cancer risk for patient undergoing kyphoplasty procedures using a radiation transport program based on the Monte Carlo method and virtual anthropomorphic phantoms considering the projections and tube tensions that can be employed during a kyphoplasty surgery.

In this study, the cancer risk (CR) in organs was normalized by KAP (**K**erma **A**rea **P**roduct) that is a quantity generally used in kyphoplasty surgery and can be easily measurement. Therefore, the results of this work are presented in the form of conversion coefficients (CCs), CR/KAP (mGy$^{-1}$.cm$^{-2}$).

## 2. Materials and methods

For cancer risk calculation were developed computational scenarios from MCNPX (**M**onte **C**arlo **N**-**P**articles e**X**tend) code (Pelowitz, 2011). The program allows users to create structures and shapes to the desired irradiation scenario providing more realistic computer simulations. The computational anthropomorphic phantoms used in this work are two adult male hybrid phantoms (UFHADM – **U**niversity of **F**lorida **H**ybrid **AD**ult **M**ale). The phantom has a mass of 73.4 kg and 1.76 m height, the same of reference phantoms of ICRP (ICRP, 2009; Lee et al., 2010). For this scenario (Fig. 1), the input file objects, e.g.: X-ray equipment, bed, polyurethane foam, etc, was inserted providing an increased

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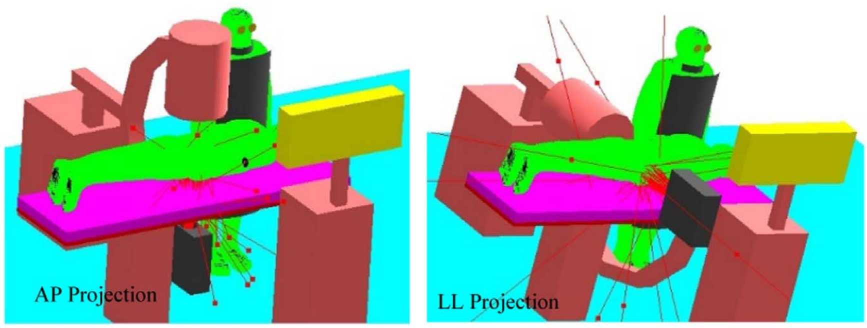


**Fig. 1.** Visualization of elaborate scenarios in the two projections.

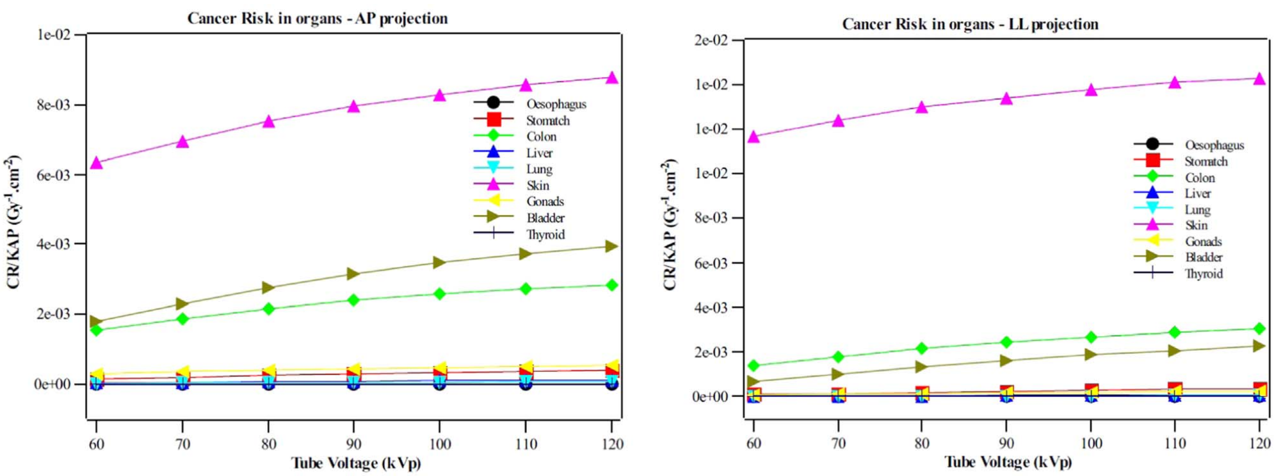


**Fig. 2.** Cancer risk in organs for patient submitted to kyphoplasty surgery in AP and LL projection. The values used for the graph plot are in Appendix A.

scattering of radiation and which can contribute to the increase of the risk associated with this practice (McConn et al., 2011). Recent studies show that computational scenarios, which are more similar to the actual medical scenarios, can better simulate the radiation transport taking into account the effects of radiation on the matter. (Santos et al., 2014, 2015 and 2016).

For this surgery, two radiographic projections are used, **A**ntero-**P**osterior (AP) and **L**atero-**L**ateral (LL). For each projection, seven X-ray spectra were generated from 60 to 120 kVp in steps of 10 kVp (Cranley et al., 1997). In LL projection, the patient's arm prevents the direct beam reaches the desired region. So, it was necessary to remove the arms in the phantom to better estimate the risk of cancer in the patient.

In this work, the measures of cancer risk are related to the KAP that can be provided by C-Arm during the surgery. For the KAP simulation, a cell filled with air with dimension $5\times5\times1$ cm$^3$ was created in tube output. Thus, through the results of this work, it is possible to estimate the risk of cancer based on KAP provided by C-Arm.

The equivalent and effective doses were calculated as recommend by the ICRP (ICRP, 2007). The dose in the phantom was calculated using the tally *F8 (in MeV/particle) and the cell filled with air was calculated using the tally F6 (MeV/g). The tally *F8 measures the total energy deposited in each organ and tissue in the body and the tally F6 measures the energy deposited in cell divided by cell mass in electronic equilibrium (Pelowitz, 2011). The cancer risk in organs was calculated by multiplying the cancer risk coefficients ($F_r$) published in ICRP 103 (ICRP, 2007) by the equivalent dose obtained in this work. The results are shown in graph in Fig. 2 and Appendix A. In addition, it was calculated the risk of lethal cancer based on the effective dose. The ICRP 103 in Table A.4.1 proposes the risk coefficient for lethality cancer as $5.5.10^{-2}$ Sv$^{-1}$. Thus, a relationship between the risk of cancer and the KAP emitted by the equipment during the examination is obtained (CR/mGy.cm$^2$). Using these coefficients, it is possible to estimate the risk of cancer for any projection and beam energy for kyphoplasty surgery.

For the calculation performed in this study, two computers were used with Intel i7 processor, 2.8 GHz, and 6 GB RAM. Each irradiation scenario takes 10 days to be processed, considering that $10^9$ particles histories were used.

## 3. Results and discussion

In this study were calculated the dose equivalent coefficients in different organs and tissues of an adult patient using projections

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