Radiation Measurements 89 (2016) 68–73

Contents lists available at ScienceDirect

Radiation Measurements

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

Evaluation of medical exposure and exposure by the public in a typical scenario of examinations using mobile X-ray equipment through the Monte Carlo simulation

Felipe A. Santos [a, *], Diego C. Galeano [a], William S. Santos [b], Albérico B. Carvalho Júnior [a]

[a] Department of Physics, Center of Exact Sciences and Technology, Federal University of Sergipe, UFS, Marechal Rondom Street, São Cristóvão, Brazil
[b] Nuclear Energy Research Institute, University of São Paulo, USP, Almeida Prado Street, São Paulo, Brazil

HIGHLIGHTS

- A computational scenario involving mobile X-ray equipment in hospitals were modeled.
- Evaluation of medical exposure and exposure by the public was made by CC_E (E/ESD).
- A pair of the anthropomorphic simulators was inserted into the input file MCNPX.
- Analyze the influence in CC_E for the different types of fields used in examinations.
- Monitoring the reduction of CC_E's with increasing distance between the beds.

ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form
7 March 2016
Accepted 9 March 2016
Available online 10 March 2016

Keywords:
Mobile X-ray equipment
Monte Carlo simulation
Conversion coefficient
Effective dose

ABSTRACT

In this work irradiation scenarios that simulated chest and abdomen examinations involving mobile X-ray equipment in hospitals were modeled with the purpose of calculating conversion coefficient for effective dose (CC_E), normalized to entrance surface dose (ESD), applied to patients and public individuals. These coefficients can easily be used in this practice. Patients and public individuals were represented by a pair of anthropomorphic phantoms inserted in the MCNPX 2.7.0 radiation transport code. One of the phantoms (patient) was irradiated with the direct beam simulating examinations of the chest and abdomen, each with two fields of irradiation, ideal (IF) and extrapolated (EF). Using the software SPECGEN X-ray spectra from 60 to 100 kVp at 10 kVp intervals were generated and used in this work. The other phantom (public individual) was positioned 50–200 cm from the patient. In relation to the CC_E calculated in the patient, the average increase obtained between the irradiation fields was 62.4% for the chest examinations, and for the same conditions the CC_E was calculated for abdomen examinations and found to be 8.0%. Increasing the distance between public individual and patient, reductions of up to 81.7% in the CC_E in abdomen examinations and 83.4% in chest examinations were observed. Through the assessment of CC_E of these scenarios, it is possible to measure the damages relating to this practice for both patients and public individuals.

1. Introduction

Clinical applications of mobile X-ray equipment are very common. Several advances in medical imaging can be used for diagnosing acute emergencies diseases by means of rapid diagnostic imaging, such as cardiovascular and thoracic abnormalities, emphysema, hemothorax, or cardiopulmonary resuscitation (Henschke et al., 1997; Graat et al., 2006). The mobile X-ray equipment is often used in general infirmary, intensive care units and surgery rooms. When the mobile X-ray machine is used, the radiation protection must be enforced for the general public and radiation workers (Bhagwanjee and Muckart, 1996; Trotman-Dickenson, 2003; Simpson et al., 1998).

The use of mobile X-ray equipment is well established in hospitals. Moreover, there are already protocols for securing the quality of service in relation to the dose and image quality (Tuohy et al., 1995). There are several studies about the radiation doses

* Corresponding author.
E-mail address: santosfa@outlook.com (F.A. Santos).

http://dx.doi.org/10.1016/j.radmeas.2016.03.005

Table 1
Variations of scenarios in this work.

Examinations type	Irradiation field (cm^2)	Voltage (kVp)	Distance between phantoms (cm)
Chest/Abdomen	Ideal 35 × 43 and Extrapolated 55 × 55	60	50/100/150/200
		70	50/100/150/200
		80	50/100/150/200
		90	50/100/150/200
		100	50/100/150/200

related to the use of the mobile X-ray equipment in hospital infirmaries (Burrage et al., 2003; Smans et al., 2008; Santos and Maia, 2012) but everything that has been made until now related to these studies is experimental. A study with chest examination simulation was developed with an acrylic phantom in a Brazilian hospital. The results show that for most cases the professional who follows recommendations of radioprotection remains with values of effective dose below the recommended limits (Santos and Maia, 2012). Computer simulations, through the Monte Carlo method, have been used in some works in the radiodiagnostic area, mainly in interventional radiology (IR) (Mah et al., 2011; Clairand et al., 2008; Jarvinen et al., 2008; McCafrey et al., 2012; Koukorava et al., 2014; Santos et al., 2014). However, these works use Monte Carlo Method to simulate beams in IR (Mah et al., 2011), for estimating doses in dosimeters and for comparing with the experimental methods (Clairand et al., 2008; Jarvinen et al., 2008), in order to evaluate types of materials that are used to ensure the security levels for procedures using high temporal resolution (McCaffrey et al., 2012). Some papers seek to produce a real scenario in IR irradiation (Koukarava et al., 2014; Santos et al., 2014).

Direct measurements of dose in organs and tissues are very complicated, and in most cases, impossible to be performed. There are some alternatives to solving this problem, like the use of physical anthropomorphic phantoms that allow the insertion of detectors for direct measurement of dose in organs (Cerqueira et al., 2011), or the estimated doses through computer simulation. In such cases the most common technique is the Monte Carlo method (MC), which uses a computational anthropomorphic phantom to represent the individual exposed (Santos et al., 2014). The creation of more realistic scenarios provides the acquisition of dose values in typical situations where the patient, professional and public individuals were exposed. Because of MC method and the advent of computers, the use of this technique has become more accessible in Medical Physics (Yorijaz, 2009). By knowing that an accurate calculation of radiation doses is a difficult task to be experimentally achieved, the use of MC simulation proved to be adequate to estimating the absorbed doses in organs and tissues of patients and public individuals.

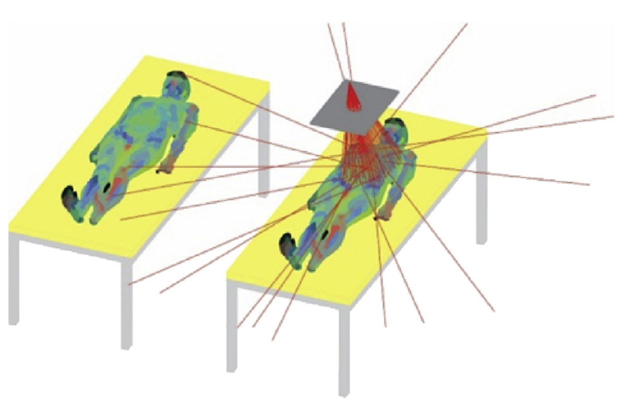

Fig. 1. Viewing example of the computer scenario.

The establishment of radiation protection and radiation safety with the use of mobile X-ray equipment is the main focus of our study. In this sense, this research aims to creating a real computational scenario for the practice of radiographic examinations performed in an infirmary using a pair of anthropomorphic computer simulators (patient and individual public). The goal is to estimate conversion coefficients (CCs) for effective dose (E) normalized to entrance surface dose (ESD) in a patient during chest and abdomen examinations for an ideal and an extrapolated field of irradiation. Additionally, we evaluated the influence of these procedures in CCs to public individuals that are restrained to a bed close to the examination equipment.

2. Materials and methods

The radiation transport code used was the MCNPX 2.7.0 (Pelowitz, 2011). This code can handle the transport and interaction of neutrons, photons, electrons and many other particles in a wide range of energies. Through this code it is possible to model complex irradiation scenarios and to achieve important applications in medical physics, as this area needs highly detailed scenarios in order to represent a rather realistic situation for the radiation exposure. The scenarios generated aimed to reproducing a typical scenario of radiological examinations that are performed in hospital beds, and for this purpose, two standard anthropomorphic phantoms (AM - Adult Male and AF – Adult Female) of ICRP 110 were used to calculate the effective dose (ICRP, 2009). In order to accomplish the duplication of the AM and AF reference phantom, the number of identification numbers (ID's) were reduced using the ImageJ (ImageJDisclaimer, 2004) software. This simplification was based on different ID's belonging to the same material. For example, the phantom had one ID for the left lung and another one for the right lung, but the simplified anthropomorphic phantoms used in this study possessed an ID for the entire lung. After the simplification the duplication of the phantom was performed using the same software. By modifying the IDs, a phantom with the same anatomical features of the original, but with different IDs, was generated. After simplification and duplication of the phantoms, they were converted into repeated structures and inserted in the form of an input file of the MCNPX code. In relation to the objects of the irradiation scenario, beds with polyurethane foam mattresses (density = 0.021 g/cm^3, composition: H (4.1%), C (54.4%), N (12.1%), O (29.4%)) and brackets stainless steel 302 (density = 7.86 g/cm^3, composition: C (0.140%), Si (0.930%), P (0.042%), S (0.028%), Cr (18%), Mn (1.860%), Fe (70%), Ni (9%)) were introduced (Mcconn et al., 2011).

In order to develop a realistic collimation system of the X-ray tube, a lead plate with a square section in the middle was created. For dealing with situations commonly found in these environments, different scenarios were elaborated. Simulations were made for examinations of the chest and abdomen considering and for each exam an ideally collimated field (IF) and an extrapolated field (EF). The technical parameters used in the computational simulation were obtained from the literature: peak voltages of 60–100 kVp at 10 kVp intervals, anode angle of 17°, tungsten