

# Evaluation of the respiratory motion influence in the 3D dose distribution of IMRT breast radiation therapy treatments

J C Lizar<sup>1</sup>, L F Santos<sup>1</sup>, F C Brandão<sup>2</sup>, K C Volpato<sup>2</sup>, F S Guimarães<sup>2</sup> and J F Pavoni<sup>1</sup>

<sup>1</sup>Departamento de Física, FFCLRP, Universidade de São Paulo, Av. Bandeirantes 3900, 14040-901, Monte Alegre, Ribeirão Preto, SP, Brazil

<sup>2</sup>Centro de Radioterapia de São Carlos, Rua Maestro João Seppe, s/nº, Jd Paraíso, São Carlos, SP, Brazil

Email: jessica\_lizar@yahoo.com

**Abstract.** This study aims to evaluate the motion influence in the tridimensional dose distribution due to respiratory for IMRT breast planning technique. To simulate the breathing movement an oscillating platform was used. To simulate the breast, MAGIC-f phantoms were used. CT images of a static phantom were obtained and the IMRT treatment was planned based on them. One phantom was irradiated static in the platform and two other phantoms were irradiated while oscillating in the platform with amplitudes of 0.34 cm and 1.22 cm, the fourth phantom was used as reference in the MRI acquisition. The percentage of points approved in the 3D global gamma analyses (3%/3mm) when comparing the dose distribution of the static phantom with the oscillating ones was 91% for the 0.34cm amplitude and 62% for the 1.22 cm amplitude. Considering this result, the differences found in the dosimetric analyses for the oscillating amplitude of 0.34cm could be considered acceptable in a real treatment. The isodose distribution analyses showed a decrease of dose in the anterior breast region and an increase of dose on the posterior breast region, being these differences most pronounced for large amplitude motion.

## 1. Introduction

Breast cancer is one of the major malignant diseases that affect women in the world [1]. It is usually treated with a combination of conservative surgery and postoperative radiotherapy [2]. Traditionally, breast cancer radiotherapy is performed using conformal radiotherapy techniques (3D-RT) with two tangential opposed beams with the possibility of using physical wedges to homogenize the delivered doses.

Considering the modern techniques available nowadays in radiotherapy, breast cancer can be treated using Intensity Modulated Radiation Therapy (IMRT) by using several beams with non-uniform intensities that varies according to the irradiated volume, this technique allows a better dose coverage at the treatment target compared to 3D-RT [3]. In addition, breast IMRT significantly reduces doses to the surrounding organs at risk, such as contralateral breast, heart and lungs [4-6]. However, during these treatments, there is significant uncertainty in the dose received by the planned target volume (PTV) because of respiratory motion [7]. The average respiratory rate for an adult at rest is between 12 to 18 breaths per minute and the moving parts induced by breathing can introduce significant errors in several



steps of the radiation treatment planning and treatment itself. These errors are difficult to predict and quantified due to non-synchronization between the radiation beams and movements of the targets.

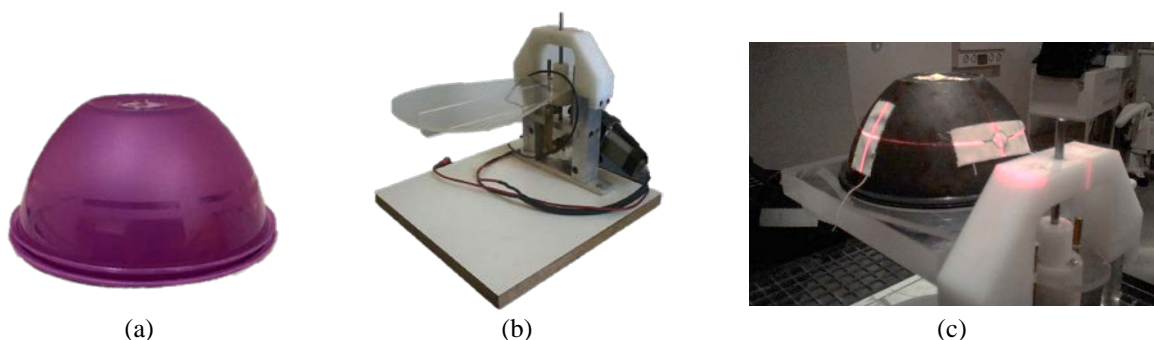
In this study, our goal is to evaluate the influence of the motion induced by breathing on the tridimensional dose delivered of IMRT breast treatments using MAGIC-*f* gel dosimeter [8] and an oscillating platform.

## 2. Materials and Methods

### 2.1. Gel preparation

MAGIC-*f* gel was prepared following the process described elsewhere [9].

Four phantoms with 0.5 L of volume and simulating the breast format were prepared (figure 1-a). Phantom 1 received the static IMRT treatment, phantom 2 received the IMRT treatments oscillating with amplitudes of 0.34 cm in the platform, phantom 3 received the same treatment oscillating with amplitudes of 1.22 cm in the platform and phantom 4 was used as a reference in the Magnetic Resonance Image (MRI) scanner. Seven calibration vials were also prepared from the same batch and were irradiated with doses up to 4 Gy.



**Figure 1.** (a) Phantom used to simulate the breast anatomy. (b) Oscillatory platform used to simulate breathing movement. (c) Phantom positioned on the platform to receive the IMRT radiation treatment.

### 2.2. Oscillatory Platform

An oscillatory platform made of acrylic material, supported by metallic bars that guide its movement and with a damping system for the maximum stability was used (figure 1-b). The platform allowed oscillations of 0.34 cm to 1.79 cm and 15 oscillations/minute.

### 2.3. Treatment planning and irradiations

CT images of the phantom positioned on the platform were acquired on a Phillips Brilliance Big CT Bore Oncology scanner with a voxel size of  $1.0 \times 1.0 \times 1.0 \text{ mm}^3$ , the platform was motionless and a point to be selected as the isocenter was marked with fiducials. It is important to mention that all the treatment planning was performed with the static CT images and, the evaluation of the motion influence on the 3D dose distribution will be considered as the variations of the measurements of the gel irradiated in the oscillating platform in relation to the gel irradiated in the static platform.

The CT data was imported on the Eclipse treatment planning system (TPS), version 10.0 (Varian Medical Systems), the isocenter was selected at the marked point, the phantom contour was delineated and a PTV was created considering a margin of 0.5cm inside the external contour. The IMRT treatment plan was created using 5 coplanar fields and a dose of 2 Gy was prescribed, simulating one fraction of the treatment.

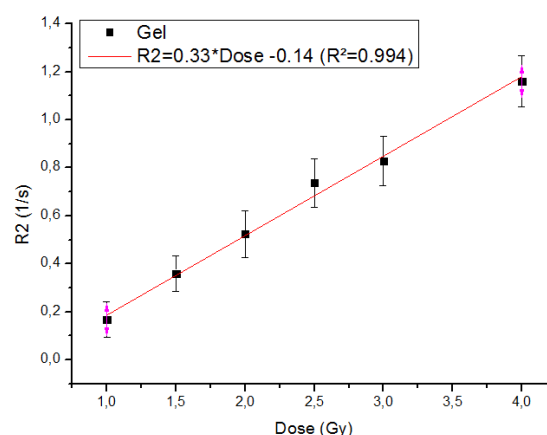
This treatment plan was delivered to the phantom as described before: phantom 1 received the IMRT treatment positioned on the motionless platform and phantom 2 and 3 received the IMRT treatments oscillating in the platform.

## 2.4. Magnetic Resonance Imaging

MRI of the three phantoms were acquired 1 day after irradiation using a Phillips Achieva 3T scanner and the head coil. A multi-spin echo sequence was used consisting of 7 echo times multiples of 22.352 ms, repetition time of 14000 ms and voxel size of  $2 \times 2 \times 2 \text{ mm}^3$  with a space between slices of 2 mm. The MRI intensity voxels were converted to R2 values by using a software developed in MatLab®.

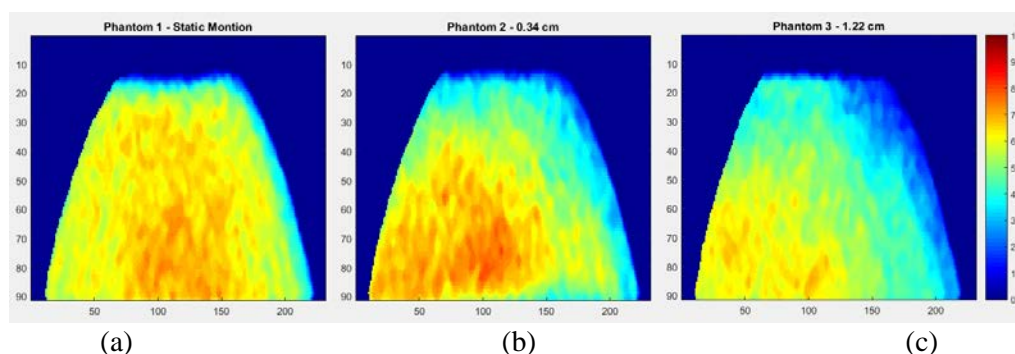
## 3. Results and Discussions

The calibration curve of this gel batch show a linear response (graph 1).



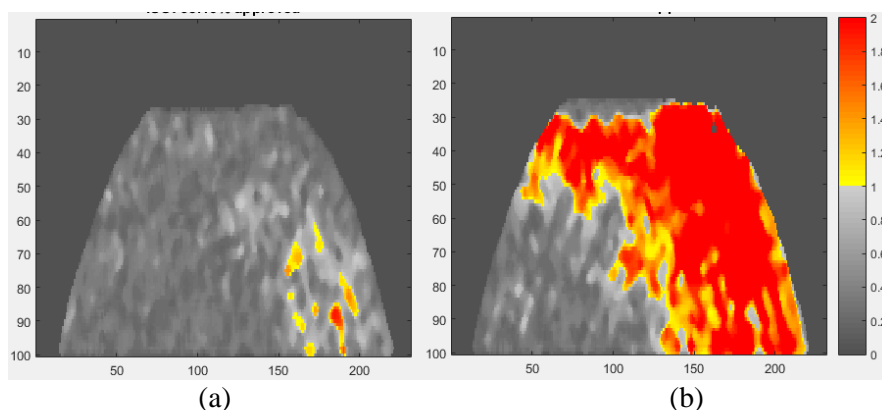
**Graph 1.** Magic-f calibration curve.

To avoid errors introduced by calibrating the gel dosimeter, but considering the linear behaviour of the calibration curve, each phantom 3D matrix data consisting of R2 values were normalized by its global maximum value (figure 2).

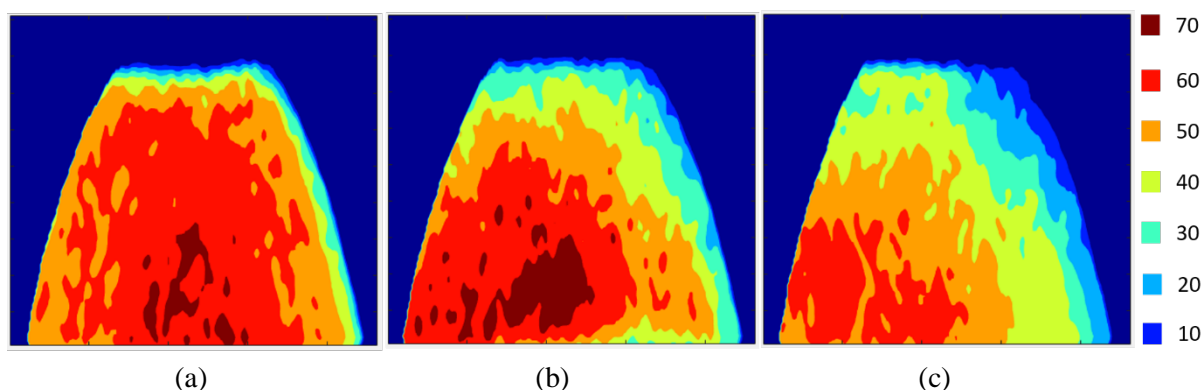


**Figure 2.** Normalized R2 distribution of isocenter images of the three phantoms treated with IMRT. (a) Phantom 1 was irradiated motionless. (b) Phantom 2 was irradiated oscillating with an amplitude of 0.34 cm. (c) Phantom 3 was irradiated oscillating with an amplitude of 1.22 cm.

To evaluate the motion influence on the dose distributions, a 3D global gamma analyses was performed using criteria of 3% of dose difference and 3mm in distance to agreement and a threshold of 15% was also used. The percentage of points approved in the 3D gamma analyses when comparing the dose distribution of phantoms 1 and 2 was 91% and for the dose distribution comparison of phantoms 1 and 3 was 62% (figure 3). These results show that the oscillation amplitude of 0.34mm, or a small respiratory breathing movement, could be considered acceptable in the clinical setting [10]. By analysing the isodose distribution, it is noticed a decrease of dose in the anterior breast region and an increase of dose on the posterior breast region. As expected, for both analyses the differences are most pronounced for large amplitude motions (figure 4) [11].



**Figure 3.** 3D gamma analyses of isocenter images, colored points represent reprovred values. (a) Gamma comparison of phantoms 1 and 2. (b) Gamma comparison of phantoms 1 and 3.



**Figure 4.** Isocenter isodose distribution for phantom 1 irradiated motionless (a), phantom 2 oscillating with amplitude of 0.34 cm (b) and phantom 3 oscillating with amplitude of 1.22 cm (c).

#### 4. Conclusions

The study demonstrated that dose inhomogeneity generated by a breathing motion using IMRT technique, could not be a concern when simulating a moderate breathing movement (amplitude of 0.34 cm), however it was observed that the increase of respiratory motion amplitude increased the dose inhomogeneity (amplitude of 1.22cm) and this impacts on the dosimetric parameters of the target volume coverage.

#### 5. References

- [1] Stewart B and Wild P. World Cancer Report 2014. Lyon, France: International Agency for Research on Cancer. ISBN 978-92-832-0429-9
- [2] National Comprehensive Cancer Network 2003 *J. Natl. Compr. Canc Netw.* **1** 148
- [3] Hill R *et al* 2009 *Med. Phys.* **36** 3971-81
- [4] Barnett G C *et al* 2009 *Radiother. Oncol.* **92** 34-41
- [5] Burmeister J *et al* 2008 *Med. Dosim.* **33** 6-3
- [6] Landau D *et al* 2001 *Radiother. Oncol.* **60** 247-55
- [7] Remouchamp V M *et al* 2003 *Int. J. Radiat. Oncol. Biol. Phys.* **55** 392-406
- [8] Baldock C *et al* 2010 *Phys. Med. Biol.* **55** R1-63
- [9] Fernandes J P *et al* 2008 *Phys. Med. Biol.* **53** N53-58
- [10] Chi F *et al* 2015 *Cancer Radiother* **19** 180-6
- [11] Menon G *et al* 2011 *Phys. Med. Biol.* **56** 7405