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DOSIMETRY OF AN ANIMAL IRRADIATION SYSTEM

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ABSTRACT

Radiation therapy uses ionizing radiation for cancer treatment, but its effectiveness may be limited by the consequent appearance of radiodermatitis. This problem may present several degrees: the highest among them is radionecrosis. Therefore, a model of study for the animal irradiation system (AIS) was built, generating radionecrosis on rat backs. The AIS is comprised by: a) a shield between the ^{60}Co irradiator metallic guide and the animal immobilizer (AI), with holes exposing the rat skin; b) a shield on the AI posterior part and (c) the AIS angle. The doses were measured with alanine pellets in seven positions (two external and five internal) and different heights, in axial planes along the AI, and irradiated with 85 Gy. The similarity in the geometry of the AIs made it possible to relate the doses of positions 1-7 with the same height among the AISs. The AISs equidistance to the source allowed simultaneous animal exposure. Minimizing the shielding and maximizing the angles among the AISs provided average doses almost identical in position **1**. A small variation among the mean doses for each of the AISs enabled to replace them by the average doses of the three AISs at position **1**. Shields allowed the attenuation of the uncertainties in the alanine pellet in the AI, reduction of the exposure time without compromising rat security and the rise of the dose in measurement positions **1** and **2**. The maximization of the angles among the AISs reduced the shielding secondary radiation contribution.

Key words: Dosimetry, Radionecrosis, Alanine, Wistar rat

1. INTRODUCTION

Radiotherapy is an important oncologic treatment modality that uses ionizing radiation for cancer treatment [1, 2]; its effectiveness depends on the maximization of the tumor control and the preservation of healthy tissues. Today, external radiotherapy uses energy magnitude megavoltage to subject the skin to high levels of ionizing radiation. The use of radiation could produce a skin damage called radiodermatitis with degrees of severity that are related to the dose rate received [3-5], with radionecrosis characterizing the highest degree of severity. According to projections from the Instituto Nacional do Câncer, in Brazil, 580 thousand new cases of cancer are forecast for the year 2015 [6], growing the number of cases of radiodermatitis. The radionecrosis can manifest during the radiotherapy sessions or after it, influencing the quality of life of patients [7]. By the time, radionecrosis remains one of the major side effects that impose limitations on the effectiveness of radiotherapy as to its benefits [8]. With the evolution of technology, there could be an increase in the concentration of ionizing radiation in the treatment area and, concomitantly, greater preservation of adjacent structures [9]: however, these advances strengthen the effects of radiodermatitis.

These effects are clinically treated depending on the degree of severity, but there are today few techniques to inhibit or eliminate radionecrosis generated by ionizing radiation. Thus, based on the irradiation of Nude mice support [10], it was prepared an animal irradiation support for Wistar rats, which was measured by means of a dosimetry mapping. The objective of this study was to obtain an animal irradiation system for Wistar rats, aiming to expand the investigation of new therapies for treating radionecrosis generated in radiotherapy.

2. MATERIALS AND METHODS

2.1. Animal irradiation support development

From experience with Nude mice irradiation support [10], an animal irradiation support (AIS) for Wistar rats was carried out: however, significant differences in size, immobilizer animal form and optimization of the number of shields occurred.

2.1.1. Animal immobilizer (AI)

It is made of polyvinyl chloride cylinder with 7.2 outside diameter, 0.2 in thickness and 19.5 cm height, with two retaining caps (Fig. 1). This cylinder has 8 holes of 8 mm diameter, allowing proper positioning of the animal and the skin portion to be exposed to gamma radiation.

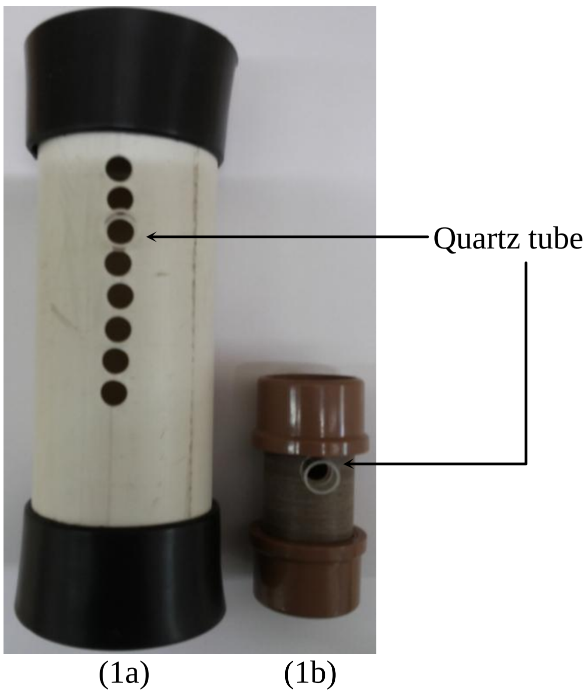

Figure 1: Differences between the Wistar rat immobilizer (Fig. 1a) and the Nude mice immobilizer (Fig. 1b).

2.1.2 Irradiation geometry

The irradiation geometry (Fig. 2) comprises three similar AIS, denominated: AIS_{Ref}, AIS_L and AIS_R. The indexes Ref. L and R represent the positions occupied by AISs, called reference, right and left in relation to the source of ^{60}Co. Each AIS consists of two lead shields: block **A**, with 9 x 10 x 20 cm^3, between the metal guide of the source of the ^{60}Co Panoramic irradiator (Yoshizawa) and the animal immobilizer; block **B**, with 5 x 10 x 20 cm^3, positioned at the back of the animal immobilizer. The face shield **A**, 20 x 9 cm^2, and the side surface of the animal immobilizer are tangent to the median plane of the source (MPS), represented by the dashed line with angular displacements $\theta_{Ref.}$, θ_L and θ_R. Thirty two alanine pellets (AERIAL®) with 3 mm^3 volume [11, 12] were fixed in positions **1** to **7**, in axial planes perpendicular to the animal immobilizer height, ranging between 10 and 19.5 cm from the plane irradiation table. The measured distance between the source of the radiator and the position **2** was 17.8 cm.

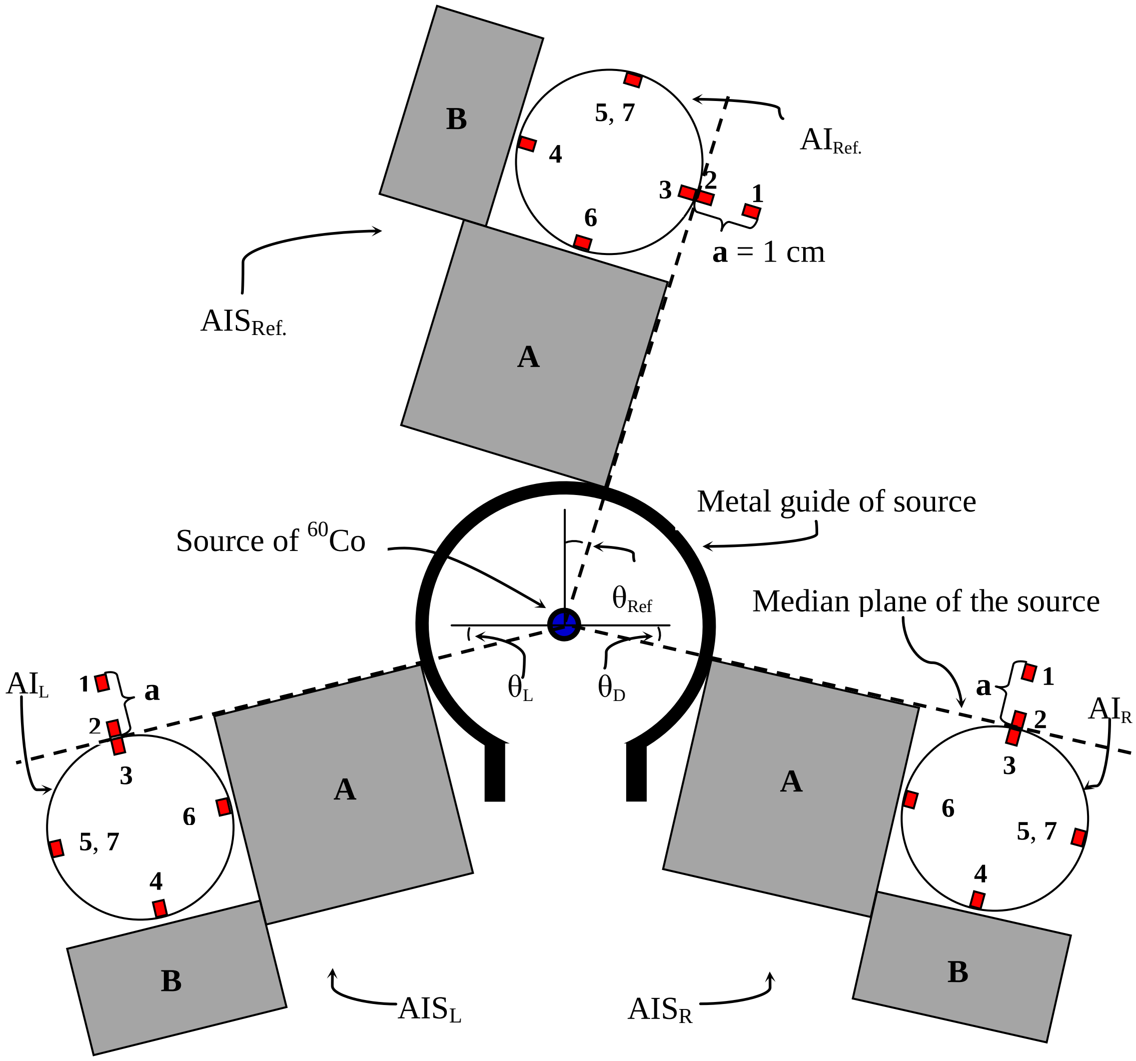

Figure 2: Upper view illustration of irradiation geometry. a) The numbers 1-7 indicate the positions occupied by alanine pellets (red rectangles) in the AI, during irradiation; b) the angular displacement ($\theta_{Ref.} = 18^o$, $\theta_R = 96^o$, $\theta_L = 265.5^o$) of each of the median plane of the source the AIS and the lead shields A and B.

2.1.3. Dosimetry of animal irradiation support

The irradiation lasted 77 minutes with the expected dose of 85 Gy. The dose distribution was determined by reading the signs of EPR alanine pellets, at a MiniScope spectrometer (MT MAGNETTECH), using dedicated software AerEDE of AERIAL®. The parameters of the spectrometer were employed as: magnetic field 3358 G, in a range of 30 G, microwave power of 10 mW and 12 seconds of scanning time. In all readings, the reference samples used were 100 Gy.

3. RESULTS

3.1. Animal irradiation support development

3.1.1. Animal immobilizer (AI)

The holes along the animal immobilizer enable a better storage of the rats, according to their size (Fig. 1). The similarity between the AI geometry made it possible to establish the relationship of doses (Table 1), in equivalent positions **1**-**7** of the same height, between the AISs (Fig. 2).

3.1.2. Irradiation geometry

The use of optimized shields afforded significant reduction of uncertainty in the positioning of alanine pellets, reducing both, the thickness of the shield [13] and the exposure time. The equidistance from the source of the AISs irradiator, made it possible to compare the doses, allowing irradiation of three animals, simultaneously (Fig. 3). Maximizing the angles among the AISs resulted in practically identical average doses of positions **1** and **2** between immobilizers (Table 1) and reduced the radiation scattered by the contribution shield of AISs in positions **1**-**3** of the AIs (Fig. 3).

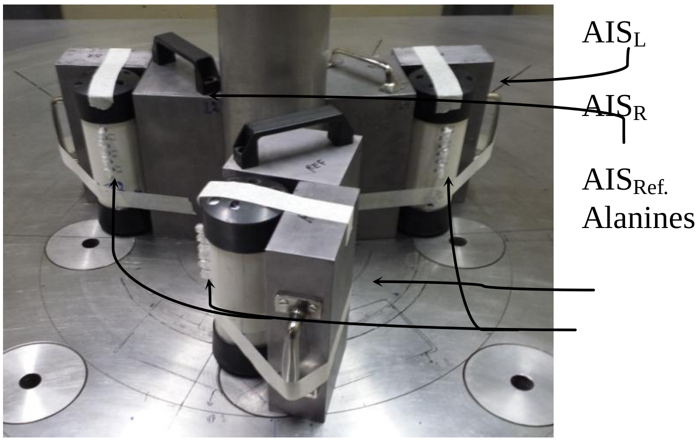

Figure 3: Top view of the irradiation geometry. Individual arrangement of 3 AISs and alanines at heights of 10 to 15 cm.

3.1.3. Dosimetry of irradiation geometry

Table 1 shows the doses obtained from positions considered relevant for the generation of radiation necrosis and protection of rats. Doses in positions **1** and **2** are less than 85 Gy due to the proximity to the shield (Fig. 3). The doses in positions **1** show little variation between them, which allows changing these by the average doses of AISs in the first position. There was average dose reduction in position **3** (internal) in respect to position **2** (external): the AI_R, AI_E and AI_D were 88%, 89% and 85% respectively. The doses in the **4-7** positions (internal) are not considered significant radioprotection effects [14, 15]. Furthermore, the positions **6-7** can be disregarded, since the rat snout does not reach 17 cm inside the AI.

Table 1: Doses in relevant positions in the AIS for skin exposure in the dorsal region, and physical integrity of the rat.

AIS irradiation angulation	Height (cm)	Dose (Gy) in calibration positions						
		1	**2**	**3**	**4**	**5**	**6**	**7**
$\Theta_{Ref.} = 18^0$	15	77	61	7	3	3	-	-
	14	77	64	8	4	3	-	-
	13	78	63	8	4	3	-	-
	12	79	66	9	4	3	-	-
	11	78	64	8	4	3	-	-
	10	78	63	8	4	4	-	-
	19.5	-	-	-	-	-	**4**	**4**
	Average dose	**78**	**64**	**8**	**4**	**3**	-	-
	$\sigma_{Ref.}$	**1**	**2**	**1**	**0**	**0**	-	-
$\Theta_R = 96^0$	15	69	*	5	3	3	-	-
	14	79	69	7	4	3	-	-
	13	82	65	9	3	3	-	-
	12	81	72	8	4	3	-	-
	11	80	72	7	4	3	-	-
	10	78	70	7	3	3	-	-
	19.5	-	-	-	-	-	**4**	**4**
	Average dose	**78**	**70**	**8**	**4**	**3**	-	-
	$\sigma_{Dir.}$	**5**	**3**	**1**	**1**	**0**	-	-
$\Theta_{L.} = 265.5^0$	15	78	67	9	3	3	-	-
	14	78	68	8	4	3	-	-
	13	77	70	11	4	3	-	-
	12	79	69	11	3	3	-	-
	11	75	69	10	3	3	-	-
	10	77	67	10	3	3	-	-
	19.5	-	-	-	-	-	**4**	**4**
	Average dose	**77**	**68**	**10**	**3**	**3**	-	-
	$\sigma_{Esq.}$	**1**	**1**	**1**	**1**	**0**	-	-

* There was no dose reading at the height of 15 cm.

4. CONCLUSION

From the results of this study, an animal irradiation system for Wistar rats was obtained to generate radiation necrosis of the skin, induced by ionizing radiation. This irradiation system will facilitate investigation of new therapies for the treatment or prevention of side effects caused by radionecrosis resulting from radiotherapy.

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