

# Extracranial doses in patients submitted to stereotactic radiosurgery for brain tumors\*

*Doses extracranianas em pacientes submetidos a radiocirurgia estereotáxica para tumores cerebrais*

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**Abstract Objective:** To estimate extracranial doses on eyes, thyroid, chest and pelvis in patients submitted to radiosurgery with 6 MV linear accelerator. **Materials and Methods:** The present study evaluated 11 patients, 7 of them with primary, and 4 with secondary brain tumors. In the latter group, 2 patients had two lesions. Thermoluminescent dosimeters were utilized to estimate the extracranial dose. Radiosurgery cones ranges between 1.50 and 3.75 cm and doses between 1300 and 2000 cGy. **Results:** Mean patients' age was 52 years, and 63.6% of them were women and 36.4%, men. Lesion locations were the following: right acoustic nerve (1), frontal (2), parietal (5), right occipital (1), cerebellum (2) and parasagittal (2). Mean received doses were the following: 5.1 cGy between the eyes; 4.8 cGy in the right eye; 6.5 cGy in the left eye; 4.2 cGy in the thyroid; 1.65 cGy in the chest; and 0.45 cGy in the pelvis. **Conclusion:** The results demonstrate that although the eye doses do not exceed the tolerance limits for occurrence of lens opacity, it is important that the risks associated with radiation doses are taken into consideration by radiotherapists in the planning of cranial radiosurgery procedures.

**Keywords:** Brain tumor; Radiotherapy; Radiosurgery; Dosimetry.

**Resumo Objetivo:** Estimar a dose extracraniana nos olhos, tireoide, tórax e pelve em pacientes submetidos a radiocirurgia com acelerador linear de 6 MV. **Materiais e Métodos:** Foram avaliados 11 pacientes com tumores cerebrais primários (7 pacientes) e secundários (4 pacientes), sendo que dois destes apresentavam duas lesões. Para a estimativa da dose extracraniana, foram utilizados dosímetros termoluminescentes. Foram utilizados cones de 1,50 a 3,75 cm e as doses de radiação variaram de 1300 a 2000 cGy. **Resultados:** A idade média dos pacientes foi de 52 anos, sendo 63,6% do sexo feminino e 36,4% do sexo masculino. As localizações das lesões foram: nervo acústico direito (1), frontal (2), parietal (5), occipital direito (1), cerebelar (2) e parassagittais (2). Os valores médios das doses recebidas na região entre os olhos foram de 5,1 cGy; no olho direito, de 4,8 cGy; no olho esquerdo, de 6,5 cGy; na tireoide, de 4,2 cGy; no tórax, de 1,65 cGy; e na pelve, de 0,45 cGy. **Conclusão:** Estes resultados mostram que embora as doses não ultrapassem os limites de tolerância para ocorrência da opacidade do cristalino, é importante que os médicos radio-terapeutas considerem os riscos de dose de radiação nessas regiões durante o planejamento de procedimentos de radiocirurgia craniana.

**Unitermos:** Tumor cerebral; Radioterapia; Radiocirurgia; Dosimetria.

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## INTRODUCTION

Cranial stereotactic radiosurgery consists in administering high doses of ioniz-

ing radiation into a stereotactically defined intracranial target. Such procedure is utilized in the treatment of small-sized lesions measuring < 4 cm and is performed with Cobalt-60 gamma beams or high-energy X-ray beams (linear accelerator (acelerador linear)<sup>(1,2)</sup>. The advantage of this type of procedure is the application of high doses of radiation on the target to be treated with minimal radiation delivered to surrounding structures<sup>(3)</sup>. However, parts of the patient's body located out of the area to be treated may receive secondary radiation because of scattering originating from parts of the apparatus and room walls, radiation leaks through the shielding of the source head,

collimators scattering, as well as scattering in the patient<sup>(4,5)</sup>. The estimation of the dose received by the patient in extracranial organs is relevant, particularly for those submitted to radiosurgery and with long life expectancy. Secondary effects resulting from radiation may manifest specially in pediatric patients and patients with benign brain diseases.

It is important to highlight that dosimetry in patients submitted to radiosurgery is of paramount relevance, considering the possibility of occurrence of biological effects. The eyes deserve enhanced attention, considering the possibility of crystalline lens opacification, since the threshold for

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cataract radioinduction is only 0.5 Gy, in acute and fractionated exposures<sup>(6-9)</sup>.

The present study was aimed at estimating the dose received in extracranial regions and organs such as eyes, thyroid, chest and pelvis.

## MATERIALS AND METHODS

The present study evaluated 11 patients submitted to radiosurgery in Instituto de Radioterapia Waldemir Miranda – Centro de Radiocirurgia de Pernambuco, Recife, PE, Brazil, utilizing a Varian Clinac 600C 6 MV linear accelerator, with a Radionics radiosurgery system of circular collimators. The study sample included seven female and four male patients, whose minimum age was 26 years and maximum age was 83 years. The patients were treated for primary brain tumors (seven) and secondary brain tumors (four). Among the patients with secondary tumors, two presented two brain lesions.

For estimating the dose in extracranial regions, TLD-100 thermoluminescent dosimeters encapsulated in pairs in numerically identified plastic envelopes. For each patient and for each treated lesion, envelopes with dosimeters were placed on the following regions: between the eyes, on the external corners of both eyes, on the region of the thyroid gland, on the chest (on the lower third of the sternum) and on the pelvis (hypogastric region). After the dosimeters positioning according to the tumor location and size, the treatment was performed with doses ranging from 1300 cGy to 2000 cGy. The cones diameter ranged from 1.50 cm and 3.75 cm. The number of fields (arches) ranged between three and six, and the angulation of the accelerator head, between 45° and 150°. Once the radiosurgery was completed, the TLDs were removed and taken to the Laboratory of Thermoluminescent Dosimetry of the Group of Dosimetry and Nuclear Instrumentation, Department of Nuclear Energy, Universidade Federal de Pernambuco, for reading. As each envelope contained two dosimeters, two readings were obtained for each point. The mean value was determined and a net value was obtained by subtracting the reading of the non-irradiated dosimeter (background reading). The

value of the net reading obtained at each point was converted into dose by utilizing the dosimeters calibration curve previously determined with dosimeters irradiation in the linear accelerator, with previously known doses. All the patients were given explanations on the present study and signed a term of free and informed consent.

## RESULTS

Table 1 presents the characteristics of all the patients included in the present study, as well as the tumor sites. Based on such data, one observes that 63.6% of the patients were women and 36.4% were men; and the mean patients' age was 52 years.

Table 2 shows the location of the tumors, the size of the utilized cone, values of total treatment doses, as well as values of the doses observed in the evaluated extracranial regions, as follows: between the eyes, external corner of right eye, external corner of left eye, thyroid, chest (between the breasts) and pelvis (below the umbilical scar). The locations of the lesions were the following: right acoustic nerve (1), frontal (2), parietal (5), right occipital (1), cerebellar (2) and parasagittal (2), which are regions where brain tumors are typically found.

Figure 1 shows the distribution of values of radiation doses received in extracranial regions according to the Box & Whiskers chart. In such type of chart, the rectangle extremities represent the first and third quartiles of the data frequency distribution, and the bar crossing the rectangle

represents the median. The lower extremity represents the minimum value and the upper, the maximum value. The external circles represent the data set outliers which, generally, are represented on the chart, but are not computed in the calculations of the mean and median.

Table 3 shows the mean values and standard deviation for doses obtained at the different evaluated extracranial sites.

## DISCUSSION

The mean patients' age is similar to the one observed in the study developed by Yu et al.<sup>(5)</sup>, who have studied the extracranial dose in 104 patients submitted to Gamma Knife radiosurgery. As their results are considered, it is observed that the mean value of radiation doses received by the region between the eyes was 5.1 cGy, with a maximum dose of 17.46 cGy. For the right eye region, the mean dose was 4.8 cGy and the maximum dose, 12.06 cGy. The left eye region received a mean dose of 6.5 cGy and maximum dose of 32.3 cGy. The dose in the eyes, as expected, depends on the position of the organ in relation to the primary radiation beam. The analysis of the data has shown that the mean dose value in the regions of the eyes ipsilateral to the lesion was  $5.3 \pm 2.4$  (cGy) and in the region of the eyes contralateral to the lesion was  $3.9 \pm 1.1$  (cGy). Such results are similar to the ones found by Ma et al.<sup>(7)</sup>, corresponding to a mean dose value in the region of the eyes ipsilateral to the lesion of  $7.6 \pm 0.6$  (cGy), and lower than the values found by

**Table 1** Characteristics of patients submitted to radiosurgery and tumors location.

Patient	Age (years)	Sex	Lesion location
1	57	Female	Right acoustic
2	53	Female	Left frontal
3	83	Male	Right parietal
4	30	Male	Right occipital
5	48	Female	Left cerebellar
5	48	Female	Cerebellar vermis
6	83	Male	Right parasagittal
7	70	Male	Left parasagittal
8	70	Female	Right frontal
9	62	Female	Left parietal
9	62	Female	Right parietal
10	59	Female	Left parietal
11	26	Female	Left parietal

**Table 2** Tumor location, cones sizes, total treatment doses and values of doses in extracranial regions.

Lesion location	Cone (cm)	Dose (cGy)						
		Total	Between the eyes	Right eye	Left eye	Thyroid	Chest	Pelvis
Right acoustic	1.5	1300	2	6	4	3	0.68	0.06
Left frontal	1.75	2000	4	3.8	4.38	3.45	1.17	0.35
Right parietal	3.75	1800	6.92	6.92	6.36	5.19	1.56	0.31
Right occipital	2.75	1800	5.14	6.16	3.79	3.99	1.26	0.25
Left cerebellar	3.5	1500	6.29	3.09	5.12	12.65	3.28	0.56
Cerebellar vermis	1.5	2000	8.86	3.66	5.57	5.53	2.37	0.79
Right parasagittal	3.25	1500	3.35	3.8	3.69	2.46	1.52	0.3
Left parasagittal	3.25	1500	2.55	4.82	3.73	1.81	1.07	0.13
Right frontal	3.25	1500	17.46	12.06	5.75	4.9	1.36	0.29
Left parietal	1.5	1800	4.05	2.84	32.3	3.06	3.71	1.54
Right parietal	1.25	1900	0.55	3.21	2.88	3.21	1.45	0.54
Left parietal	1.75	1820	3.31	3.34	5.02	2.52	1.07	0.42
Left parietal	2	1800	2.43	2.8	2.34	3.2	0.97	0.33

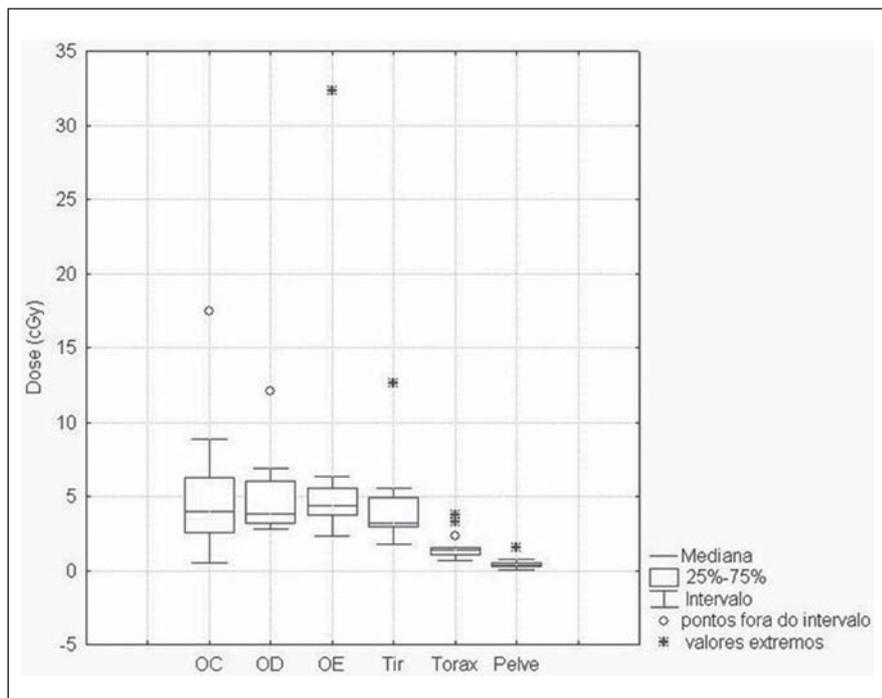
**Table 3** Mean values and standard deviation for extracranial doses.

Sites	Mean dose (cGy)	Standard deviation
Between the eyes	5.1	± 4.3
Right eye	4.8	± 2.6
Left eye	6.5	± 7.8
Thyroid	4.2	± 2.8
Chest	1.6	± 0.9
Pelvis	0.4	± 0.3

these authors for the region of the eyes contralateral to the lesion, corresponding to  $6.9 \pm 0.6$  (cGy). It is important to note that, in the present study, there was one patient who presented a dose in the region of the eye ipsilateral to the lesion corresponding to 32.3 cGy, which was excluded from the above mentioned standard deviation calculations for being much higher than the other values. Such radiation dose, in this case, may be justified by the proximity of the left

eye with the treated area, the total radiation dose applied and the utilized arches angulation. The values of doses observed in the present study are similar to data in the literature and are below the threshold for occurrence of opacity in the human crystalline lens, which ranges between 0.5 and 2.0 Gy, for a single exposure<sup>(9)</sup>. The study developed by Yu et al.<sup>(5)</sup> presented a mean value of 24 cGy in the lateral region of the eyes for 104 patients submitted to Gamma Knife radiosurgery. A study developed by Novotný Jr et al.<sup>(10)</sup> also presents mean dose values of 22 cGy in the region of the eyes.

In the thyroid, the mean dose value in the present study was 4.2 cGy, with the maximum value of 12.6 cGy. The analysis of data on Table 2 demonstrates that the dose in the thyroid varies as a function of the lesion location. Treatment of tumors in the cerebellar region result in higher doses in the region of the thyroid. Such values are similar to the ones reported by Novotný Jr et al.<sup>(10)</sup> and Yu et al.<sup>(11)</sup>, and lower than the ones reported by Yu et al. in a study developed in 1997<sup>(5)</sup>. The mean dose value in the region of the chest was 1.65 cGy and the maximum value was 3.71 cGy. For the region of the pelvis, the mean dose value was 0.45 cGy and the maximum value was 1.54 cGy.



**Figure 1.** Radiation doses distribution in extracranial regions. (OC, between the eyes; OD, right eye; OE, left eye; Tir, thyroid).

**CONCLUSIONS**

In the present study, the values of radiation doses observed in extracranial regions

are lower than the values reported by studies in the literature approaching treatment with cranial Gamma Knife radiosurgery. The dose values for extracranial regions of the patient reach levels as high as 30 cGy in the region of the eyes, and 12 cGy in the region of the thyroid. The dose in the thyroid varies as a function of the lesion location. Treatment of tumors in the cerebellar region result in higher doses in the thyroid. Suchs results demonstrate that, although the doses in the eyes do not exceed the tolerance threshold for occurrence of opacity of the crystalline lens, it is important that radiotherapists take the risks of radiation doses in these regions into consideration during the planning of cranial radiosurgery.

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