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Stereotactic radiotherapy for choroidal melanoma: analysis of eye movement during treatment

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Abstract: This study aims to analyze the eye's movement during radiotherapy treatment for choroidal melanoma, as well as the methodology used in the repositioning of the patient between treatments sessions. For this purpose, the procedures used by the hospital staff were analyzed on site and videos were recorded during the treatments. The methodology for the fixation of the eye is correct in its objective. However, the repositioning needs improvements in its reproducibility. It is recommended the study to fix the eye by the healthy eye and the feasibility study for the development of a software that assists in patient repositioning.

Keywords: radiotherapy; ocular tumor; choroidal melanoma.

1. INTRODUCTION

Malignant choroidal melanoma is a tumor arising in the layer of blood vessels, choroidal, positioned under the retina. It is a rare occurrence, affecting five to every million inhabitants, but rapidly evolving to metastasis [1, 2].

The procedure of removal of the tumor by enucleating it does not offer advantage regarding the occurrence of metastasis, when compared to treatments that preserve the eye [3].

One of the treatments for choroidal melanoma is the application of small photon bundles directed to the volume to be treated, the prescribed dose is applied in multiple sessions [4]. The most common side effects in this type of treatment are retinopathy, optic neuropathy, development of cataract, neovascular glaucoma and problems in the corneal epithelium [5].

1.1 Treatment success

Since the patient needs to be repositioned between sessions on different days according to the planning reference, a lot of care should be taken to ensure positional reproducibility.

For the repositioning of the table, the treatment software will read, by infrared, six spheres positioned in the array, above the patient's chest. In addition, before each field, the table can also be adjusted by comparing two x-rays and a reference image performed by tomography.

In the case of intraocular radiotherapy, a non-invasive device is necessary to fix the patient's eye. Therefore, a led lamp has been added to the original configuration, which one the patient is instructed to maintain eye contact during treatment.

Therefore, the success of the treatment depends directly, among other biomedical factors, on the precision of the application and, above all, on the accuracy of the repositioning of the patient between sessions.

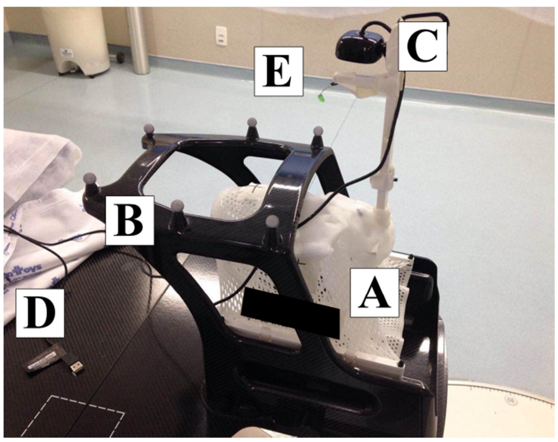
Thus, as radiotherapy has evolved to increase beam precision, this work consists of studying the feasibility of reducing uncertainties associated with patient repositioning and fixation of the gaze, identifying critical points of imprecision.

2. METHODS AND MATERIALS

2.1. Radiotherapy equipments

The treatment was performed on a Novalis radiotherapy equipment of the Brainlab brand. The patient's skull was immobilized using a stereotactic mask made of thermoplastic material (a), positioned under a structure called array (b), both manufactured by Brainlab.

Figure 1. Set-up of the equipments.



2.2. Devices for analysis and fixation of the eye gaze

In order to analyze and control the iris displacement during the radiotherapy treatment, it was added to the standard configuration, a webcam (c), which one with a ten meters HDMI cable (d), took the image of the patient's eye in real time to a laptop located on the outside of the treatment room. The figure 1 shows the set-up.

In addition, as previously mentioned, the patient was instructed to look at the led light (e), located on the same vertical axis of the isocenter and positioned above the webcam. For this, the patient used the diseased eye.

2.2. Motion analysis methodology

A hospital professional was responsible for looking at the image in real time during treatment and visually comparing it with a reference photograph taken on the day of the CT scan used in treatment planning.

In case of movement of the eye, the professional intuitively should guide the operator to turn off the equipment, thus stopping the irradiation.

At the same time, the image of the patient's eye was recorded and later analyzed by its displacement. The videos were transferred to the software Tracker [6], a motion analysis software, and separated as their lighting quality. Some videos could not be used for analysis due to the fact that the gantry passes between the light source and the camera, plus it is not a place with constant lighting.

In the analysis software, the video was digitally treated to increase the contrast between the iris and the conjunctiva. Consequently, it was possible to follow the movement of the center of the iris in an automated way, returning the values of the position in the axes x (horizontal displacement) and y (vertical displacement).

3. RESULTS

Table 1 shows the sample analyzed for this study.

Table 1. Study samples.

	Total
Videos	5
Fields	16
Frames	1791
Time (s)	215,7

3.1. Displacement of the iris center relative to the orthophoria point

After analyzing the positions of the center of the iris in the software and calculating its displacements relative to the orthophoria point, the values found were grouped in table 2.

Table 2. Displacements statistics values.

	X-axis	Y-axis
Mean	-0.018 mm	-0.020 mm
Standard deviat.	0.368 mm	0.364 mm
Standard uncert.	0.009 mm	0.009 mm
Variance	0.136 mm	0.133 mm

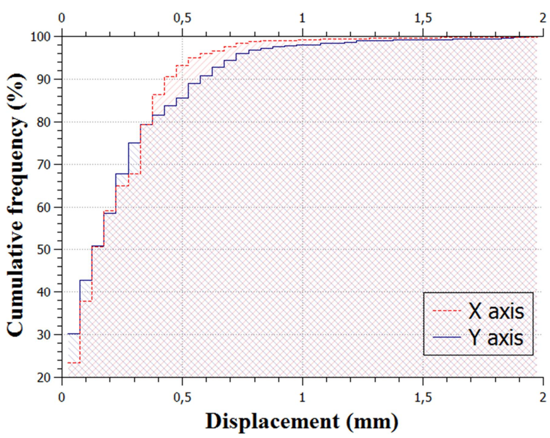
In order to analyze the absolute displacements, these values were also grouped as shown in table 3.

Table 3. Absolute displacements statistics values.

	X-axis	Y-axis
Mean	0.228 mm	0.227 mm
Standard deviat.	0.290 mm	0.286 mm
Standard uncert.	0.007 mm	0.007 mm
Variance	0.084 mm	0.082 mm

So that the effects of accumulated displacements could be analyzed, the cumulative displacement distribution relative to the orthophoria point was also plotted as shown in Figure 2.

Figure 2. Cumulative distribution of displacements relative to the orthophoria point.



3.2. Displacement of the iris center relative to the first day of treatment – repositioning accuracy

The displacements of the iris center were analyzed by taking the first day of treatment as reference; this means that this statistic measures the capacity of repositioning of the patient by the accuracy of the equipment used. Table 4 shows the statistic values for the displacements of the iris center relative to the first day of treatment. Table 5 shows the absolute values for the same analytical reference.

Table 4. Displacements statistics values.

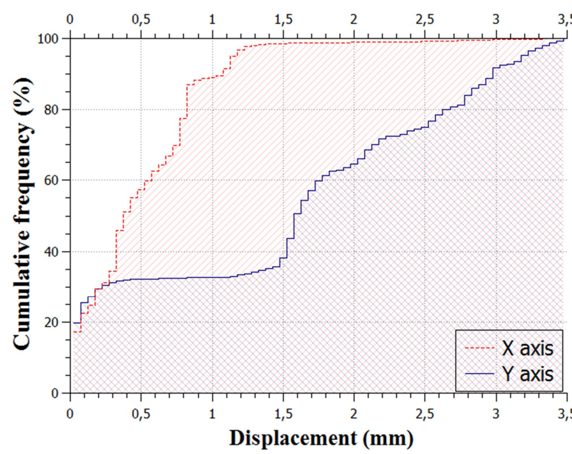
	X-axis	Y-axis
Mean	-0.43 mm	1.90 mm
Standard deviat.	0.62 mm	1.85 mm
Standard uncert.	0.02 mm	0.05 mm
Variance	0.38 mm	3.42 mm

Table 5. Absolute displacements statistics values.

	X-axis	Y-axis
Mean	0.54 mm	2.06 mm
Standard deviat.	0.53 mm	1.66 mm
Standard uncert.	0.01 mm	0.04 mm
Variance	0.28 mm	2.77 mm

Figure 3 shows the cumulative displacements distribution relative to the first day of treatment, so that the effects of accumulated repositioning errors could be analyzed.

Figure 3. Cumulative distribution of displacements relative to the first day of treatment.



4. DISCUSSION

As could be observed during the study, the led is enough for noninvasive fixation of the patient's eye during treatment. Besides that, it is certain that during the treatment the visual acuity of the patient suffers worsening as a side effect, consequently his ability to locate the led lamp decreases as the therapy progresses.

Concerning the current beam disconnection system in case of unplanned movement of the patient's eye, it is necessary to understand that there are multiple sources of possible systematic errors in the case the equipment needs to be stopped. Because it is a non-automated method and depends on the reaction time of two people, first to visual stimulus, and then the reaction time to audio stimulus, which have values of 331 ms and 284 ms [7], respectively. Therefore, it is not the best methodology for the procedure, which allows further studies in order to determine the best method of this procedure.

In the analysis of movement that was performed after treatment, it was evident the poor quality of the videos (resolution, lighting and frame per second rate). However, it is worth mentioning that the result obtained in the study is compatible with analyzes carried out by other groups [8].

Uncertainties of type B were not used in the results for the following reasons: the manufacturer of the product informs that the accuracy of the positioning in radiotherapy is submillimetric; besides the poor quality of the acquired images, the uncertainty due to positioning reading (pixel resolution), is too small compared to uncertainties of type A.

By interpreting the results, it is clear that the greatest problem of the system lies in the repositioning accuracy of the patient between different sessions, in other words, it lacks reproducibility of the patient's reference position that is used as basis for treatment planning. Such a problem can lead to a dose depot outside the planning field.

5. CONCLUSION

The led lamp is essential for fixing the patient's eye, so an alternative to the current system is necessary due to the loss of visual acuity of the eye affected by the disease.

It is recommended to study the feasibility of positioning the led above the healthy eye, and obstructing the unhealthy eye, contrary to the current method. In addition to that it is also recommended the image acquisition during the treatment by a high definition camera with the possibility of capturing in the range of the infrared light spectrum.

Besides that, the procedure for repositioning the patient between sessions can be studied so that its accuracy can be improved, reducing the dose outside the planning field for radiotherapy treatment.

Simultaneously, a software can be developed for performing real-time analysis of the movement of the patient's eye which, in the case of previously established and established displacement detection, can disconnect the beam without further damage to the patient being treated.

7. REFERENCES

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