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PAUL SCHERRER INSTITUT PSI

Image guidance for eye tumors treated with proton therapy: Noninvasive eye tracking versus X-ray imaging

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INTRODUCTION & AIM

Ocular proton therapy relies on tantalum clips sutured to the outer surface of the eye that serve as fiducials for treatment geometry verification through radiographic imaging. An alternative approach based on non-invasive optical eye tracking has been prospectively tested and compared to the clinical standard for twelve patient undergoing proton therapy at our institution.

METHOD

The eye tracking system (ETS) was integrated in the beamline (Figure 1): it consists of four optical cameras geometrically calibrated with respect to the treatment room isocenter and cross-calibrated to the X-ray imaging system using a dedicated phantom. The planned pupil position is obtained by applying the geometrical transformation from simulation to treatment eye geometry, retrieved using clips, to ETS measurement performing during simulation (Figure 2). As a result, the following patient positioning protocol could be applied for 12 uveal melanoma patients treated at out institution: first, real-time measurements of the pupil position from which the initial translational chair corrections could be calculated; second, X-ray imaging of clips was applied to fine tune these corrections. Thus, the accuracy of the ETS-guided approach was directly measured by the first X-ray images, enabling dosimetric evaluation of target coverage and geometrical comparison to the actual treatment position (determined from the final X-ray images before delivery).

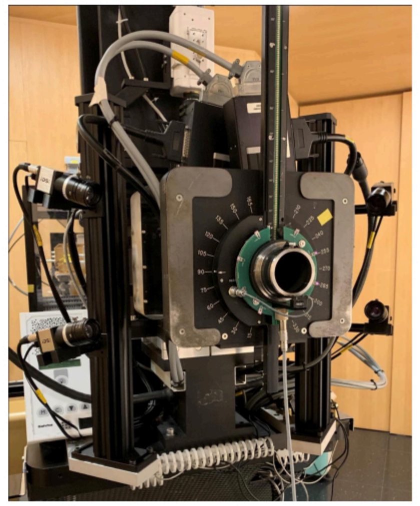


Figure 1 – Eye Tracking System set-up in the treatment room

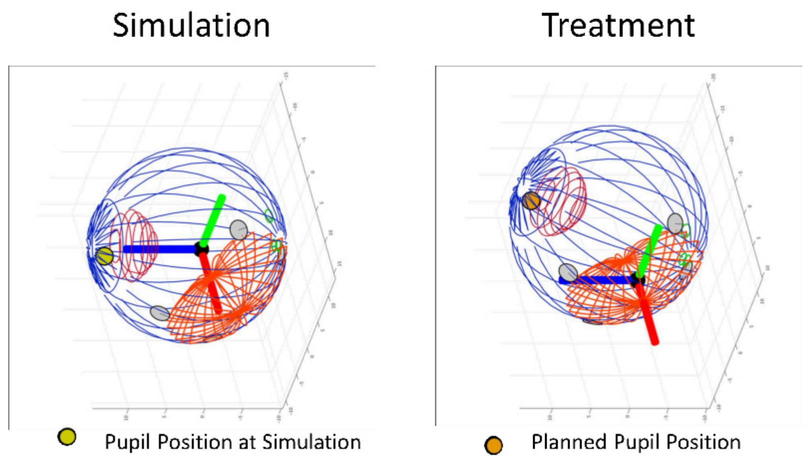
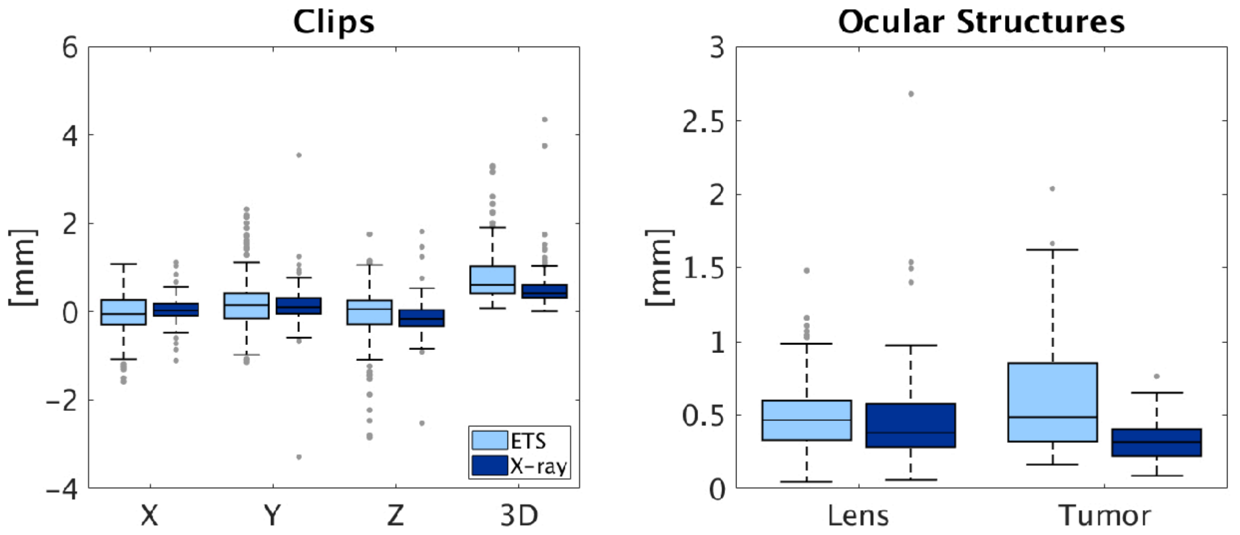


Figure 2 – Schematic representation of the method applied to identify the pupil position corresponding to the planned patient position.

RESULTS

Clip-based radiographic imaging provides higher accuracy than pupil-based positioning even though median misalignments below 0.65 mm and 0.50 mm were measured by the ETS for clips and tumor center-of-mass respectively (Figure 3).
Nevertheless, target coverage was never compromised despite the inferior accuracy of pupil-based alignment, with 95% of the target volume receiving 95% of the prescribed dose for all the examined fractions (Figure 3).
Lens misalignment exhibited similar distributions for ETS and X-ray based alignment (Kruskal-Wallis test p-value: 0.23) whereas the opposite is true for errors on the target center-of-mass by the two system (Kruskal-Wallis test p-value < 0.05). In addition, errors distributions for pupil-based alignment are significantly different between lens and tumor (Kruskal-Wallis test p-value: 0.28), while clip-based errors followed similar distributions (Kruskal-Wallis test p-value < 0.05) for both structures.



% of tumor volume covered by 95% of the prescribed dose (V95)

	V95>90%	V95>95%	V95=100%
	ETS-based positioning		
Distribution [%]	**100**	**100**	**93**

Figure 3 – Accuracy of ETS-based and X-ray based patient positioning on left panel. Results of the dosimetric analysis for pupil-based positioning on the right panel.

CONCLUSIONS

This study shows how a pupil-based approach for noninvasive patient positioning in ocular proton therapy does not guarantee the same level of accuracy of the clinical standard based on clips. The statistical analysis shows how the two systems feature similar level of accuracy in the alignment of the anterior segment of the eye (lens), while performing differently for the tumor. This is a direct consequence of the simplified method applied for ETS-based patient positioning which, contrarily to X-ray imaging of clips, dose not account for eye rotations. Including a compensation of rotational misalignment (gaze direction correction) will be necessary to improve the accuracy of the proposed system. However, the results are encouraging, as sufficient target coverage was always achieved for ETS-based alignment even with this simplified approach.

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