Impact of patient specific mass density in ocular proton therapy

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Introduction

In ocular proton therapy (OPT) treatment planning a uniform relative stopping power of 1.05, based on the ICRP110 ocular mass density, is commonly applied for the whole eye. The stopping power uncertainty has a significant impact on the projected range of a proton beam. Not all elements however have the same mass density.

In this study, we determine the mass densities of ocular structures for a cohort of patients and subsequently assess the corresponding stopping powers and distal 80% ranges (R80) through Monte Carlo simulations for three different positions in the eye.

Methods and Materials

- The mass density of different eye structures (vitreous body, lens and sclera) was derived from CT imaging data of 22 patients without ophthalmological history.
- Monte Carlo (MC) simulations were performed with Stopping and Range of Ions in Matter (SRIM) in an average eye model (Escudero-Navarro) to calculate the distal 80% ranges (R80), for three different proton energies corresponding Bragg-peak positions relative to the eye (Figure 1).

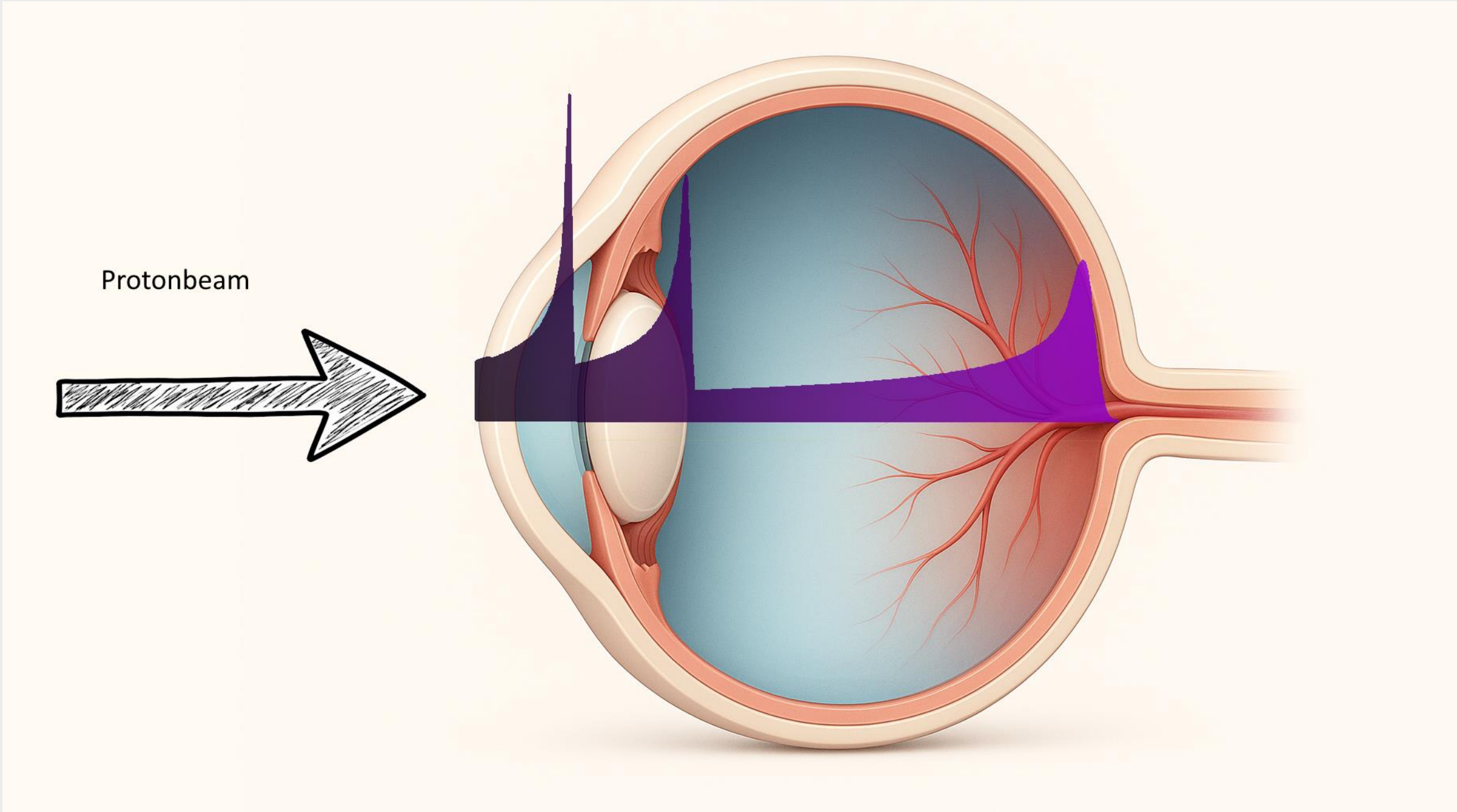

Figure 1: Schematic eye with three simulated Bragg peak positions

- MC simulation input consisted of a mono-energetic proton pencil beam with the derived mass densities and two elemental compositions: namely water for all structures and the structure-specific elemental compositions reported by Lesperance et al. The retrieved ranges were compared with MC simulations with the currently used uniform stopping power of 1.05.

Results

- The median values and the interquartile range (IQR) per structure were: vitreous body (including aqueous): 1.003 g/cm^3 (IQR: 0.001 g/cm^3), lens: 1.107 g/cm^3 (IQR: 0.002 g/cm^3), sclera: 1.057 g/cm^3 (IQR: 0.011 g/cm^3).
- Table 1 summarizes distal 80% ranges (R80) and the energy losses for three starting energies corresponding with the positions of the Bragg peak just before the lens, after the lens and at the posterior pole. Figure 2 shows the simulated Bragg peak distributions for these configurations.
- The impact of the variation in the determined mass density of the patient cohort on the R80 for 52 MeV was low with a standard variation of only 0.025 mm.

	In front of the lens	**Behind the lens**	**Prior to posterior pole**
Energy (MeV)	**18.5**	**29.5**	**52.0**
	R80 (mm)		
Cohort configuration	3.632	8.070	23.190
ICRP configuration	3.518	8.063	22.460
Difference (mm)	**0.114**	**0.007**	**0.730**
	Energy loss (eV/Å) at the Bragg peak		
Cohort configuration	1.69	1.25	0.82
ICRP configuration	1.54	1.27	0.86
Energy ratio (-)	0.91	1.02	1.06

Table 1: Projected range and energy loss for three different Bragg peak positions derived for Monte Carlo simulations

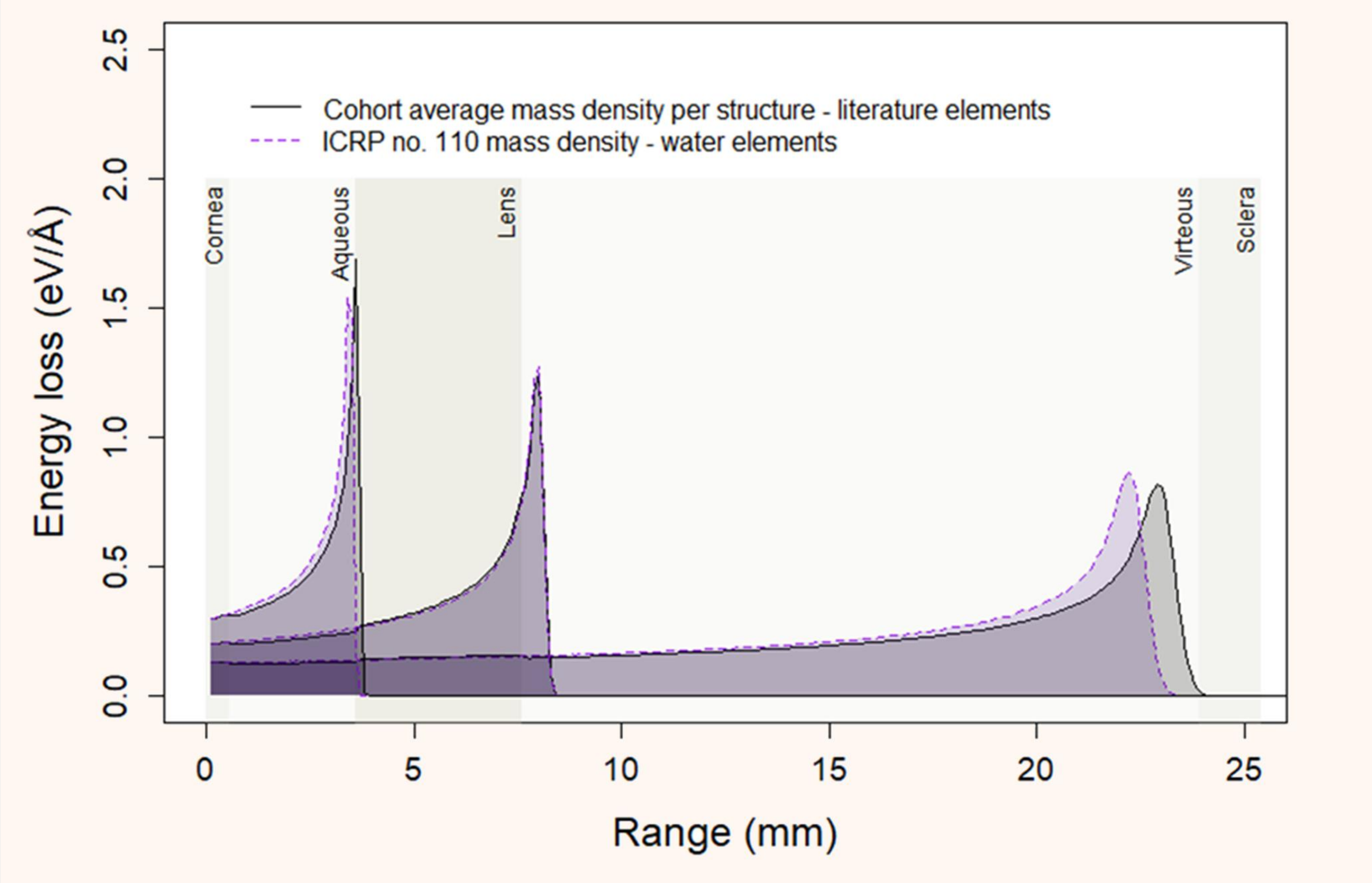

Figure 2: Monte Carlo simulation results based on the ICRP no. 110 and the patient cohort configuration for three different Bragg peak positions

Conclusion

- **In ocular proton treatment planning a default homogeneous stopping power is commonly applied to all the eye structures.**
- **This relative stopping power can introduce systematic errors up to 0.7 mm in distal 80% range.**
- **As the inter-subject variation in mass density was small, the use of a common value for each eye structure is clinically acceptable.**

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