Investigation of 3D library-based planning for uniformly and non-uniformly loaded generic and notched eye plaques with Monte Carlo simulations

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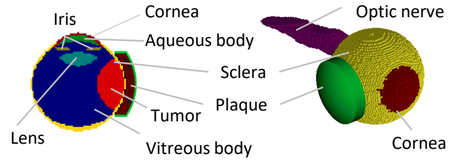
INTRODUCTION

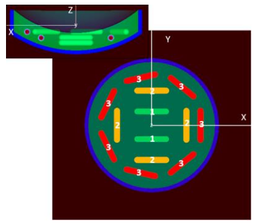
- Low dose rate (LDR) brachytherapy using temporarily implanted plaques is currently the most common treatment option for ocular melanomas. LDR uniquely offers equivalent tumor control to enucleation, while preserving the eye and vision function. [1].
- Our center treats over 100 patients with choroidal melanomas annually. To reduce costs, a seed library is maintained, with plaque loadings using seeds of different source strengths. [2]
- The non-uniform seed loading is modeled with the Pinnacle treatment planning system (TPS) so that the plaque dose matches that of a uniformly loaded plaque.
- For complex treatments close to the optic nerve, a combination of notched plaques and non-uniform source distribution are used to target the tumor while minimizing dose to the optic nerve.
- Steep dose gradient and pronounced effect of heterogeneities (not accounted in Pinnacle TPS) pose significant challenges for accurate eye plaque dosimetry that is largely studied for uniformly loaded generic COMS eye plaques[3].
- Monte Carlo (MC) methods improve dosimetric accuracy, but are computationally intensive.
- **To enable accurate and efficient 3D dose calculations, we are exploring using pre-computed MC-based dose distribution libraries of individual seeds for various eye plaque models.**

METHOD

- Using the egs_brachy package of the EGSnrc MC code[4], we compared two calculations:
  - **$MC_{All\ seeds}$: simultaneously MC calculation of all seeds**
  - **$MC_{seed\ library}$: Σ individual MC seed kernels from a pre-computed seed library, where all seeds are present, but only one is active at a time.**
- Dose distributions computed in an anatomically representative in silico eye phantom[5]. Shapes, elemental compositions and densities of ocular structures selected for the phantom are based on published literature[6,7].
- Statistical uncertainties are below 1% (110 histories). Phantom size = 6x6x5 cm^3 with the voxel size of 0.4x0.4x0.4 mm^3.
- Compared **TG43**, and full MC simulations that account for the presence of the plaque and inter-seed effects in water to water ($D_{w,w}$) and plus tissue inhomogeneity effects ($D_{m,m}$).

16 MM PLAQUE





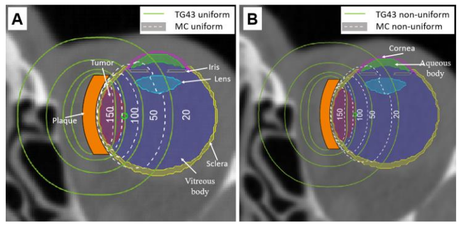
SET-UP

- 12 mm in diameter eye and 5 mm thick tumor
- 85 Gy prescription dose by plaque at 5 mm depth (apex)
- Tumor lies on the medial side of the right eye, centered along z

Activity of orange seeds:

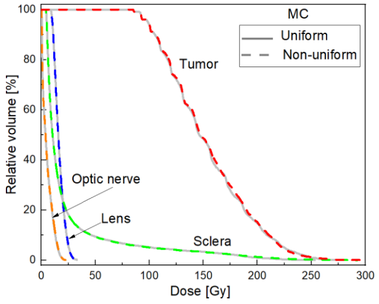
~2x activity of **red** seeds

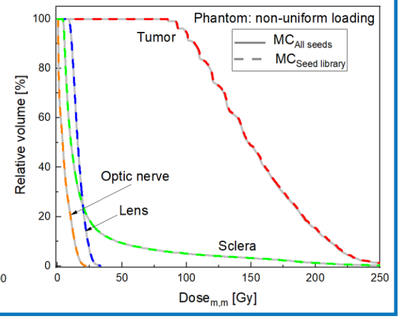
~4x activity of **green** seeds



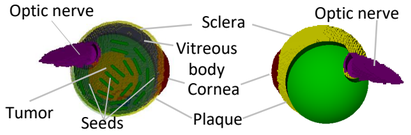
KEY POINTS

- TG43 calculations overestimate tumor and OAR doses
- Non-uniform loading mimics uniform loading distribution
- Library plan closely resembles distributions of MC with all seeds TG43 within ~1%





20 MM NOTCHED PLAQUE



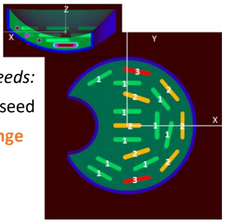
SET-UP

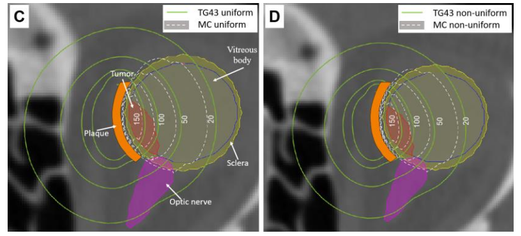
- 12 mm diameter tumour
- Prescription of 85 Gy at 5 mm
- Notch 1 mm from optic nerve
- Tumour lies posteriorly, abutting the optic nerve

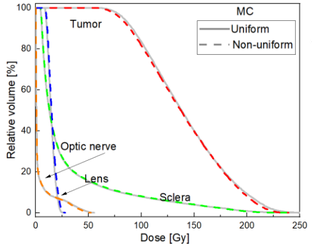
Activity of green seeds:

~2x activity of **red** seed

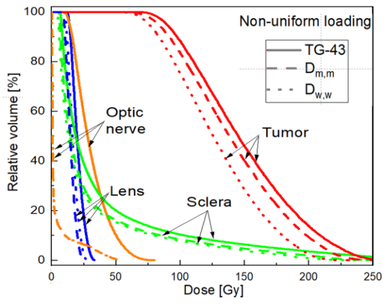
~4x activity of **orange** seeds

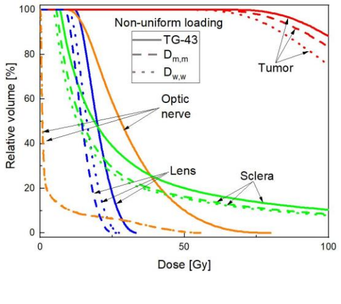




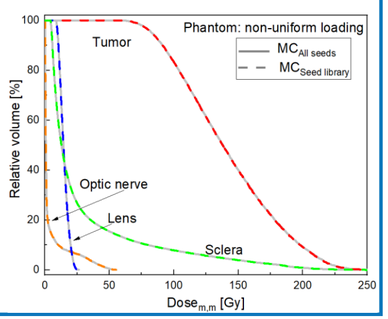


- Non-uniform loading mimics uniform loading distribution
- Optic nerve D20% reduced from 41.7 Gy to 3 Gy; D95% from 14 Gy to 0.2 Gy when comparing the TG43 calculation to the MC result.
- Optic nerve dose reduction attributed to attenuation by the modulay surrounding it





- **$MC_{Seed\_library}$** matched **$MC_{All\ seeds}$** simulations within ~1% for both uniform and non-uniform seed activity loading in water and eye phantom



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CONCLUSIONS

- Library-based dose distributions for 16 mm COMS plaque and 20 mm notched plaques were in excellent agreement with the full MC simulations for both uniform and non-uniform loadings.
- Impact of $D_{m,m}$ vs $D_{w,w}$ in library planning accuracy requires further investigation
- With the computational costs paid in advance, the library–based planning uniquely allows for accurate MC based dose calculation with reduced planning time.
- **This work establishes feasibility of a library-based MC-based treatment planning for eye plaque LDR brachytherapy**.