Master's Thesis Engineering Technology

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Proton radiotherapy dose calculations with Monte Carlo code in TOPAS - a comparison with Varian Eclipse treatment planning system

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Introduction

Figure 1: Incidence vs. mortality worldwide in 2020 [1]

Brain cancer has a high mortality rate; see Figure 1. Tumors in the brain are challenging to treat. Often, **proton beams** are used because of their advantageous energy deposition pattern. In Sweden, proton therapy is done at the **Skandion Clinic** using **Eclipse by Varian** with an analytic computational algorithm. Compared with this system, **TOPAS** can, in principle, do more accurate dose calculations via the **Monte Carlo method**. This thesis focuses on using TOPAS for clinical treatment planning in radiotherapy, as shown in Figure 2.

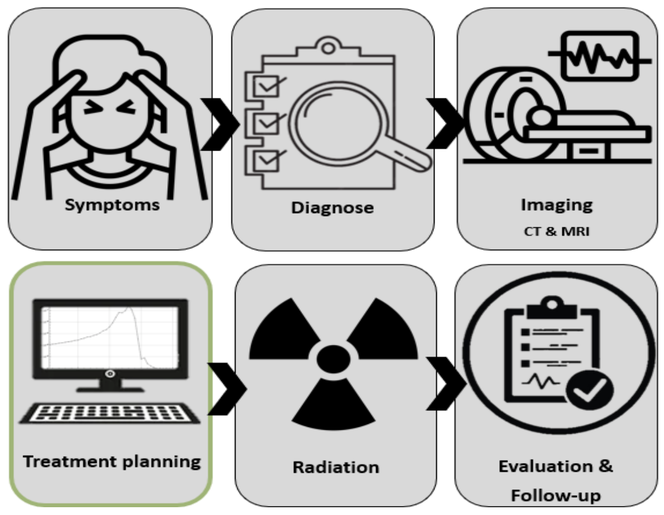
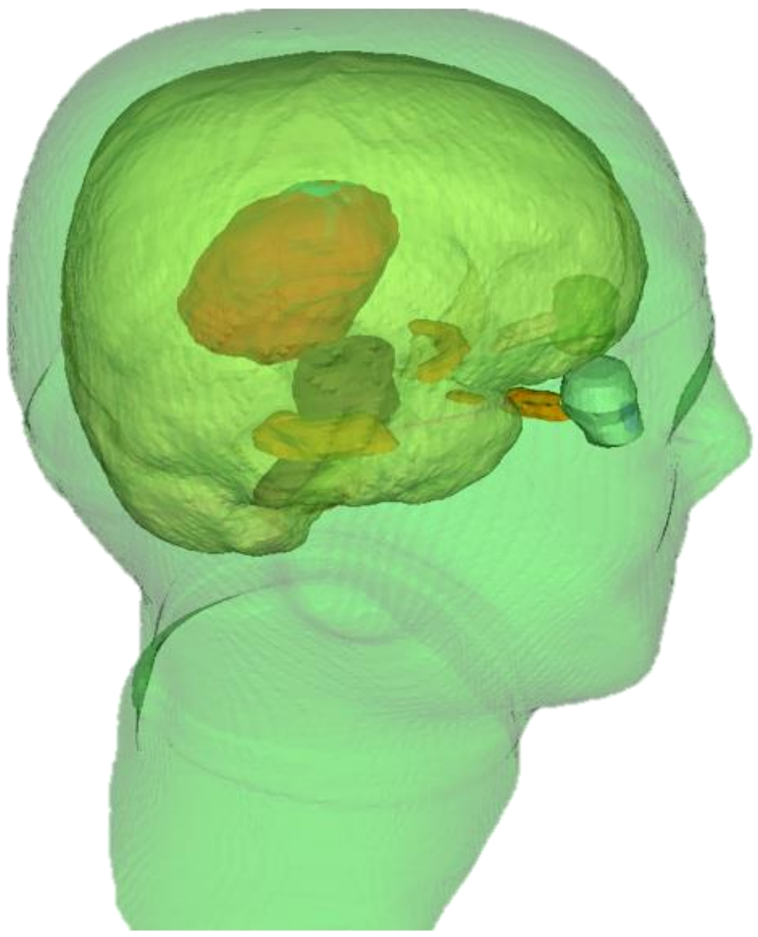


Figure 2: Overview radiotherapy processes

Materials and methods

Eclipse software was used to make a **radiation treatment plan** (RTP) for a fictive brain tumor in the CIRS model 731-HN head phantom. The plan used three proton fields containing about 2800 beams. CT DICOM images of the brain were imported to TOPAS to visualize the treatment and make dose calculations using the **reference** and **Schneider's** methods in TOPAS. The reference TOPAS method used the manually segmented image made with ITK-snap. TOPAS results were compared with those produced by Eclipse via **color maps, dose-volume histograms** (DVH), and **the root mean square error (RMSE).**



Results

The spatial distribution of the absorbed dose predicted by Eclipse is shown in Figure 3. The prescribed dose to the CTV was 49.08 Gy. Figure 4 shows that the TOPAS-based reference method gave similar calculated doses as Eclipse in the tumor region. Further away from the tumor, the differences were larger. The DVHs shown in Figure 5 were similar for the three approaches. The reference method and Eclipse met the criterion of $D_{98\%} \geq 95\%$ of the prescribed dose, while TOPAS with Schneider's method did not. For the CTV, the RMSE for Eclipse and TOPAS with Schneider's method were 1.6% and 4.6%, respectively.

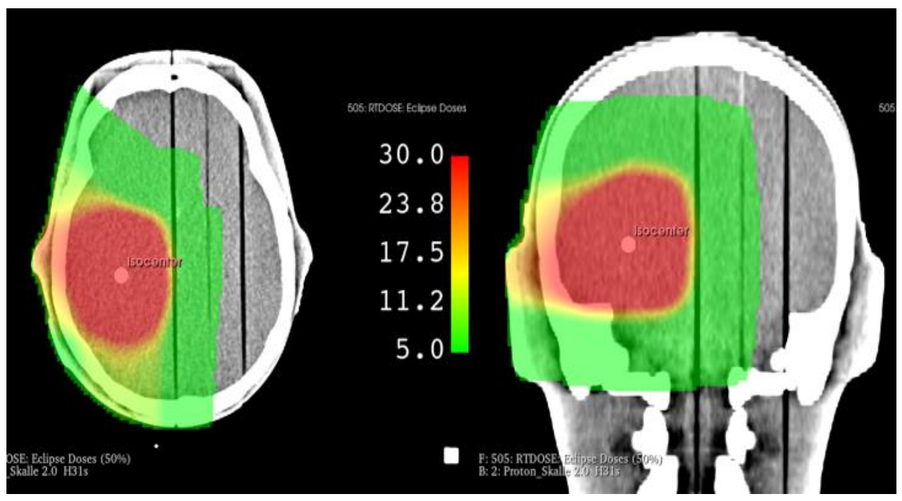


Figure 3: Dose deposition in head phantom visualized by 3D Slicer

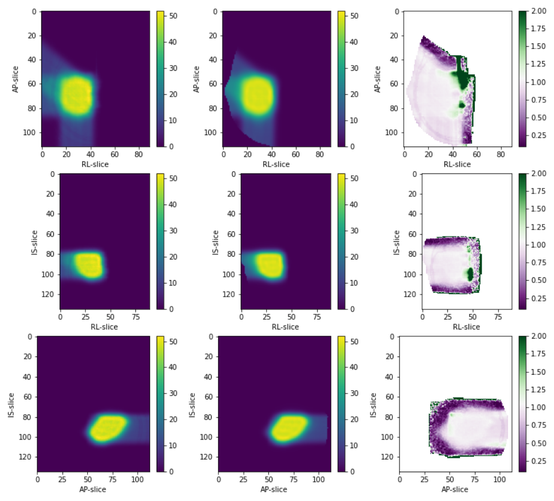


Figure 4: Spatial distribution of absorbed dose for TOPAS (left), Varian Eclipse (middle), and its ratio (right)

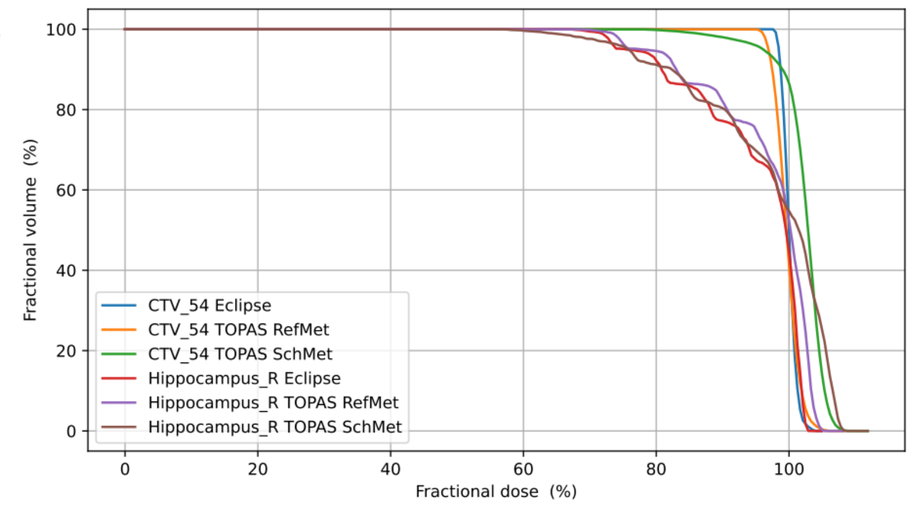


Figure 5: DVHs calculated using Eclipse and TOPAS with the reference and Schneider's methods

Conclusion

The spatial distributions of the absorbed dose in the CTV calculated using Eclipse and TOPAS agreed well. It indicates that the developed TOPAS-based model worked as expected. TOPAS with Schneider's method was less accurate because Schneider's method needs to be adapted to the used CT scanner. The developed model needs to be generalized and tested to incorporate it into the quality assurance processes at Linköping's University Hospital.

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[1] World Health Organization, "Cancer today," 2020. [Online]. Available: https://gco.iarc.fr/today/home. [Accessed 20 April 2023].