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Manipulating Gamma Knife Collimator Size in Treatment Planning to Improve Plan Quality

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INTRODUCTION

- Gamma Knife (GK) stereotactic radiosurgery (SRS) deliveries are uniquely collimated to 4-, 8-, or 16-mm diameter shots.
- Inverse planning is rare in GK, thus collimator shot selection differs for each planner even if prescription isodose line (IDL) is identical.
- **This work explores the impact on tumor control probability and equivalent uniform dose which could arise based on planners' collimator choice.**

MATERIALS & METHODS

- Two **reference** plans were created using a single-shot of either 8 mm (Ref-8) or 16 mm (Ref 16) collimators.
- **Comparison** plans were created using multiple shots of only 4 mm collimators.
- Prescription isodose volume (PIV_R) from each the reference plans was used as the benchmark
- Common metrics calculated: average dose (D_{avg}), minimum dose, maximum dose
- **Tumor control probability (TCP)** & **equivalent uniform dose (EUD)** were calculated assuming a Poisson distribution based on the linear-quadratic cell survival model, using clinically realistic radiological parameters: α=0.23 Gy^{-1}, α/β=10.0 Gy, and N_0=1x10^6.

RESULTS

- Comparison plans (multiple 4-mm shots) were able to effectively mimic the prescription isodose volume (PIV) of reference (single-shot) plans.
- Comparison plan #1 had PIV isodose line (IDL) coverage of 99.2% for Ref-8 contour (single shot from 8 mm collimator) contour.
- Comparison plan #2 had PIV IDL coverage of 99.5% for Ref-16 contour.
- PIV_R/ $PIV_{4\text{-mm}}$ ratio was 1.008 for Ref-8
- PIV_R/ $PIV_{4\text{-mm}}$ ratio was 1.005 for Ref-16
- **Regardless of the similarity in PIV, the differences in dose distribution within the target itself were evident,** shown in cDVHs.

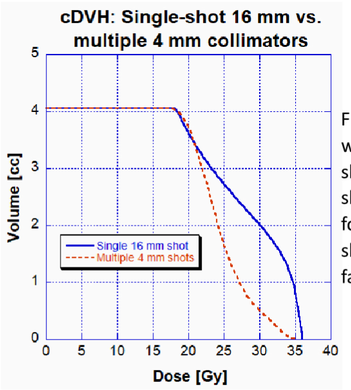

Fig 1. cDVH for ref plan with single 16 mm shot shows small shoulder, with slow fall-off while cDVH for multiple 4 mm shots shows larger shoulder with fast fall-off.

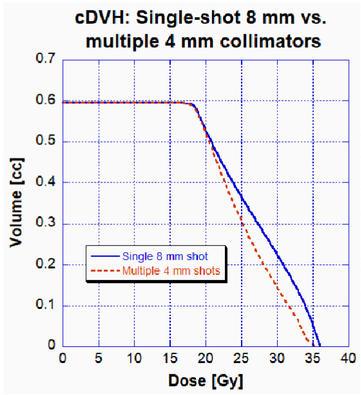

Fig 2. cDVH for ref plan with single 8 mm shot shows very similar shoulder regions. The 8 mm single-shot shows slower fall-off than the multiple 4 mm shots.

- These differences in cDVH resulted in very different dDVHs, which subsequently produced different TCP, D_{avg}, EUD_T (EUD in single-fraction), and EUD_R (EUD converted to fractionated 2-Gy scheme).

	single-shot 8 mm	multiple 4 mm	single-shot 16 mm	multiple 4 mm
D_{avg}	27.4 Gy	25.8 Gy	28.7 Gy	24.7 Gy
TCP	0.644	0.572	0.655	0.684
EUD_T	21.8 Gy	21.6 Gy	21.9 Gy	21.9 Gy
EUD_R	57.9 Gy	56.9 Gy	58.0 Gy	58.4 Gy

Abbreviations: Average dose (D_{avg}), tumor control probability (TCP), equivalent uniform dose for single-fraction (EUD_T) and 2-Gy fractionated (EUD_R) regimens

- **Higher average dose did not always result in higher TCP (and/or EUD)** when comparing two plans with identical PIV isodose lines.

CONCLUSIONS

- It is possible to emulate a large GK (8 or 16 mm) collimator using only multiple 4 mm GK shots.
- Two plans can be created which possess identical PIVs, but the dose distributions within the target can be extremely different due to the 200% hotspot characteristic to GK.
- The cDVH was a useful tool for visualizing the dose-volume characteristics with the 4 mm collimator plans always having a sharper fall-off.
- Analytically, TCP calculation would be correlated most strongly with the shoulder of the cDVH.
- GK planners should keep in mind that higher average dose are not always correlated with higher TCP and/or EUD.

REFERENCES

Z Chen *et al.* Dose-volume considerations for Gamma Knife® stereotactic radiosurgery treatment planning. 12th International Meeting of the Leksell Gamma Knife® Society; 2004; Vienna, Austria.

CONTACT INFORMATION

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