Plan comparison and verification of FLASH-IMPT and FLASH transmission for deep seated and superficial tumors

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Introduction

For proton FLASH delivery, there are two major techniques: **transmission** and **IMPT-like** FLASH using 3D range modulators (**3DRMs**), both of which have their benefits and weaknesses in terms of plan quality and dose rate (DR). The aim of this study was to compare the performance of these two techniques in the context of superficial and deep-seated targets. We also assessed the deliverability of some plans through dose and DR verification measurements.

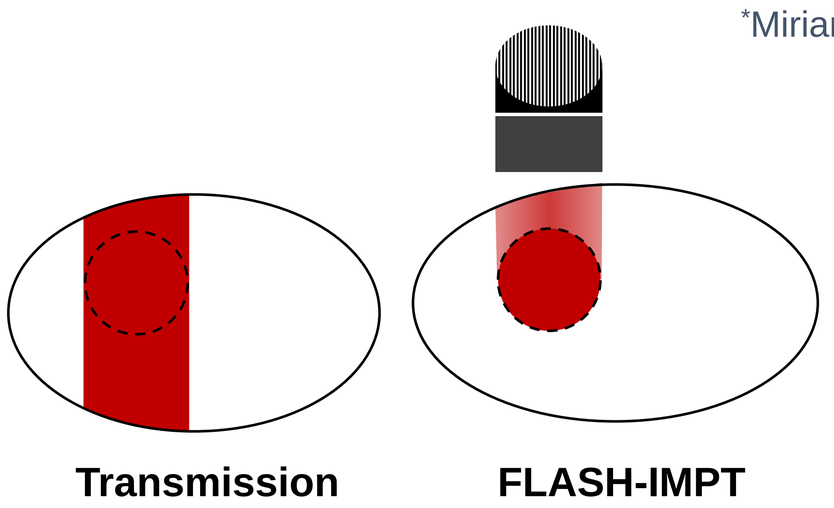

Figure 1: Illustration of a transmission beam (left) and a FLASH-IMPT beam using a 3DRM (right).

Materials and Methods

Patient cases:

1) Superficial tumor: GBM (brain)

2) Tumor at intermediate depth: peripheral lung

3) Deep-seated tumor: prostate

Planning scenarios:

a) Transmission:

- 250 MeV
- Multi-field optimization

b) FLASH-IMPT:

- 250 MeV + 3D range modulator + range shifter
- Multi-field optimization

Evaluation:

- Dosimetric scorecard analysis (Plan scores)
- Dose rate calculation [1]
- Dose / dose rate measurement (Varian ProBeam)
- Research-only version of Eclipse

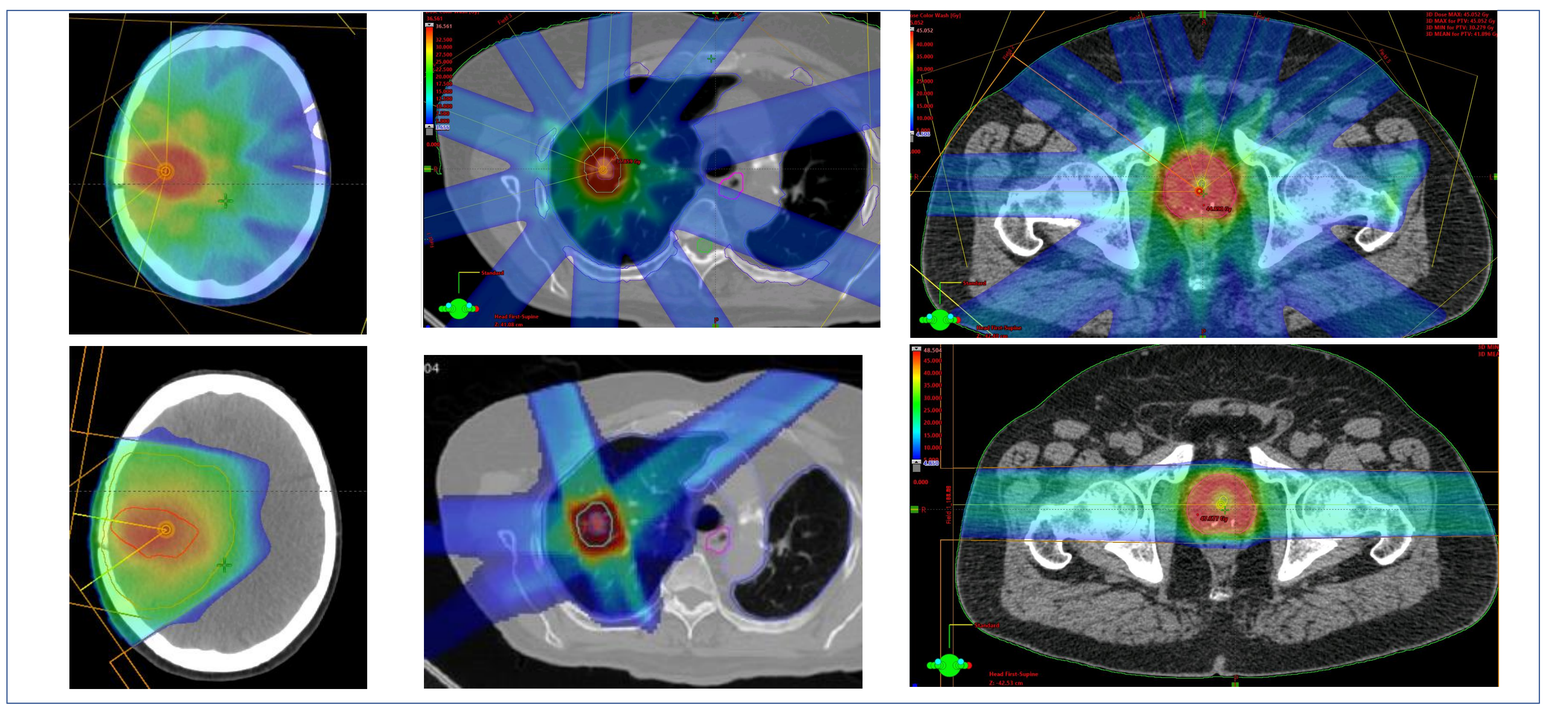

Figure 2: Dose distributions for each plan for the brain, lung, and prostate cases. Top row: Transmission, bottom row: FLASH-IMPT.

Table 1: Score card evaluation of each plan. The higher the score, the better the plan quality (only comparable within single patient cases).

Plan scores	Brain (max: 236.5)	Lung (max: 143.5)	Prostate (max: 220)
Transmission	~200	139.5	155.42
FLASH-IMPT	217.4	140.7	69.6

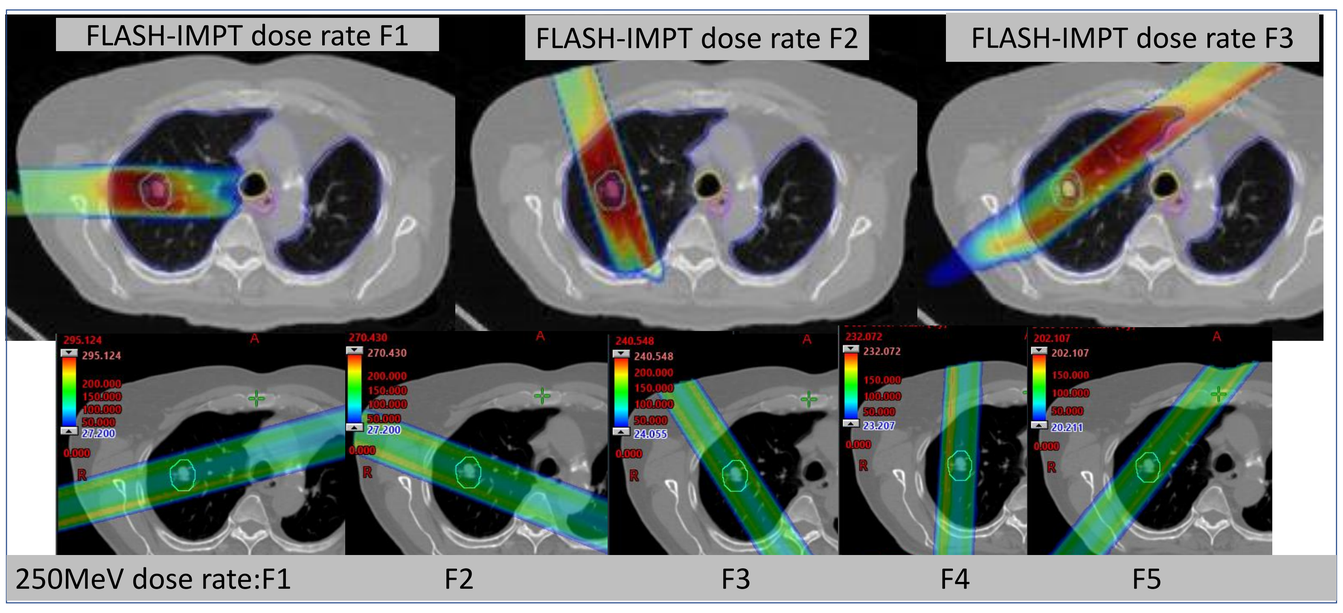

Figure 3: Dose rate distributions for each field of the lung FLASH-IMPT plan (top) Transmission Flash (bottom).

Results

Scores are shown in Table 1. Best planning scenario per patient case:

1. Brain: FLASH-IMPT
2. Lung: FLASH-IMPT (close results)
3. Prostate: Transmission

Example dose rate distributions for lung FLASH-IMPT are shown in Figure 3. Dose delivered at FLASH dose rates are shown in Figure 4.

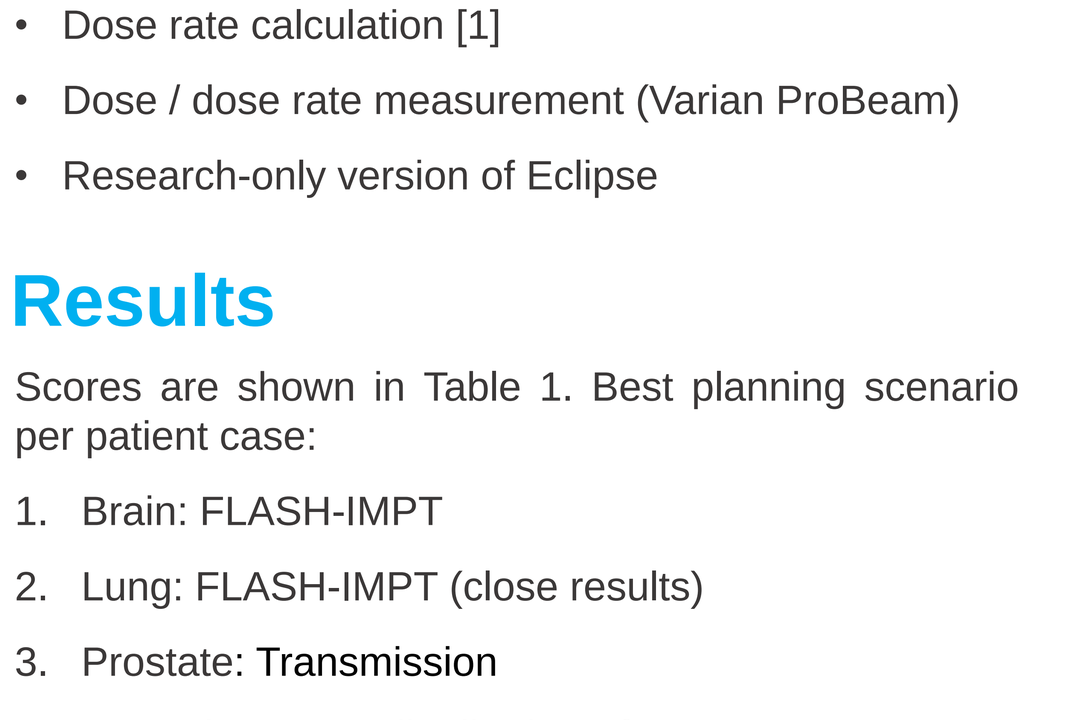

Figure 4: Dose delivered at > 40 Gy/s for lung FLASH-IMPT and Transmission, DRDVH for lung Transmission

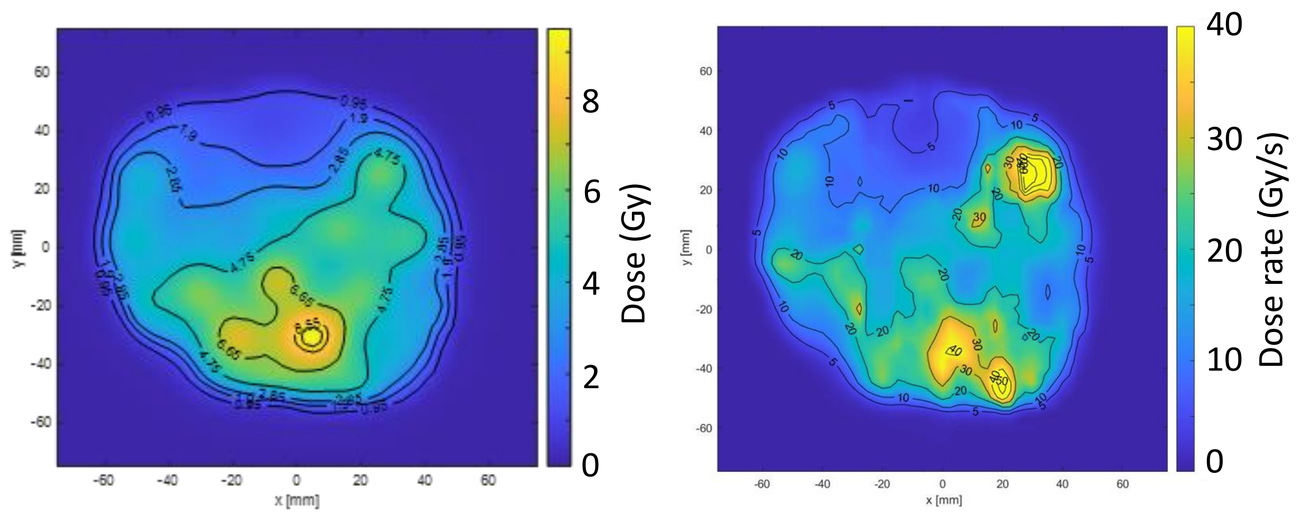

Figure 5: Dose and dose rate measurement for the brain FLASH-IMPT plan. The dose (left) is highly non-homogenous due to the MFO, which also translates to the dose rate distribution (right).

Conclusion

Highly modulated plans were achievable using both transmission and FLASH-IMPT, with dose rates in the FLASH regimes. Transmission plans may be beneficial for deep-seated tumors, while FLASH-IMPT could be preferable for superfical targets.

References

[1] Folkerts, Abel, et al 2020: https://doi.org/10.1002/mp.14456

FlashForward Consortium

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