Optimizing Radiotherapy Treatments of Brain Metastases

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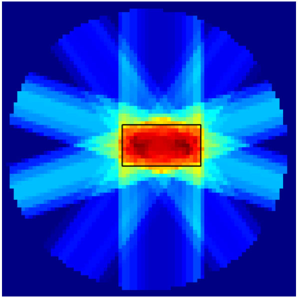
Radiotherapy

Use of radiation in treating illness.

More than 50% of cancer patients receive some form of radiotherapy during the course of their treatment.

Deliver beams from **multiple angles**.

Tumor cells receive high dose, while neighboring healthy cells can maintain lower dose.



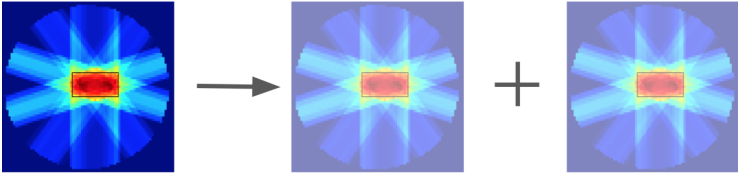
Fractionation

Delivering the dose all at once can still be too much for the healthy cells.

To mitigate, we use fractionation, **spreading the treatment over multiple lower dose fractions**.

Gives healthy cells a chance to recover between fractions.

Cumulative effect of over all fractions still leads to tumor irradiation.



Fractionation schemes

Two broad categories:

1. **uniform** fractionation: identical doses on each fraction
2. **non-uniform** fractionation: different doses on each fraction

    E.g. some tumors are radiated on fraction 1, the rest in fraction 2.

Even with same total dose over all fractions, choice of fractionation scheme can lead to different clinical effects.

Biologically E ective Dose (BED) Model

BED equation

n: number of fractions

d_i: dose on fraction i (Gy)

= : parameter representing sensitivity to fractionation

$$\mathrm{BED} = \sum_{i=1}^{n} \left(d_i + \frac{d_i^{2}}{[\ =\ ]} \right)$$

Higher BED corresponds to a larger clinical e ect.

For the same total dose,

high dose in fewer fractions ! LARGE BED,

low dose in many fractions ! small BED.

Project aim

Investigate the e ectiveness of non-uniform fractionation for patients with multiple brain tumors.

- Uniform fractionation is the current clinical practice.
- Non-uniform may have potential to decrease damage to healthy cells.
  - Tumor cells see few fractions (higher BED), but healthy cells see many fractions (lower BED).
- Use mathematical optimization with BED model to compare fractionation schemes.

Mathematical model

Objective: minimize mean BED of healthy cells

Variables: fractionation scheme and beam angles/intensities

Constraints: (primarily) prescribed BED must be delivered to every tumor cell

Example result

Comparison ofuniform and non-uniform treatment.

Identical on both treatments

- 6 tumors
- prescribed tumor BED = 72 Gy
- maximum of four fractions

Di erent fractionation schemes

1. optimal uniform , 4 identical fractions for each lesion
2. optimal non-uniform , number of fractions for each lesion determined by solver

Example result

Uniform
Mean healthy BED = 58.2

Non-uniform
Mean healthy BED = 52.7

Future steps

Non-uniform is not necessarily always better. Deeper understanding of when each fractionation scheme is preferable (number of tumors, patient geometry, etc).

Refine model to be more realistic and medically relevant (objective function, constraints, etc).

Expand to 3D patients.

Keep reasonable runtime for optimization.