Specifics of treatment planning for active scanning and IMPT

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Treatment planning for scanning

1. Single Field, Uniform Dose (SFUD)

2. Intensity Modulated Proton Therapy (IMPT)

3. Dealing with uncertainties

4. Summary
Single field, uniform dose (SFUD) planning

The combination of individually optimised fields, each of which deliver a (more or less) homogenous dose across the target volume.

SFUD is the spot scanning equivalent of treating with ‘open’ fields.
Treatment planning for scanned proton beams and IMPT

Spot scanning in practice

1. Incident field
2. Spot selection
3. Selected spots
4. Initial dose distribution
5. Dose calculation
6. Spot weight optimisation
7. Optimised dose
8. Dose calculation

Single Field, Uniform Dose (SFUD)
A SFUD plan consists of the addition of one or more individually optimised fields.

Note, each individual field is homogenous across the target volume.
Treatment planning for scanning

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Intensity Modulated Proton Therapy (IMPT)

The simultaneous optimisation of all Bragg peaks from all fields (with or without additional dose constraints to neighbouring critical structures)

IMPT is the spot scanning equivalent of IMRT (and field patching for passive scattering proton therapy).
The simultaneous optimisation of all Bragg peaks from all incident beams. E.g.

Lomax 1999, PMB 44: 185-205
Intensity Modulated Proton Therapy (IMPT)

The three ‘orders’ of proton therapy compared

1 field

Passive scattering

1 field

Spot scanning

1 field

IMPT

3 fields

3 fields

3 fields

Treatment planning for scanned proton beams and IMPT

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Example clinical IMPT plans delivered at PSI

Skull-base chordoma

3 field IMPT plan to an 8 year old boy

4 fields

3 fields

Intensity Modulated Proton Therapy (IMPT)
Intensity Modulated Proton Therapy (IMPT)

There’s more than one way to optimise an IMPT plan...

Two, 5 field IMPT dose distributions

Corresponding spot weight distributions from field 2

Planning degeneracy
Treatment planning for scanning

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4. Summary
To PTV or not to PTV? – that is the question

- Definition of a PTV is conventional way of dealing with potential delivery errors
- For passive scattering protons, PTV often not used with uncertainties dealt with through expansion of apertures and smoothing and shaving of compensator
- No collimators or compensators for scanning, therefore current method is to define PTV
- Is this necessarily the best approach?
Do we need field specific PTV’s?

E.g. could be necessary if $\sigma_{\text{pos}} <> \sigma_{\text{range}}$

..or when passing along strong density interfaces (c.f. smearing of compensators)
Range adapted PTV’s

Dirk Boye, PSI

Dealing with uncertainties – To PTV or not to PTV

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Dealing with uncertainties – range uncertainties.

Range uncertainty for SFUD and IMPT plans


Treatment planning for scanned proton beams and IMPT

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Dealing with uncertainties – range uncertainties.

Range uncertainty for SFUD and IMPT plans

+5% CT

-5% CT

Dealing with uncertainties – range uncertainties.

Dealing with range uncertainties - robust IMPT planning?

Dealing with uncertainties – range uncertainties.

Dealing with range uncertainties - robust IMPT planning?

Nominal  
-10% CT

IMPT

Single field

DVH analysis

Spinal cord


Treatment planning for scanned proton beams and IMPT

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Uncertainties and the need for adaptation

Robust IMPT planning – the automated approach

Optimised fields using ‘robust’ optimisation

Unkelbach et al, PMB, 52;2755-2773, 2007

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Treatment planning for scanned proton beams and IMPT
Dealing with uncertainties – displaying uncertainties

Displaying ‘error-bars’ for dose distributions
Max-min displays

Albertini et al 2011, PMB, 56: 4399-4413
Typical skull base treatment at PSI

1st series
(0-40CGE)
3 field SFUD
plan to PTV

1st series
(0-40CGE)
3 field SFUD
plan to PTV

2nd series
(40-74CGE)
4 field IMPT
plan with
constraints on
brainstem, optic
structures...

Full treatment

How we do it at PSI...

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Summary

- Although many similarities with passive scattering, there are some significant differences and issues for planning active scanned proton and IMPT plans.
- Is the conventional PTV criteria still valid? Are field specific PTV’s required? Do we need probabilistic planning?
- Active scanned plans (fields) have a large degeneracy – many distributions of pencil beam intensities give very similar dose distributions.
- In general, SFUD plans are more sensitive to errors than conventional photon plans and IMPT plans more sensitive than SFUD plans.

Don’t abandon ‘simple’ planning techniques (e.g. SFUD)!