Fachhochschule Nordwestschweiz
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Robustness comparison of optimization techniques in Intensity Modulated Proton Therapy (IMPT)

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Bachelor-Thesis, Medical engineering

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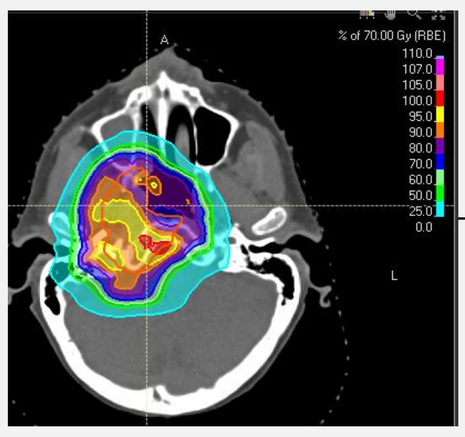
Introduction

Proton therapy is an advanced form of cancer treatment. Due to its sophisticated dose modulation and proton-based physics, proton therapy treatments are well known for their ability to generate conformal high-dose areas and a steep dose fall-off. However, due to the higher sensitivity—compared to conventional photon-based radiotherapy—to tissue density, these treatments are more affected by daily patient positioning and other types of uncertainties. This project aims to compare the so-called 'robustness' of different optimization techniques. In order to be clinically acceptable, a plan dose distribution should be robust, that is, as little as possible affected by the before mentioned uncertainties.

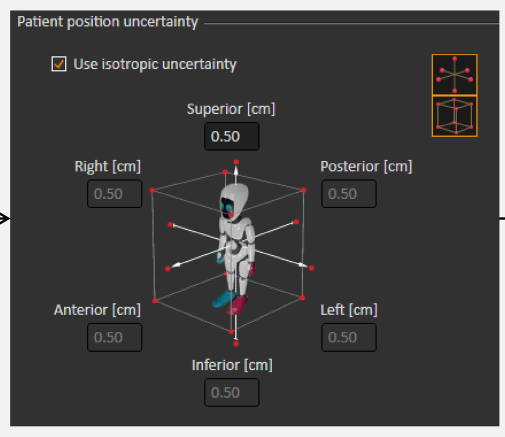
Project Workflow

4 different techniques were used: PTV-based and fully robust optimization for both single-field optimization (SFO) and multi-field optimization (MFO).

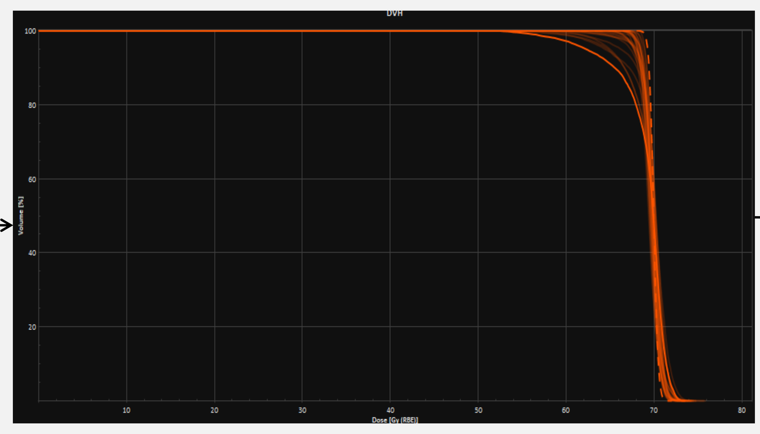
Optimization



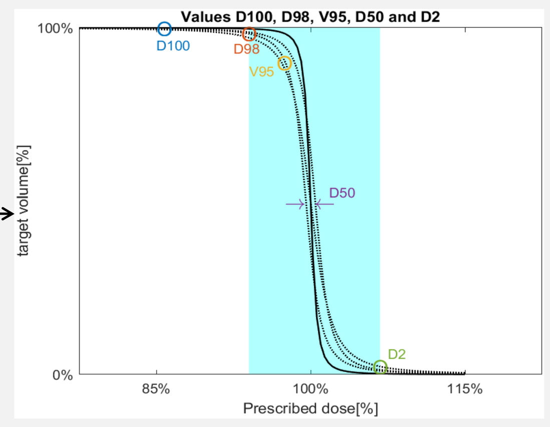
Uncertainties



DVH evaluation



Worst case metrics



Geometrical and density uncertainties evaluated on 6 different metrics, related to the coverage of the target volume.

The ability of sparing Organs is also evaluated.

Results

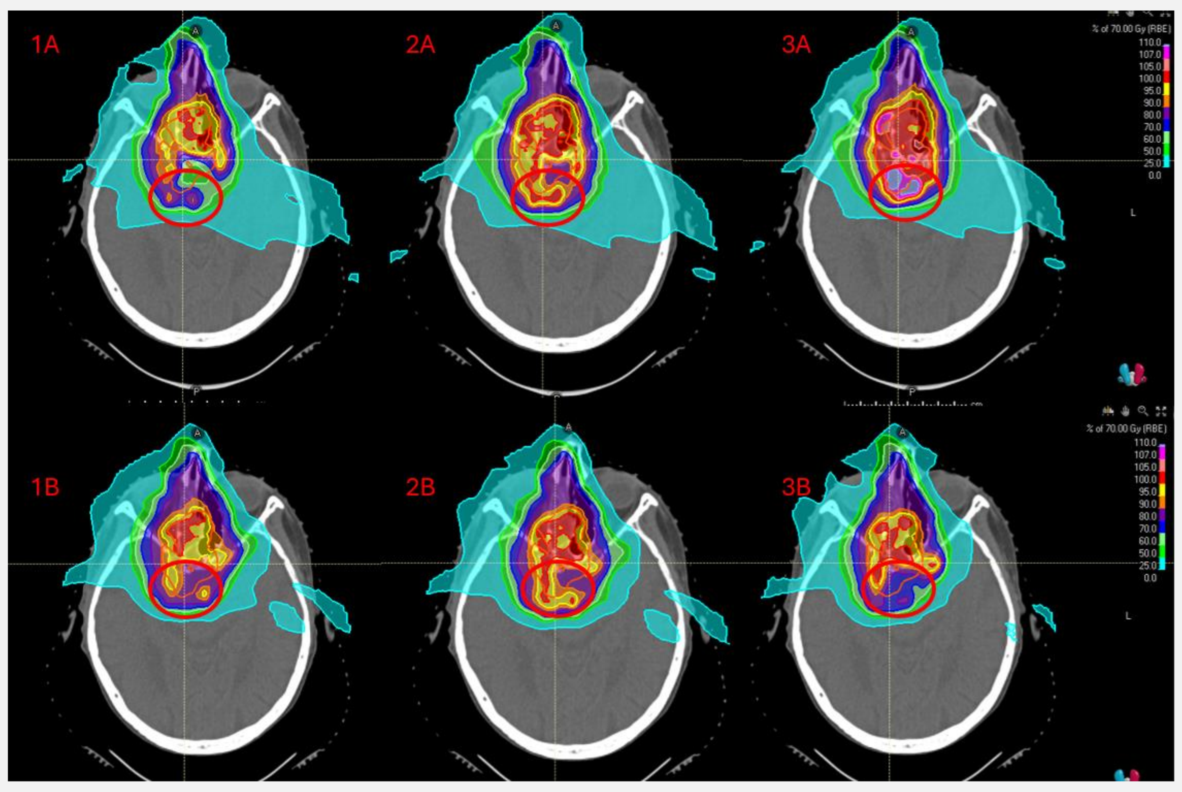


Figure 1 example wise dose distribution of a non-robust plan(1A-3A) and a robust plan (1B-3B)

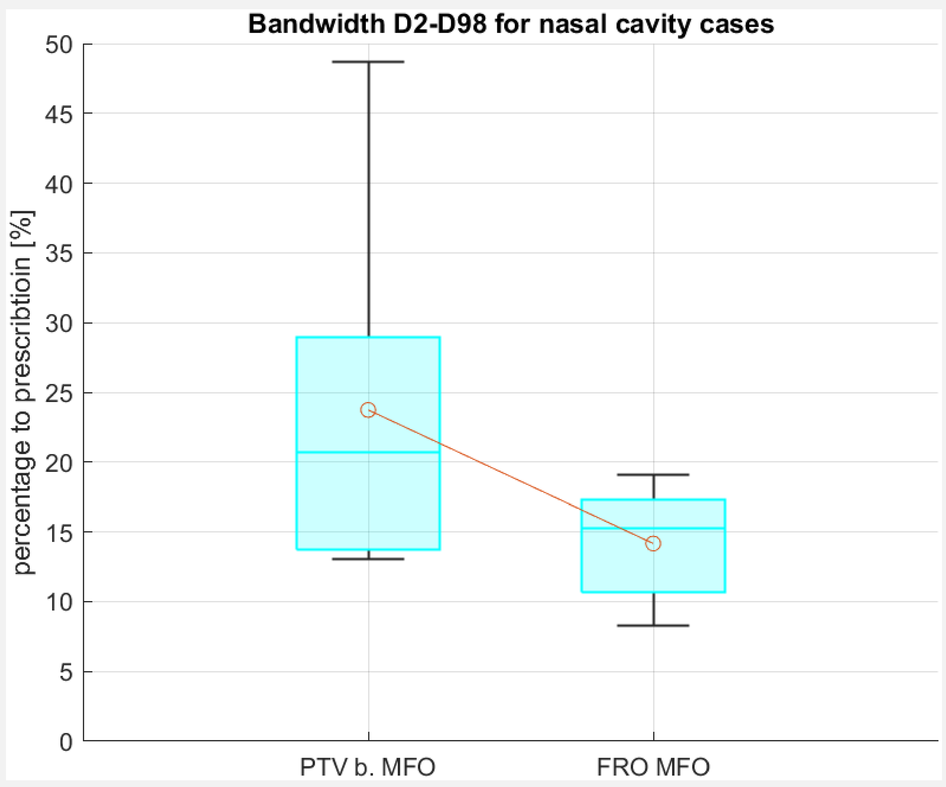


Figure 2 Results of the bandwidth measurement for nasal cavity cases.

Target coverage

Goal: Homogeneous coverage

Figure 1: A series, PTV based plan, large difference between 1A (minimal worst case) and 3A (maximal worst case), 2A as reference the nominal dose distribution.
Same for the B series but the differences are a lot smaller, highlighted areas as example.

Figure 2: Boxplot of the band with measurement for 5 nasal cavity cases. Like the example from Figure 1.

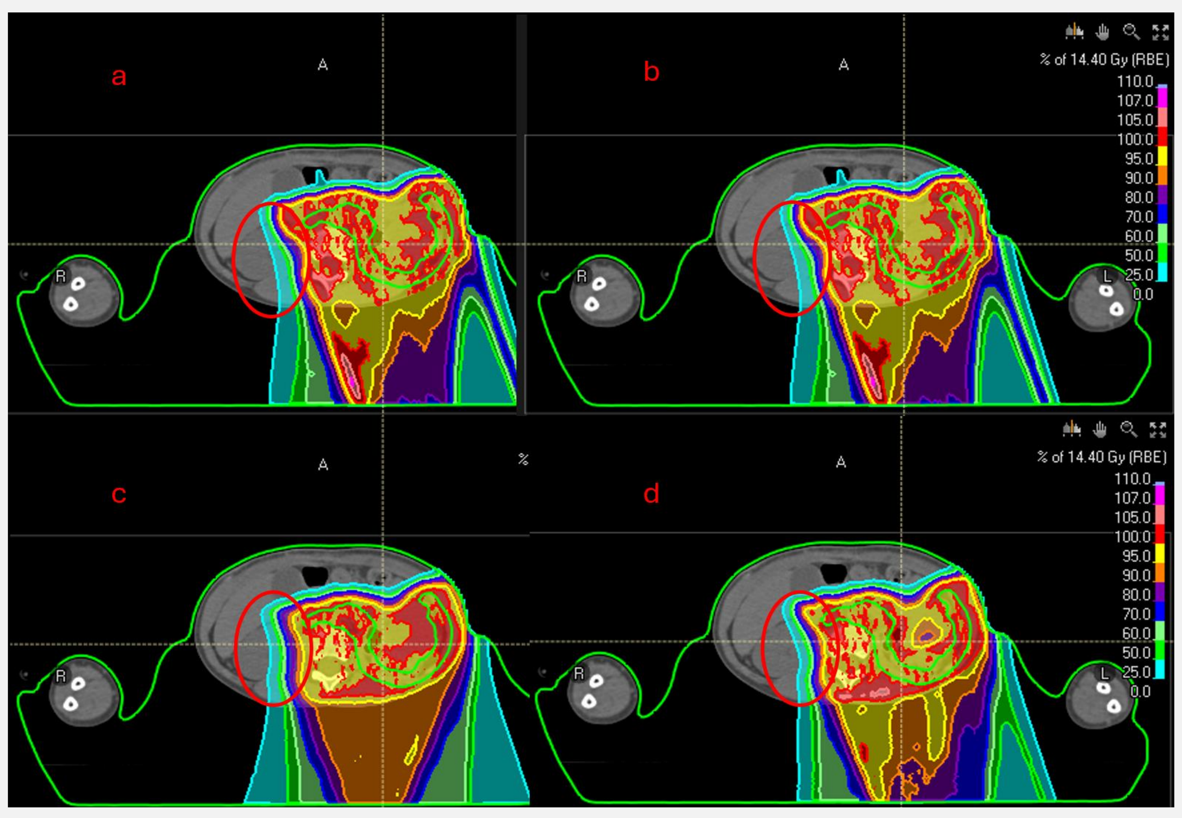


Figure 3 example wise dose distribution sparing the right kidney on different plans.

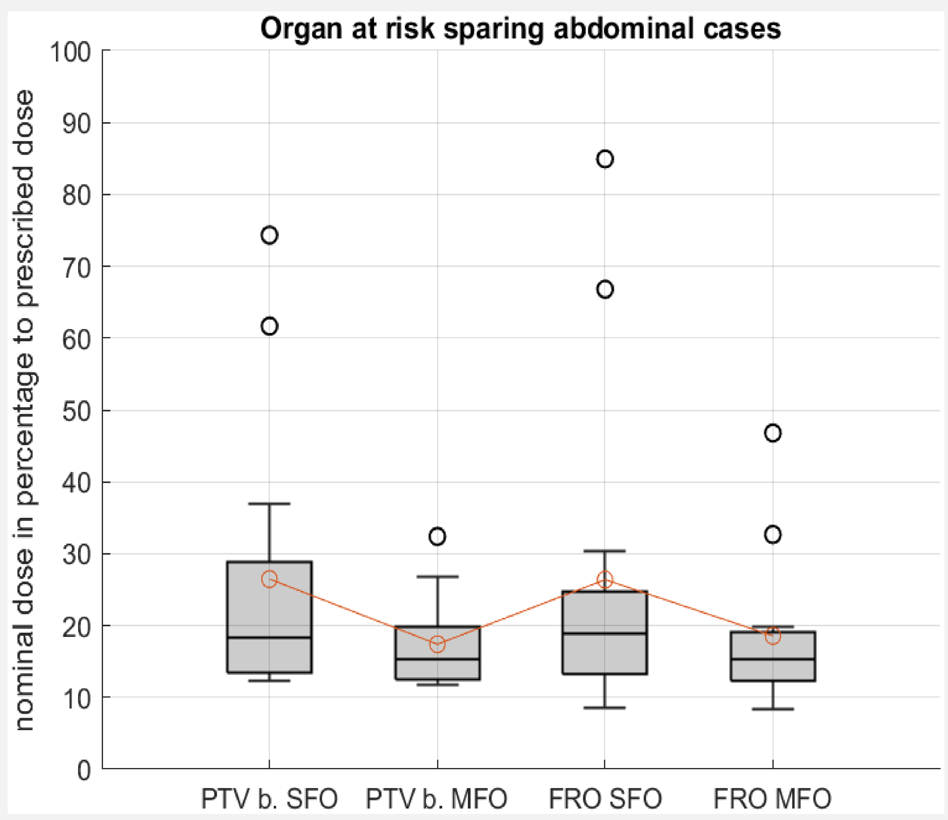


Figure 4 Results of OAR nominal mean dose

Organ at risk sparing

Goal: deliver as few dose as possible to surrounding healthy tissue.

Figure 3: example wise sparing the kidney with different optimization approaches. Biggest impact on the highlighted area.

Figure 4: Boxplots of the nominal mean dose to the kidney, points out the advantage of the MFO techniques on sparing healthy tissue.

Conclusion

This project has shown that the **robust optimized plans perform better than the PTV based plans** based on the robustness against geometrical and range uncertainties.
Furthermore, the **multi field plans could perform better on the aspect of sparing organs** at risk and radiosensitive tissue. The aspect of sparing tissue along the trajectory of the individual fields could lead to a loss of robustness but decrease the dose to a critical organs near the target.

References

M. Cubiullos-Mesias et. al., Impact of robust treatment planning on single- and multi-field optimized plans for proton beam therapy of unilateral head and neck target volumes
W. Lui et. al., Robust optimization of intensity modulated proton therapy

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