A comparative treatment planning study of IMPT and IMXT for cervical cancer

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Introduction

- The aim of this work was to compare intensity modulated proton therapy (IMPT) planning with intensity modulated photon therapy (IMXT) planning for patients with cancer of the cervix.

- All the treatment planning were optimized with a new software, ORBIT Workstation, developed by RaySearch Laboratories AB.

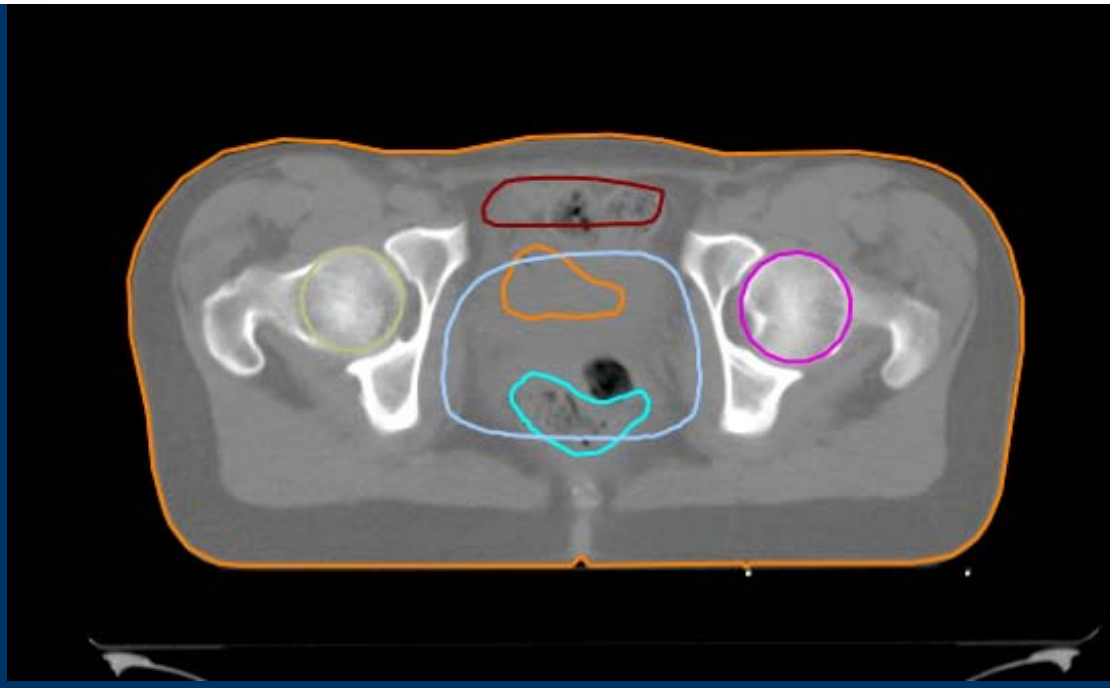
- IMPT has been investigated for various tumour sites, but the use of this technique in treatment of cervical cancer is rather unexplored.

- IMPT for cervical cancer has potential benefits due to large target volumes and organs at risk adjacent to the tumour.

Materials and Methods: Patient data

Patient data

- 4 patients were selected from a clinical database.
- Contours for each dataset:
  - PTV (based on a 1.5 cm margin to the CTV)
  - Bladder and rectum
  - Small bowel
  - Femoral heads
- The small bowel was grossly estimated and the other OARs were delineated according to generally accepted clinical practice by an oncologist.
- In average 64% of the bladder and 59% of the rectum were overlapped by the PTV.



Small bowel,
PTV, Bladder,
Rectum,
Right femoral head,
Left femoral head

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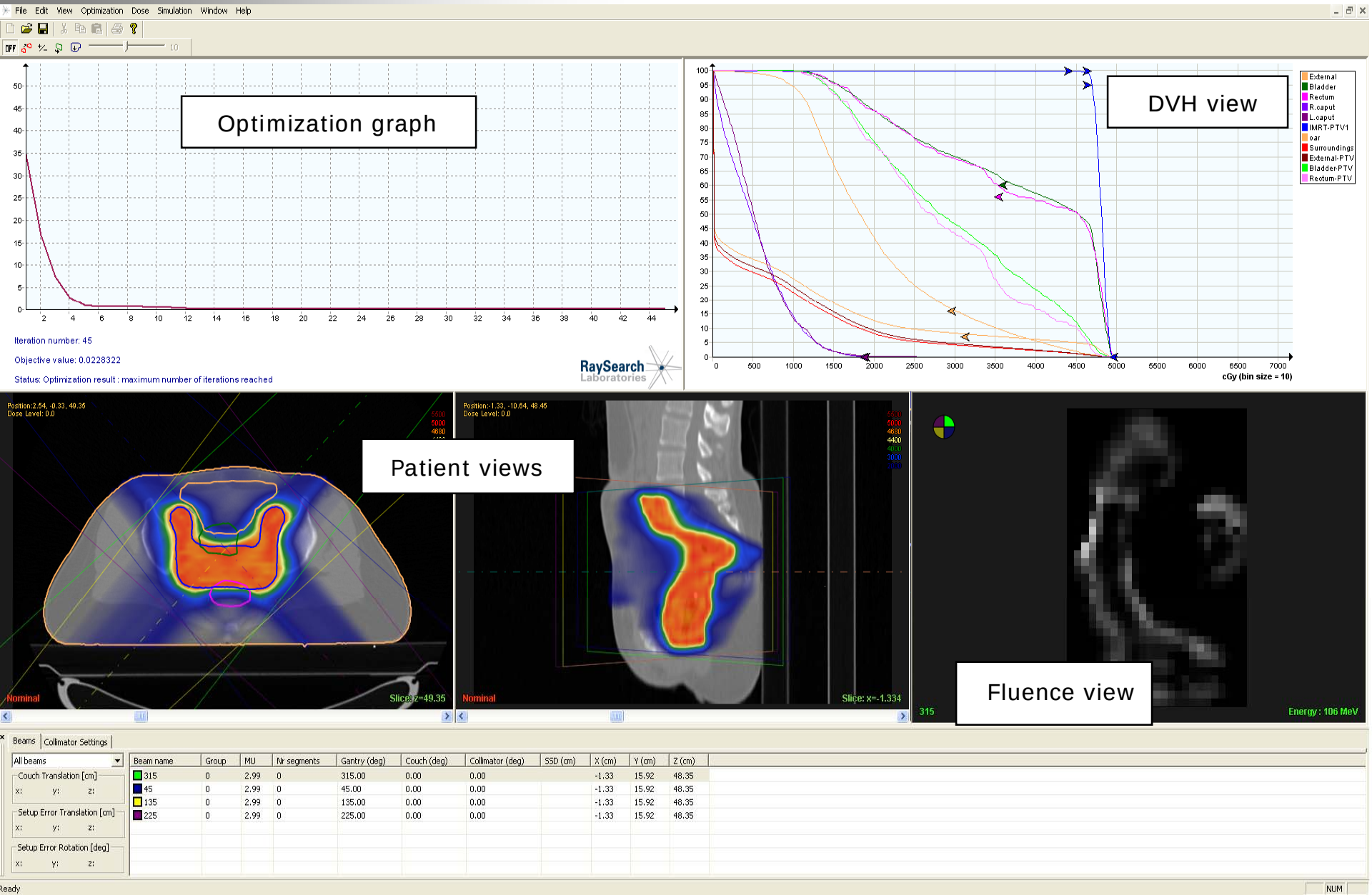
Materials and Methods: Research software

- ORBIT Workstation is a stand-alone Windows-based software, developed in C++.
- Runs on a standard PC or high performance laptop.
- ORBIT Workstation is not used clinically and is intended to serve as an environment for research and development.

Materials and Methods: Research software

- The software has functionality within the following fields
  - standard IMXT optimization
    - direct optimization of step-and-shoot segments (DSS)
    - gantry angle optimization
  - adaptive radiation therapy
    - 4D architecture and GUI
    - deformable dose accumulation
    - replanning based on accumulated dose and organ motion prediction
  - biological optimization
    - Poisson-LQ TCP models
    - Poisson-LQ and LKB based NTCP models
    - EUD
  - proton beam scan patterns

Materials and Methods: Treatment planning software

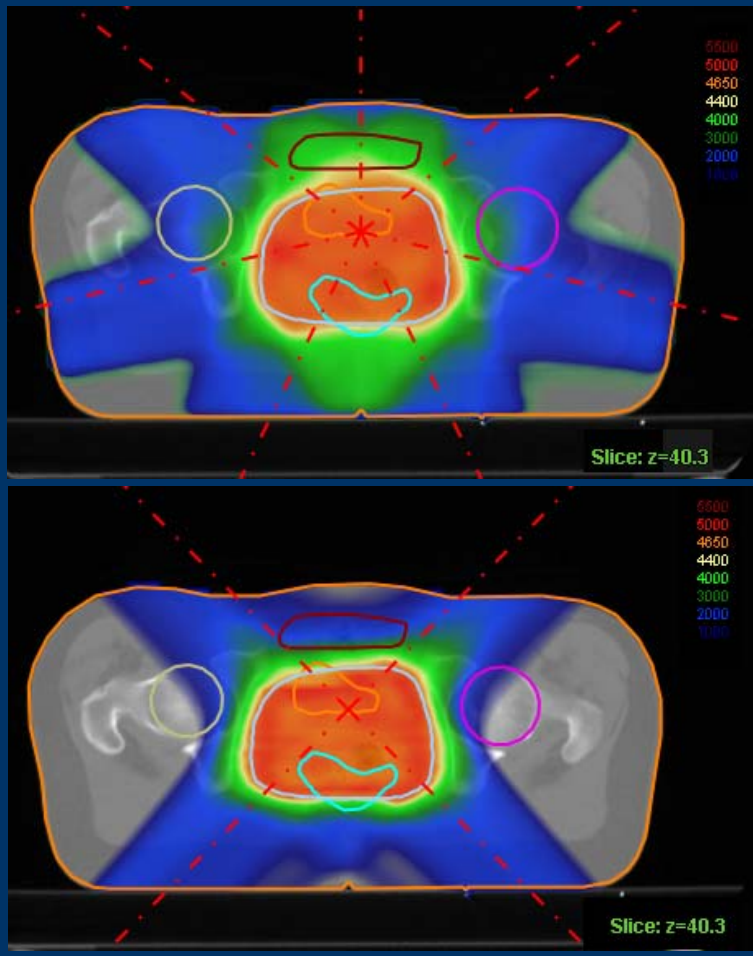


Materials and Methods: Planning

46.8 Gy or CGy were delivered in 26 fractions

- IMXT planning
  - 7 equispaced beams (0°, 51°, 103°, 154°, 206°, 257°, 308°)
  - 90 segments in total.
  - Direct optimization of step-and-shoot segment shapes and weights.

- IMPT planning
  - 4 equispaced beams (45°, 135°, 225°, 315°)
  - 25 energy levels for each beam



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Materials and Methods: Evaluation criteria

- Target dose homogeneity criteria to PTV was defined as: D_{100}>95%, D_{95}>100%, D_{max}<107% of prescribed dose.
- Irradiated volume, defined as V_{50}
- Treated volume, defined as V_{95}
- RTOG0418-specified evaluation parameters
  - Bladder D_{60}
  - Rectum D_{35}
  - Small bowel D_{30}
  - Femoral heads D_{15}
- All patients were planned so that target coverage was achieved.
- Comparison was made based on OAR protection.

Results: Min, Mean and Max dose differences

The min, mean and max dose differences between IMXT and IMPT, normalized to the photon plans.

Volume	Dose level	Min	Mean	Max
Rectum-PTV	D_{60}	10%	26%	45%
Bladder-PTV	D_{35}	7%	16%	24%
Small Bowel	D_{30}	45%	49%	54%
Femoral heads	D_{15}	53%	61%	70%

The entire bladder and rectum volume did not exhibit any major difference in D_{60} and D_{35}, respectively.

Results: Min, Mean and Max dose differences

The min, mean and max dose differences normalized to the photon plans.

Volume	Dose level	Min	Mean	Max
Treated volume	V_{95}	15%	22%	32%
Irradiated volume	V_{50}	37%	43%	48%
PTV-surrounding tissue	D_{mean}	39%	43%	48%

Results: Equivalent Uniform Dose (EUD)

The relative min, mean and max EUD differences.

Volume	a-value	Min	Mean	Max
PTV	-10	-0.06%	0.05%	0.10%
Bladder[1]	2	3%	7%	13%
Femoral Heads[1]	4	50%	60%	68%
Rectum[1]	8.33	0%	2%	3%
Small bowel[1]	6.67	29%	32%	37%

1: C. Burman *et. al.* Fitting of normal tissue tolerance data to an analytic function. Int. J. Radiation Oncology Biol. Phys. Vol. 21, pp. 123-135

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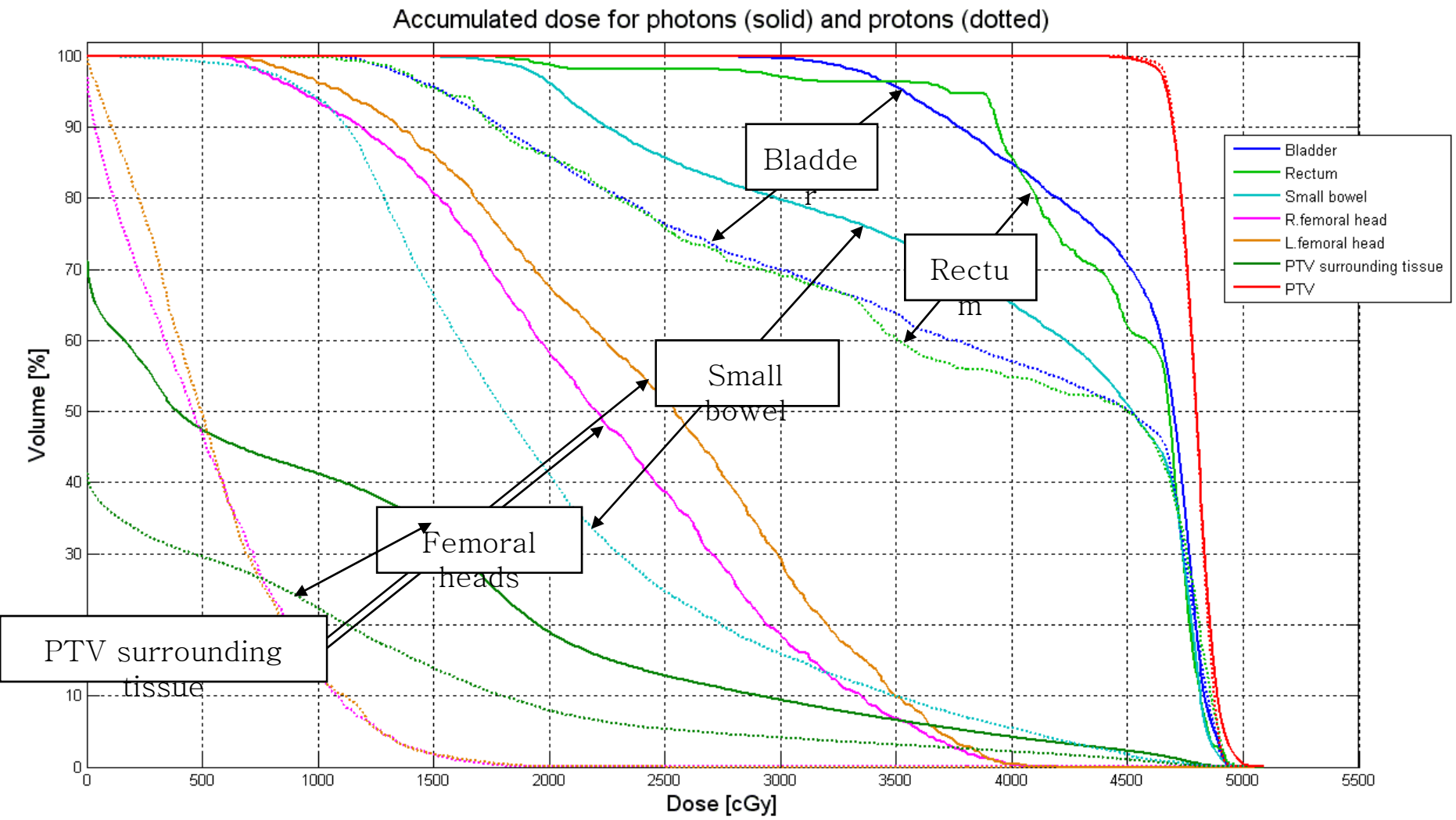
Results: DVH



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Summary and discussion

Summary

- Research software for IMPT treatment planning has been developed and cervical cancer has been studied.
- The IMPT plans exhibited significant dose reduction to the small bowel and femoral heads compared to IMXT, with preserved target coverage.
- IMPT gives, with same target dose homogeneity, significantly lower irradiated and treated volumes compared to the photon techniques.
- Results from this study suggest that the IMPT technique is suitable for tumors of the cervix.

Further work

- Clinically accurate dose calculation, using beam model from Nucletron
- Biology-based fractionation schedule optimization
- Adaptive PT strategies
- Carbon ions