Proffered Papers: RTT 6: Treatment planning and quality assurance

OC-0615 Investigating online adaptive workflows for prostate patients on the MR-Linac: an in-silico study

S. Jones[1], R. Chuter[2], A.J. Pollitt[2], M. Warren[1], A. McWilliam[2]
[1]*University of Liverpool, Directorate of Medical Imaging and Radiotherapy, Liverpool, United Kingdom*
[2]*The Christie NHS Foundation Trust, Christie Medical Physics and Engineering, Manchester, United Kingdom*

Purpose or Objective

On the MR-Linac system (Elekta Unity, Elekta AB, Stockholm, Sweden) any change in patient set-up will be corrected for using a 'virtual couch shift", where the defined MLC aperture shifts, rather than the couch. Additionally, segment weights and shapes may be re-optimised to account for daily anatomical changes. This study investigates swift, dosimetrically acceptable processes for re-optimisation of treatment plans for set-up and rectum volume changes for prostate patients.

Material and Methods

4 prostate step and shoot IMRT plans, optimised to 60Gy in 20 fractions, were created using a MR Linac beam model on Monaco research TPS v5.19.02 (Elekta AB, Stockholm, Sweden). The 1.5T magnetic field was included in the optimisation. For investigating the adaptive workflows, the reference CT was re-imported into Monaco with two changes introduced. 1) a 5mm and 10mm setup error 2) rectal volume variation +/- 20% (simulated by deforming the CT using ImSimQA).

To correct for translational and anatomical changes, three re-optimisation methods were tested: Shift-only (SO); Segment Weight Optimization (SWO); and Segment Weight and Shape Optimization (SSO). The time taken to re-optimise and the resulting DVH values were recorded, with the change in dose from the original plan calculated.

Results

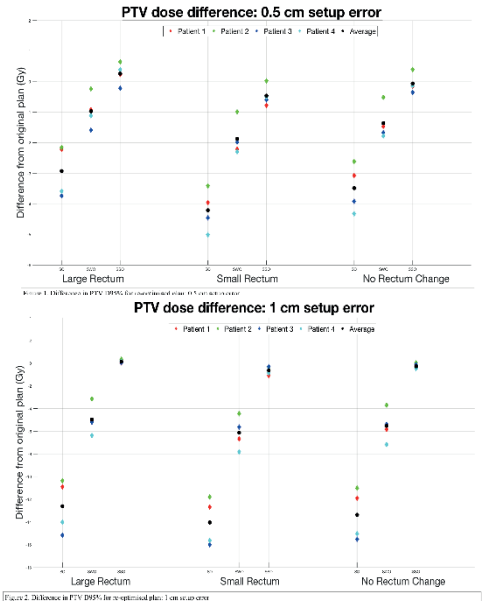


Figure 1 and 2 show individual and mean difference in PTV coverage (D95%) from the original plan using the 3 optimisation methods. With no change in the rectal size, mean difference in PTV dose for each optimisation method varied between 0.06-3.48Gy for 0.5cm setup error, and 0.25-13.4Gy for 1cm setup error. For small and large rectal changes, the mean change in dose varied between 0.26-4.21Gy for 0.5cm setup error and 0.15-14Gy for 1cm setup error. SSO optimisation produced the smallest difference in PTV dose for all setup conditions, whilst SO optimisation produced the largest. Overall, recovered plans had a lower maximum dose to 2cc of rectum. The mean difference for SO, SWO and SSO was 1.84Gy, 0.85Gy and 0.71Gy respectively.

The mean time taken to complete each of the 3 methods of plan re-optimisation are 61, 64 and 239 seconds for SO, SW and SSO respectively.

Conclusion

This preliminary study suggests available optimisation methods can be used for daily strategies. However, SO struggled to recover PTV dose when large translations of 1cm were introduced, this is unsurprising as the MR-Linac uses an unflattened beam. SSO was the optimal method for recovering the original parameters of the plan, however there was a mean time increase of 3 minutes between this and the other methods.

The efficiency of treatment speed and quality could therefore be assured by ensuring good immobilisation strategies in the pre-treatment stages. Given the time differential between optimisation strategies, further work is needed to determine which cases are best suited to each method.

OC-0616 1.5T MRI-Linac treatment planning for multiple lymph node oligometastases in the pelvic area

I.H. Kiekebosch[1], D. Winkel[1], A.M. Werensteijn-Honingh[1], J. Hes[1], M.P.W. Intven[1], W.S.C. Eppinga[1], G.H. Bol[1], B.W. Raaymakers[1], I.M. Jürgenliemk-Schulz[1], P.S. Kroon[1]
[1]*UMC Utrecht, Radiation Oncology, Utrecht, The Netherlands*

Purpose or Objective

Currently, in our center, patients with lymph node oligometastases are treated with SBRT on a conventional linac. About 35% of these patients present with multiple lesions which are treated simultaneously in one plan or two separate plans. PTV margins are partly based on the visibility on online cone-beam CT. MRI-Linac seems to be a promising treatment modality for lymph node oligometastases because of superior soft tissue contrast and online replanning possibilities to account for daily variations. The purpose of this study was to investigate the treatment plan quality of multiple lymph node oligometastases in the pelvic area for the 1.5T MRI-Linac accounting for magnetic field, a fixed isocenter and a non-rotating collimator.

Material and Methods

Ten patients with multiple lymph node oligometastases (2-3), only in the pelvic area were included. PTV margins were created using a 3mm margin, resulting in 2 PTVs per patient (mean PTV 8.7 cc; mean cranial-caudal distance 4.9 cm, Fig. 1). For each patient, one treatment plan was created including both PTVs. MRI-Linac treatment plans were generated using an IMRT-template with 7 or 9 beams of 7MV (Monaco Research version 5.19.03) with grid size of 0.2 cm and magnetic field. Organs at risk (OAR) within 5 mm of the PTV and a PTV ring structure of 2 cm were used to optimize the treatment plans. The prescription dose (PD) was 35 Gy in 5 fractions, $V_{100\%}$>95% and $D_{0.1cc}$ <135% of the PD. OARs dose constraints were based on the UK SABR consortium guidelines[1]. To quantify the treatment plan quality the procedure was used from the NRG-BR001 phase 1 trial[2]. In summary, the actual prescription dose (PD*) was given by $D_{95\%}$ of the PTV and must be ≥60% and ≤90% as a percentage of D_{max}. The conformity metrics $R_{100\%}$ (=V_{PD*}/PTV), $R_{50\%}$ (=$V_{0.5xPD*}$/PTV) and D_{2cm} (max dose at 2 cm from PTV as % of PD*) were calculated and compared to the benchmark values[2].

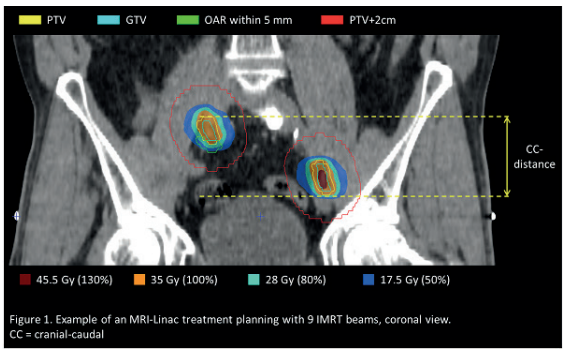


Figure 1. Example of an MRI-Linac treatment planning with 9 IMRT beams, coronal view. CC = cranial-caudal

Results

All treatment plans meet the PTV objectives without violations of the OAR constraints. The mean $D_{95\%}$ is 81% and mean $R_{100\%}$ is 1.15. $R_{50\%}$ and D_{2cm} are volume dependent and displayed in Table 1. This shows that the MRI-Linac treatment plans easily meet the conformity criteria except for $R_{50\%}$. However, the benchmark values of $R_{50\%}$ are based on single lesions and it is already stated in NRG-BR001 trial document that the 50% may be elongated as long as normal tissue constraints are met.

Table 1: Conformity results

Patient	PTV [cc]	CC-distance [cm]	PD* [%]	D_{2cm} [%]	$R_{100\%}$ [-]	$R_{50\%}$ [-]	Benchmark $R_{50\%}$*
1	5.7	8.7	84	51.2	1.13	*8.3*	< 6.0-6.5
2	4.3	2.8	84	56.2	1.19	*8.8*	< 6.0-6.5
3	10.1	4.0	81	52.4	1.09	*6.2*	< 5.8-6.0
4	6.5	8.0	82	49.3	1.20	*7.8*	< 6.0-6.5
5	10.8	6.6	79	47.0	1.05	*6.4*	< 5.8-6.0
6	7.9	6.3	77	48.9	1.29	*8.1*	< 5.8-6.0
7	3.6	2.6	85	55.9	1.12	*9.8*	< 6.5-7.5
8	20.3	4.2	79	53.6	1.11	*6.0*	< 5.5-5.8
9	3.3	2.4	84	55.1	1.15	*11.5*	< 6.5-7.5
10	14.7	3.6	78	56.2	1.17	*6.0*	< 5.5-5.8

* NRG-BR001 Trial[2]; Benchmark values[2]: $D_{95\%} \geq 60\%$ and $\leq 90\%$, D_{2cm} <57% or <63% dependent on PTV volume, $R_{100\%}$<1.2, acceptable till 1.5, $R_{50\%}$ see last column in Table. (given in *Italic* = above Benchmark values; CC = cranial-caudal; PD* = actual prescription dose as a percentage of D_{max})

Conclusion

This study shows that multiple lymph node oligometastases could potentially be treated on the MRI-Linac. High SBRT plan quality is shown with conformity that meets the international criteria for multiple lesions. All treatment plans meet the PTV objectives and OAR constraints. These MRI-Linac treatment plan results are very promising and offer perspective to use smaller PTV margins which pave the way for further dose escalation and hypofractionation.

1.UK SABR consortium guidelines 2016
2.Chmura S.,*NRG-BR001: A Phase 1 Study of Stereotactic Body Radiotherapy for the Treatment of Multiple Metastases*, version 11/13/2015

OC-0617 A new technique for robust VMAT treatment planning of total craniospinal irradiation

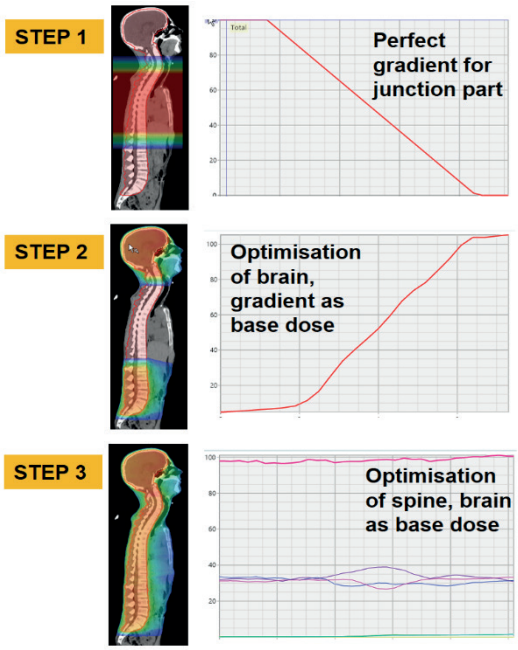
M. Chamberlain[1], S. Klöck[1], C. Linsenmeier[1], M. Di Martino[1], M. Guckenberger[1], S. Tanadini-Lang[1]
[1]*University Hospital Zurich, Department of Radiation Oncology, Zürich, Switzerland*

Purpose or Objective

Total craniospinal irradiation on a conventional linear accelerator most often has to be performed using multiple isocenters. This makes the junction regions prone to uncertainties against setup errors and patient motion. Often multiple plans with junctions on different locations are used to overcome this problem. Here we have developed a volumetric modulated arc therapy (VMAT) planning technique for total craniospinal irradiation, which aims at increased robustness against patient motion and positioning inaccuracy between fields.

Material and Methods

A gradient dose technique has been developed, which is based on a 7 cm long perfect gradient dose distribution created in Matlab (MathWorks). This gradient is used as a base dose plan for optimising the brain section of the plan (as well as the lower spine section in double junction plans) in Eclipse treatment planning system (V 13.6, Varian Medical Systems). The upper spine section is created using the first plan as a base dose plan in the optimiser (Figure 1). This technique was tested on four patients previously treated in our clinic using standard VMAT technique, two of which had a single junction, and two with a double junction. Each of these four patients was re-optimised using the gradient dose technique. The robustness of the plans was evaluated by shifting the isocenter of the brain plan closer towards the second isocenter by 1mm, 3mm, and 5mm, and recalculating the maximum point dose of each plan. The maximum point doses were then compared with the original clinical plans that were treated with a VMAT technique with two or three isocenters.



Results

This new technique has been successfully implemented. Treatment planning has to be performed in two optimisation steps; time needed per plan is approximately 100-160 min (10 min Matlab part, 60-120min optimisation and 30min dose calculation). Robustness in the junction region was improved with using the gradient technique (Table 1) as we observed a mean increase in maximum dose for the 3mm shift of 5% (range 4%-7%) for gradient technique, and 15% (range 6%-30%) for standard VMAT technique respectively. This was even more pronounced for the 5mm shift (10% (range 9%-12%) in the gradient technique, and 23% (11%-42%) in the VMAT technique).

		Maximum Dose			
		Original	1mm shift	3mm shift	5mm shift
Body	VMAT	110% (109%-111%)	112% (111%-113%)	125% (119%-137%)	133% (122%-149%)
	Gradient Technique	113% (112%-114%)	114% (112%-115%)	116% (113%-118%)	118% (114%-121%)
Junction	VMAT	109% (107%-110%)	112% (109%-113%)	123% (114%-137%)	132%(119%-149%)
	Gradient Technique	108% (102%-112%)	109% (105%-113%)	113% (109%-118%)	118% (114%-121%)

Table 1: Average of the maximum doses in the body and in the junction region for the original plans and the plans including 1mm, 3mm and 5mm shifts.