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EP-2198: Implementation of very high energy electron grid therapy: Monte Carlo study of source definition

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There is a large variability in dose prescription and normalization methods in stereotactic body radiation therapy (SBRT) for lung cancer. Historically an inhomogeneous dose was prescribed to a certain isodose-line enclosing the planning target volume and the normalization was done on the maximum dose (in agreement with ICRU 50). The new ICRU 91 report for stereotactic treatments recommends prescribing and normalizing the dose to the isodose surface that covers an optimal percentage of the planning target volume (PTV). Independent from the method for normalization, only one dosimetric parameter for the target can be fixed, which might lead to large variations in the other dose-parameters. This study aimed to evaluate and compare different dose normalization methods, in particular considering the recently published ICRU 91 report.

Material and Methods

Thirty-eight patients previously treated with SBRT for stage I NSCL or lung metastases were included in the study. VMAT treatment planning was performed on the average CT using an internal target volume (ITV) concept. Additionally, for each patient, a conformal arc plan (CA) was prepared. A dose of 40.5 Gy in 3 fractions was prescribed to the 65% isodose-line covering at least 95% of the PTV. Normalization was performed on the maximum dose (max normalization), which was 62.3Gy. Additionally all plans were re-normalized to:

- 98% of the PTV covered with at least the prescribed dose of 40.5Gy (ICRU 91) (coverage normalization)
- 100% (52Gy) as the median PTV value (ICRU 83) (median PTV normalization)
- 100% (57Gy) as the median ITV value (median ITV normalization)

For the different normalization methods the inter-patient and inter-technique variability of several dose parameters (PTV and ITV median dose and dose to 98% of PTV and ITV) was analyzed. Additionally it was assessed if volume and tumor motion could explain this variability.

Results

The inter-patient and inter-technique variability of the assessed ITV and PTV dose parameters was smallest for median ITV normalization (1 SD < 1.5 Gy for both techniques, Table 1).

| Normalization method | max | | median PTV | | median ITV | | 98% coverage | |
|---------------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | VMAT | CA | VMAT | CA | VMAT | CA | VMAT | CA |
| Median dose ITV (mean \pm SD) [Gy] | 59.7 (\pm 1.1) | 59.0 (\pm 0.9) | 59.0 (\pm 2.2) | 57.4 (\pm 1.5) | 58.5 (\pm 1.0) | 58.5 (\pm 1.0) | 59.5 (\pm 1.3) | 59.6 (\pm 2.2) |
| Median dose PTV (mean \pm SD) [Gy] | 53.1 (\pm 2.8) | 52.6 (\pm 2.1) | 52.5 (\pm 1.0) | 52.5 (\pm 1.0) | 52.1 (\pm 1.5) | 53.6 (\pm 1.4) | 53.0 (\pm 2.2) | 54.6 (\pm 2.7) |
| 98% ITV coverage (mean \pm SD) [Gy] | 55.3 (\pm 1.1) | 52.6 (\pm 2.1) | 55.3 (\pm 2.4) | 52.1 (\pm 2.1) | 54.7 (\pm 0.8) | 53.1 (\pm 1.3) | 55.7 (\pm 1.4) | 54.1 (\pm 2.5) |
| 98% PTV coverage (mean \pm SD) [Gy] | 40.5 (\pm 0.9) | 38.5 (\pm 0.9) | 40.2 (\pm 1.8) | 39.1 (\pm 1.9) | 39.8 (\pm 0.9) | 39.8 (\pm 1.5) | 40.5 (\pm 0.9) | 40.5 (\pm 0.9) |

Table 1: Mean and standard deviation of the ITV and PTV median dose and coverage for the two treatment techniques VMAT and CA. Green color shows significant differences between treatment techniques (p<0.05).

For normalization on the maximum dose value, the 98% coverage and the median PTV dose resulted in similar variability between patients and a significant difference in two out of the four dosimetric parameters between the two treatment techniques. For all normalization methods, all dosimetric parameters (except for normalization parameter) were correlated with the ITV volume and the tumor motion (Figure 1).

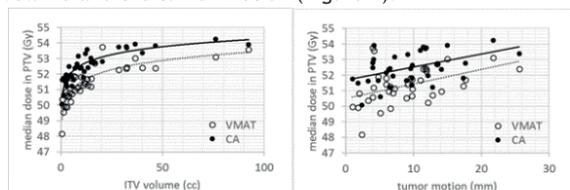


Figure 1: Correlation of the median PTV dose with the ITV volume (left) and with the tumor motion (right) for a normalization on the ITV median dose.

Conclusion

Normalization on the ITV coverage as recommended in ICRU 91 resulted in a similar variability between patients compared to the traditional normalization on the maximum dose and was significantly inferior to dose normalization to median ITV dose. Independently from the dose normalization method, relevant interpatient variability remained due to the influence of ITV volume

as well as tumor motion. Consequently, reporting a single dosimetric parameter is insufficient even when using a strictly defined planning protocol.

EP-2198 Implementation of very high energy electron grid therapy: Monte Carlo study of source definition

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Purpose or Objective

The use of very high-energy (70-300 MeV) electron (VHEE) beams for radiation therapy has recently started to be explored [1,2]. The main advantages over photons include the fact that small diameter VHEE beams can be scanned, thereby producing finer resolution intensity modulated treatment than photon beams, a sharper lateral penumbra in the first centimeters and a reduced sensitivity to tissue heterogeneity. Along this line, the combination of VHEE with the benefits of Spatially Fractionated Radiotherapy (a significant increase in normal tissue tolerance [3]) has been recently proposed [4]. This novel approach, called VHEE grid therapy, is to be implemented at the future French Platform for Research and Applications with Electrons (PRAE). This facility [5] will deliver 70 MeV electron beams in a first phase, reaching 140 MeV in the second one. The purpose of this work was to define the most adequate source and beamline parameters for pre-clinical studies.

Material and Methods

Monte Carlo simulations (GATE version 7.1) were used to assess the dose distributions resulting from various possible configurations. The influence of technically feasible beam parameters (beam sizes, beam energies) achievable at PRAE facility, as well as that of various air gaps, were characterized (see Figure). Depth-dose curves and beam width were used as figures of merit. In addition, the influence of center-to-center (ctc) distance between the pencil beams was evaluated to study the variation in terms of peak-to-valley dose ratio (PVDR), a relevant dosimetric parameter for normal tissue sparing. Our main targets are neurological, i.e., targets that can be immobilized against cardio-respiratory cycles.

Results

Our results show the feasibility of implementing our strategy at PRAE. If sub-millimetric beams would be requested at all depths in the rat head in order to exploit dose-volume effects, high energies (\geq 140 MeV) and low air-gap (\leq 15 cm) would be needed. This would be associated with very high PVDR values over the rat brain, thus potential high tissue sparing could be expected. However, energies around 70 MeV could be used to treat tumors up to 1 cm depth (center of rat head, approximately). Experimental dosimetry measurements are foreseen to validate our calculations.

Conclusion

The present Monte-Carlo study show the potential of the VHEE Grid-Therapy approach to increase high normal tissue tolerance with technically feasible beam parameters achievable at PRAE. This support the interest of performing pre-clinical experiments to evaluate its therapeutic benefit to treat brain cancer.

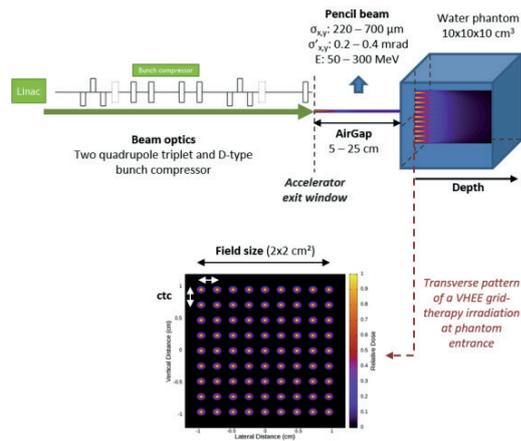
[1] DesRosiers C. et al., Phys. Med. Biol. 2000;45(7): 1781-1805.

[2] Bazalova-Carter M. et al., Med. Phys. 2015;42(5):2615

[3] Prezado Y. et al., Radiat Res. 2015;184(3):314-321.

[4] Martinez-Rovira I. et al., Med. Phys. 2015;42(2):685

[5] Marchand D. et al., EPJ Web of Conferences, 2017;138:01012.



EP-2199 Developing Head-and-Neck IMRT Organ-at-risk Sparing Decisions Support System using Model Tree
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Purpose or Objective

To develop a system that captures head-and-neck (HN) intensity modulated radiation therapy (IMRT) cases with single-lateral and bi-lateral parotid sparing decisions using model tree.

Material and Methods

Seventy-three HN IMRT cases were included in this study, with 45 bilateral parotid sparing (90 spared parotids) and 28 single parotid sparing (28 spared parotids) cases. The model tree training: the combined set of 80 bi-laterally and 23 single-laterally spared parotids.

Baseline model training:

1. bi-lateral sparing model was trained using 80 bi-laterally spared parotids
2. single-lateral sparing model was trained using 23 single-laterally spared parotids.
3. non-differentiated model was trained using the combined set of 80 bi-laterally and 23 single-laterally spared parotids

Model evaluation:

The remaining 10 bi-laterally spared parotids and 5 single-laterally spared parotids were used to validate the model tree and the three baseline models. The experiment was repeated 20 times using bootstrap. The Weighted Sum of Residual (WSR) was used to evaluate the accuracy of dose-volume histogram (DVH) prediction. The difference between predicted and the clinically planned parotid D50% was assessed.

Results

The mean WSR of the validation bi-lateral cases was 0.021, 0.034, 0.026 and 0.022 for the bi-lateral model, the single-lateral model, the non-differentiated model and model tree, respectively. Model tree predicted similarly as the bi-lateral model based on the mean WSR while single-lateral model predicted unfavorably for the bi-lateral cases. For the single-lateral validation cases, the mean WSR was -0.007, 0.010, -0.001 and 0.004 for the bi-lateral model, the single-lateral model, the non-differentiated model and model tree, respectively. The mean D50% difference of the bi-lateral model, the single-lateral model, the non-differentiated model and model tree were -0.40Gy, -2.00Gy, -1.12Gy and -0.87Gy for bi-lateral cases, and 1.63Gy, -0.13Gy, 0.89Gy and 0.60Gy for single-lateral cases. Model tree improved prediction accuracy for both bi-lateral and single-lateral cases over non-differentiated model.

Conclusion

An organ-at-risk sparing decision support system was proposed for HN treatment planning. Results showed the deficiency of using a single regression model for HN IMRT modeling because different parotid sparing decisions were involved in clinical cases. Results suggest that the model tree is effective in modeling HN IMRT cases with different parotid sparing decisions. The decision support system could aid make sparing decisions for HN patients based on patient specific anatomy.

EP-2200 Statistical process control for VMAT quality assurance: an eight-year retrospective study

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Purpose or Objective

Statistical Process Control (SPC) is a tool widely used in industrial engineering for monitoring, controlling and, ideally, improving a process through statistical analysis. We applied this strategy for patient-specific VMAT pre-treatment verification.

Material and Methods

In the last eight years, more than 1700 patients were treated with Elekta VMAT at our institution. Plans were re-grouped according to treatment technique and disease sites Group 1: 736 high-modulated complex treatments using simultaneous integrated boost for multiple targets for head-neck, pelvic (high-risk prostate and gynaecological), brain and other sites; (2) 441 low-risk prostate treatments and (3) 558 liver, lung, abdominal and other metastasis treated with extracranial stereotactic radiotherapy (SBRT). Groups 1-2 and 3 plans were optimized with Oncentra Masterplan and Ergo++ TPS. A total of 4942 planar dose measurements were performed with the PTW Seven29 array/Octavius phantom, both on coronal and sagittal planes. Doses comparison were evaluated using 3%/3mm γ -analysis. Three metrics were simultaneously evaluated: (a) $\gamma\%$: points-percentage with γ -value less than one, (b) γ mean: mean gamma value and (c) $\gamma 1\%$: the near-maximum gamma defined as the 99th percentile of the γ -distribution. Clinical specifications were: $\gamma\% > 90\%$, γ mean < 0.67 and $\gamma 1\% < 2$. Shewhart charts were used to calculate the central (CL), upper control (UCL) and lower control limits (LCL). The capability of the processes was evaluated by means of Cpk indexes. Processes were considered capable if $Cpk \geq 1$. A Gage R&R study was also performed to assess the capability of our ion-camber device in order to quantify how it influences the variability of the dose delivery process.

Results

γ pass-rate values significantly depend on plan complexity. For $\gamma\%$, CL and LCL were 93.8%, 99.1%, 99.5% and 87.9%, 96.6%, 97.9%, for group 1,2 and 3 respectively. For γ mean, CL and UCL were 0.42, 0.36, 0.29 and 0.54, 0.49, 0.40, for groups 1, 2 and 3