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Introduction into the concept of dose painting

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The term “dose painting” was launched by Ling et al. in 2000 [1]. Given advances in tumor biology and imaging technology, non-invasive 3D-visualization of different biological abnormalities within the tumor becomes possible. Those abnormalities – tumor hypoxia, metabolic and proliferative activity, abnormal blood flow among others – may drive the tumor aggressive and resistant to treatment. Mapping abnormal tumor subvolumes detected by biologic imaging (biologic MR imaging [DCE, DWI], MRS, PET, MR/PET, ...) with higher radiation dose presents a promising treatment strategy. The rest of the tumor may not need higher radiation dose but conventional radiation dose or even dose de-escalation in its radiosensitive subvolumes. Generally, dose painting is a concept of intentionally non-uniform radiation dose prescription and delivery based on (multimodality) biologic imaging. There are three principle components in dose painting: 1) identifying and validating a target volume for dose painting; 2) 3D-imaging of the target volume; 3) treatment planning and delivery. Each component has uncertainties and limitations, understanding of which is important for a successful implementation of dose painting. Proof-of-principle studies demonstrated technical and clinical feasibility of dose escalating dose-painting in solid tumors [2-5] and a number of randomized phase II-III clinical trials are on their way [6-9] aimed at improving disease control and survival. Although the tumor is the primary target volume for dose painting, unavoidably irradiated normal organs and tissues may present another target volumes. Healthy tissue subvolumes of higher importance for their function or of higher radiosensitivity (detected by biologic imaging) may need dose de-escalating dose-painting. Planning studies demonstrated possibility of this approach [10]. However, such clinical trials have not yet been conducted.

References

Automated treatment planning – from theory to practice

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Usually, treatment plans are generated by dosimetrists in a trial-and-error process. Plan quality may then be affected by the dosimetrist’s planning skills and experience, and by available planning time. Recently, several systems have been proposed for planning automation, including Erasmus-iCycle/Monaco, with Erasmus-iCycle our in-house developed system for fully automated multi-criterial plan generation [1-2], and Monaco, our clinical TPS (Elekta AB, Stockholm, Sweden). Erasmus-iCycle generates a Pareto-optimal plan with clinically favourable trade-offs between all treatment objectives, while Monaco is used to convert the Erasmus-iCycle plan into a clinically deliverable plan. The quality of Erasmus-iCycle/Monaco plans is equal, or superior to the quality of manually generated plans [3-6]. The system is now in routine use for VMAT plan generation for prostate cancer, head-and-neck cancer, cervical cancer (plan-of-the-day adaptive therapy), and advanced lung cancer. The system is clinically used since 2012. In this presentation aspects of practical implementation of automated planning will be discussed with an accent on challenges for converting scientific success into an application for routine practice.

Quality control of protocol for drinking water before treatment, for patient receiving radiation therapy to prostate. Test of volume, dose and execution of constraints for bladder(RTOG 0415).

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**Background:** The volume of pelvic organs (such as bladder and rectum) can change significantly at time of RT. To reduce the potential toxicity to the bladder and volume changes at time of RT for prostate cancer our department adopted a drinking protocol for all patients who are undergoing RT (the protocol is for CT-simulation and prior to each RT fraction). According to our protocol, 30 minutes before CT-simulation/treatment the patients are asked to empty their bladder and then drink 4 cups of water (about 200 ml) and not go to the toilet until after CT-simulation/treatment. The aim of the study is to determine whether the bladder volume and dose is the same at time of CT-simulation and RT what are the clinical factors that might influence differences in the bladder volume (waiting time, disease stage, RT dose, etc) on change, information and existence.

**Methods:** A total of 115 CBCT scans of 13 patients send to the Monaco planning system (by Elekta) and bladder was contours in each of the CBCT. Afterwards, an original treatment plan was applied to them and dose for bladder was re-calculated. In addition, we extracted demographic data from medical records, (time of treatment, awaiting time for treatment, age, Glison stage etc.) We performed a correlation and regression test between the demographic data and the calculated data (change in volume, percentage of change, and adherence to the constrains (per RTOG 0415)).

**Results:** An average waiting time for treatment is 52 min [range 9 to 158 min,]. Correlation between waiting time with change in bladder volume and percentage is medium straight (r=0.48, p<0.001 by regression test). Correlation after splitting waiting time to the groups (0-30, 30-45, 45-70, >70 min) is strong (r=0.99, p<0.001). For the same groups constrained failed is 26.5%, 21.6%, 7.7%, 7.5% (average) respectively.

**Conclusions:** There is a direct and strong relationship between waiting time to the change in the bladder volume. This has significant implications on the dose to the bladder. When radiation therapy is performed after 30 minutes of waiting (as indicated in the protocol) adherence to the constrains are improving. All this highlights the importance of taking into account factors (such as waiting time) that are not commonly thought of.
Surface Guided Radiation Therapy as replacement of the Online Treatment Monitor for monitoring intrafraction motion in voluntary Deep Inspiration Breath Hold for left-sided breast cancer patients.

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**Purpose/objective:** Evaluation of AlignRT, a Surface Guided Radiotherapy system of VisionRT, for intrafraction monitoring of left-sided breast patients being treated with voluntary deep inspiration breath hold (DIBH). The results were compared with the Online Treatment Monitor (OTM) implemented in Theraview NT (Cablon Medical), which we clinically used in the past years.

**Methods and Materials:** For this study 15 left-sided breast cancer patients were included after receiving written informed consent. All patients were treated with DIBH and were monitored during treatment both with AlignRT and the OTM.

**Results:** In total, data of 452 treatment beams were evaluated. Variations in the 3D patient surface map as observed with AlignRT were converted to 2D projections as used by the OTM. The observed differences between both systems were 1 mm ± 1 mm (1 SD) on average. For 5% of the treatment beams differences of more than 4 mm were observed between both systems. In the AlignRT system, the observed intrafraction variations in DIBH are instantaneously displayed using deltas. In contrast, in the OTM system quantitative information is lacking; instead the RTT’s have to visually monitor variations in the patient’s chest wall on the OTM. Additionally, while monitoring of small (boost) treatment fields and hybrid IMRT fields is not possible with the OTM due to lack of anatomical information, this restriction does not apply for AlignRT.

**Conclusion:** For intrafraction monitoring of breast patients treated with DIBH, AlignRT and the OTM showed a good agreement. Based on these results, since May 2018, we now solely use AlignRT for this purpose.
Percussion Assisted RadioTherapy (PART): Daily use of a ventilation system to suppress respiratory motion during RT Treatment.

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PART consists in assisting the patient with a modified percussive ventilation device to maintain breath in a state of almost full inspiration long enough to deliver complex RT treatments. It has been tested in our department for two first patients in a pilot study to assess the feasibility of the technic.

We are now doing a phase II study to evaluate the benefit of PART for lung or breast cancer radiotherapy. We also treat mediastinum lymphomas with this technic.

The purpose of this presentation is not to give results of the study, but to describe the evolution of the implementation of this completely innovative technic on a daily practice. Commercial device instead of prototype, organisation of the workflow, daily realisation of the treatment will be shown from the RTT point of view. Practical aspects such as material, duration of the sessions, integration in the agenda and collaboration with other health professionals will be presented in a very pragmatic presentation.
**Introduction:** An eye sparing treatment modality for uveal melanoma is radiation. Stereotactic radiation therapy makes it possible to irradiate the tumor with a high dose and simultaneously reduce the dose in surrounding tissues. This article describes the specific workflow of stereotactic radiation therapy for uveal melanoma patients treated on the Cyberknife. The feasibility of this technique within the radiation therapy department is considered. Also, preliminary results of the treatment are discussed.

**Methods:** 25 patients were treated with stereotactic radiation therapy on the Cyberknife in 5 fractions of 10 Gy, prescribed to the 80% isodose line. Multiplan version 5.3.0 was used for contouring and planning. Delineation of the gross tumor volume (GTV) and critical structures was done based on the CT scan. The planning target volume (PTV) was constructed by adding a 3 dimensional margin of 2mm to the GTV. Planning constraints consisted of: PTV coverage ≥ 98%, n. opticus dmax 20 Gy, gl. lacrimalis mean dose < 25 Gy, maximum of 25% of corpus ciliare > 12.5 Gy, brain any point < 10 Gy. A maximum treatment time of 15 to 20 minutes was pursued. The maximum time between the CT scan and the start of treatment was 1 week. Reproduction of the CT position was obtained by the use of the double-shell-positioning-system with a camera above the affected eye and a blinking red light above the non-affected eye. Intrafractional position variation of the head was online corrected through table shift and robotic adjustments as a result of orthogonal kV-images. The eye position was continuously monitored by comparing the camera feed to the recorded eye contours from the CT-scan. The treatment was interrupted when eye contours didn’t match the recorded eye contours.

**Results:** requirements of the different aspects of the workflow were satisfied. Patients were able to undergo the proposed treatment. Treatment time was feasible for an optimal planning and for the patient. Treatment plan characteristics were overviewed and preliminary results of local control and toxicity (visual acuity, glaucoma, cataract, optical neuropathy, retinopathy) were discussed. Until now, no enucleations have been done.

**Conclusion:** stereotactic radiation therapy for uveal melanoma patients on the Cyberknife is a feasible way of treatment. For clinical conclusions about local control and toxicity, more extensive investigation and a longer follow-up period are necessary.
Online-adaptive SRT for abdominopelvic lymphnode oligometastases

Wilhelm den Toom

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**Introduction:** Stereotactic Body Radiation Therapy (SBRT) shows promising results in the treatment of recurrent lymph node cancer. An important challenge for the treatment of these tumors is the day to day variation in the position of internal organs such as the bowel. Online adaptive SBRT (OA-SBRT) is a novel concept based on an active feedback that integrates updated data from imaging acquired during the treatment course to modify plans, in order to improve tumor coverage and minimize toxicity.

**Methods:** Patients are treated with a fractionation scheme of 5 times 9 Gy prescribed to the 90% isodose line. The treatment is performed on a Cyberknife M6 with a robotic table. As the tumors are stationary compared to the spine, Spine Tracking is used to track the target. A treatment plan (plan A) is generated on a conventional planning CT. In addition to this plan, two extra treatment plans are generated (plan B and C). In one the target coverage is increased by prescribing to a lower isodose. In the other, the organ at risk (OAR) delineation based on a diagnostic CT that has been made prior to radiotherapy is used. This gives a library of three different possible treatment plans. Prior to every fraction, a CT-scan is acquired in treatment position using the in-room CT. The robotic couch moves to its treatment position, so that the patient can remain on the treatment table. The OAR on the daily CT are being contoured using a non-rigid propagation of the structure set from the planning CT in MIM software. The target GTV and PTV and the three dose distributions from the library plans are rigidly transferred to the daily CT using a spine match. Three different windows sets are displayed in MIM to aid the choice of the best plan from the library. A decision tree is used to guide the plan choice. The plan that shows the highest PTV coverage and still meets the OAR constraints, is used for treatment. If there is no decision 15 minutes after CT acquisition, our default plan A is selected for treatment.

**Results:** Two patients have been treated using daily CT scans to show the day to day variation of the OAR positions. All ten fractions were delivered using MIM as a tool to determine the best plan of the day. No more than fifteen minutes were needed between the acquisition of the CT scan and the choice of the plan. Total treatment time per fraction has not exceeded 60 minutes. Effect of this approach is under evaluation.

**Conclusion:** The procedure we developed to introduce OA-SBRT to our Cyberknife has been successfully introduced into the clinic. More patients are needed to further fine-tune the plan of the day procedure possibly by changing the plans in the library.
The Development of advanced clinical practice roles in Radiotherapy

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In the year 2000 the UK Department of Health (DoH) announced the introduction of a non-medical consultant role to help; address the retention of skilled staff in the health service, offer a career progression opportunity and help tackle the chronic shortage of doctors. Eighteen years later this concept has grown to establish around 25 Consultant Radiographers in radiotherapy across the UK with more than three times that number working in radiology departments as well as a host of roles across the various allied health professional and nursing groups.

The development of these roles has taken a varied and often inconsistent route, particularly in radiotherapy where role development has often arisen from a local service need within a particular cancer site. In response to this evolving non-medical workforce, the DoH has been proactive in establishing a national framework for the educational and clinical standards of those working at advanced clinical practice level (HEE, 2017). In relation to cancer treatment, it is hoped that this drive, combined with the realization that our ageing population with increasing expectations of care, will be well served by this new model of health care provision (CRUK, 2017).

This talk will describe the main developments in role creation for Consultant Radiographer roles in radiotherapy and the training requirements for them. It will also provide local examples of how one such role within breast radiotherapy fulfils the 4 core domains of practice as set out by the DoH, along with the impact the role provides:

1. Expert clinical practice.
2. Professional leadership and consultancy.
3. Education, training and development.
4. Practice and service development, research and evaluation

References

On treatment review/support by radiographers- The Southend experience

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The review of patients on treatment has developed throughout the years to provide reflexive support to various patient groups to meet service delivery and patient needs. With the exception of one advanced practitioner who covers two patient groups and prescribes medication, the other members of staff all work in either pre-treatment or treatment delivery alongside their patient review roles. This maintains technical skills and knowledge to complement the patient review skills.

Staff undertaking patient reviews have all completed in-house competencies and the majority have gained MSc modules in relevant specialist topics for example, advanced communication.

Some site specific radiographers review patients as part of a multidisciplinary team including clinical nurse specialists, dietician and speech therapists.

Patients groups include breast, lung, brain, gynae, urology and ENT.

Currently we are working towards the on treatment review of palliative patients.

Each site has developed different support networks, depending on need but all sites have radiographers attending new outpatient clinics and review patients on treatment.

Different specialisms include:

Urology- Catheterisation, pre-treatment information sessions (VERT), consent, post treatment follow up review and Trial.

Breast- Patient consent, Holistic Need Assessment.

Lung-SABR pathway from MDT through to follow up.

We have an independent prescriber who prescribes medication to manage side effects of treatment.

All sites are covered by specialist oncologists, or an on call Doctor who are not necessarily in the department but can be contacted for advice.

This way of working has proved to be beneficial for patients, oncologists, the radiotherapy department and radiographers.
Personalized care by RTTs

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The vision of NKI-AVL is to provide tailored care during and after the radiation treatment, to improve the quality of the service provided and efficiently deploying personnel with the emphasis on workload and work pleasure. With the physicians experiencing an increase in workload and based only once a week in NKI-AVL Hoofddorp (a satellite), they are unable to provide tailored care and continuity. The physicians also find that most consultations are not medically necessary. Therefor a pilot was set up to investigate the possibilities of shared care by a physician and a radiation therapy technologist.

The aim of the pilot Ondersteuning Op Maat (Personalized Care) is to investigate the effects of having a radiation therapy technologist as a case manager during the radiation treatment, for breast patients, who is available whenever the patient has the need to be seen and/or heard. Other objectives of the pilot are to register radiation toxicity during and after the radiation treatment and to determine whether the physician can utilize his time more efficiently and effectively.

Prior to the start of the pilot, interviews were conducted and a questionnaire was distributed amongst former breast cancer patients who have been treated in NKI-AVL Hoofddorp to evaluate patients’ view of the care provided by their physician during and after the radiation treatment. Whilst all the respondents had scheduled appointments with their physician, only 35% of the respondents believed the physician to be their case manager. 75% of the respondents would have liked to have had a case manager. The questionnaire also investigated how the respondents view the possibility of a radiation therapy technologist being their case manager instead of a medical specialist (i.e. physician or physician assistant). The results show that the majority of the respondents are comfortable ( (strongly) agree (64%) or neither agree nor disagree (16%)) with a radiation therapy technologist as their case manager. The results also show that the majority of the respondents experienced a lack in uniformity, continuity and follow-up care by their physician.

The pilot patients were also asked to complete the same questionnaire to determine whether or not the personalized care is indeed an improvement. Although all data is still to be analyzed, patients have reported that they feel well informed, cared for and heard. We hope to present the results of the pilot in this presentation.

So far the physicians are positive about the role of the radiation therapy technologist as case manager. Only when medically necessary, on request of the case manager and/or the patient, is an appointment scheduled with the physician. This is efficient and physician feels better informed about the patients’ wellbeing.
Custom care for palliative patients; Care, efficiency and research combined by a dedicated team

Marcella Cramer

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**Introduction:** Since September 7, 2015, the Department of Radiotherapy of the Erasmus MC Cancer Institute, Daniel Den Hoed, has started with the Palliative Radiotherapy Clinic. There was a need to adjust the process of the palliative patient and more attention for the palliative patient. There was only room for 1 patient per day. Given the size of this patient group, this was insufficient. After a work visit in Toronto by 2 radiotherapists and a RTT, the department Radiotherapy decided to set up a Palliative Clinic in which all sub-acute palliative patients are central and a dedicated team is present.

**Purpose:** Due to the presence of a dedicated multidisciplinary team, more attention is paid to the process surrounding the palliative patient. Eventually, all sub-acute palliative patients are treated in this way. In addition, the specialized palliative RTT’s are involved in the research.

**Result:** Four days a week, four patients a day are seen on the palliative clinic and, if possible, irradiated the same day. The specialized RTT is the leading person of the day. Because of the dedicated team of a Radiotherapist, an AIOS, 2 RTT’s and a nurse, the entire process is aimed at giving the patient the full attention. The research provides a lot of data, and this is used for two study that are going to be published. One of the results is that survival after radiotherapy varies by primary tumor, overall condition and progression.

**Conclusion and discussion:** To treat or not to treat? Should palliative patients always be treated? Is not irradiating an option? Is the patient’s wish important for treatment? 1x8, 5x4 or 10x3?
Treatment planning for proton therapy – a challenge for the whole team

Ingrid Kristensen,

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The first Scandinavian Proton Centre; Skandionkliniken, started to treat patients in August 2015. It is a facility owned by the seven regions with university hospitals. Patients are referred to Skandionkliniken through these hospitals utilising “distributed competence” [1]. The patients are prepared for treatment at their “home centre”; immobilization, CT-scanning and treatment planning are be performed at the university hospital. All treatment plans are reviewed at joint teleconference meetings [2] prior to the treatment start. The patient and any individual immobilization device are be sent to Skandionkliniken for treatment. Skandionkliniken is a “spot scanning only” facility.

In order to prepare for the clinical start and to train a group of medical physicists, dosimetrists and radiation oncologists, working in different centres and with different treatment planning systems, in proton treatment planning we started the Proton School in January 2012 [3,4]. We have had a couple one day face-to-face meetings with lectures and workshops, two four day courses and biweekly teleconferences. The purpose with the face-to-face meetings was to give everyone the same basic knowledge in proton treatment and planning. It also gave the students a chance to get to know each other, which eases the discussions during the teleconferences. Prior to the bi-weekly teleconferences the centres were expected to create treatment plans for selected patient cases in the proton TPS. Also, as preparation for these sessions relevant scientific articles were distributed for discussions in the group. During the teleconferences, the desktop of the proton TPS was shared for everyone to view and/or demonstrate. The teleconferences consist mainly of discussions about the suggested plan solutions, patient immobilization, margins, dose distributions and plan robustness. The four-day courses were mainly directed to dosimetrists and physicists and jointly arranged with Varian and with clinical experts to increase the skills in treatment planning for protons. Many of the participants of the proton school, has also attended other courses, like the PSI winter school, ESTROs ion and proton course as well as PTCOG meetings and courses. We have continued with the Proton School even after the clinical start as there still are issues, difficulties and new ticks to discuss and learn.

Still we are faced with challenges; which patient groups do we treat in general, which do we start with? Thinking protons instead of photons has been the greatest challenge for the group as a whole. How do we create the best plan? Comparing proton plans to photon plans is also a part of both learning and the clinical routine [5]. Discussions about target volumes has been frequent, as the use of them. Delineation is a major issue, not only for CTV/PTV but for other structures the protons might interact with in its beam path, as well as optimization structures to provide the best plan and thereby “steer” the spots.

The school has worked out well with active participation both in planning and discussing, helping each other in gaining experience in a field where we were novices.

An important step is now to use and produce standardized treatment protocols, a treatment planning manual and other types of common instructions and check lists so that all seven centres create plans in the same technical manner.

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Robustness and organ sparing potential of intensity modulated proton therapy for lung cancer

Hans Paul van der Laan (HP), Melissa Anakotta (RM), Erik Korevaar (EW), Margriet Dieters (M), Fred Ubbels (JF), Hans Langendijk (JA), Stephen Both (S), Kristel Muijs (CT), Antje Knopf (AC)

University of Groningen, University Medical Center Groningen, Department of Radiation Oncology, Groningen, The Netherlands

Background and aim: Proton therapy is more sensitive (less robust) to geometrical and density uncertainties than photon therapy. Especially in lung cancer, where breathing motion demonstrated to increase these uncertainties, it is essential to thoroughly verify the robustness of proton therapy delivery procedures. Pencil-beam scanned intensity modulated proton therapy (IMPT) has the potential to reduce the dose to heart and lungs. Therefore, the aim of this study was to test the robustness of IMPT on weekly 4D repeat CT scans and to compare the robustness and organ sparing capabilities of IMPT to that obtained with volumetric arc photon therapy (VMAT).

Method: Seventeen lung cancer patients, scheduled for curative chemoradiation, underwent a 4D planning-CT (pCT\(_0\)) and 5 weekly 4D repeat-CT scans. 4D-average scans were used for this study. CTVs were delineated on pCT\(_0\) and on repeat-CT scans. For VMAT only, a PTV was created. VMAT plans on pCT\(_0\) were optimised for adequate PTV coverage (D\(_{98} \geq 57\) Gy), spinal cord dose (D\(_{max} < 50\)Gy), and minimal heart and lung dose. IMPT plans were optimised with similar objectives using CTV-based robust planning and reviewed by a radiation oncologist. Finally, VMAT and IMPT plans were reconstructed on each weekly repeat-CT including setup (2 mm) and range (3\%) error scenarios. Accumulated dose distributions were obtained by deforming and summing the weekly reconstructed dose distribution back to the reference pCT\(_0\) simulating 5 fractions per repeat-CT. In case of inadequate summed CTV coverage on pCT\(_0\), the effect of treatment plan adaptation on one or more repeat CTs was simulated.

Results: The summed doses from the weekly repeat-CTs on pCT\(_0\) resulted in adequate CTV coverage for all 17 VMAT plans and for 15 out of 17 IMPT plans (Table). In 2 patients, IMPT treatment plan adaptation was required. Adapted plans in the first week (one patient) and in the first and second week (one patient) then also resulted in adequate CTV coverage in the accumulated plan. The summed CTV D\(_{98}\) on pCT\(_0\) was > 57 Gy in all plans and patients. On average the D\(_{98}\) was 58.2 Gy with VMAT and 57.8 Gy with IMPT. The spinal cord tolerance dose was exceeded in 2 patients by the VMAT plans only (with 0.5 Gy and 1.0 Gy, respectively). The average mean heart dose with VMAT was 5.3 Gy (SD: 6.6 Gy; range: 0.2 – 24.8 Gy) and with IMPT 1.0 Gy (SD: 1.2; range: 0.0 – 4.3 Gy; p < 0.007). The average mean lung dose with VMAT was 10.5 Gy (SD: 2.9 Gy; range: 6.0 – 17.7 Gy) and with IMPT 7.2 Gy (SD: 2.6; range: 2.8 – 14.5 Gy; p < 0.001).

Conclusions: Robust planned IMPT for lung cancer, with optional weekly plan adaptation, resulted in adequate target coverage similar to that of PTV-planned VMAT. Inter-fractional variation for breathing and anatomy were considered in this analysis under various error scenarios. With IMPT, no spinal cord dose thresholds were violated and significant and clinically relevant dose reductions were obtained for the heart and lungs compared to VMAT.

Table
MHD = mean heart dose
MLD = mean lung dose

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<td>7.1</td>
<td>-2.2</td>
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<td>7.5</td>
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<tr>
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</table>

Voxel-wise average dose

Voxel-wise highest spinal cord dose, summed on pCT0 -51 Gy in VMAT plan only

Adequate CTV coverage summed on pCT0 obtained with simulated IMPT plan adaptation in week 1

Adequate CTV coverage summed on pCT0 obtained with simulated IMPT plan adaptation in weeks 1 and 2

Voxel-wise worst CTV coverage, summed on pCT0; objective CTV D98 ≥ 57 Gy fulfilled in all cases.

CTVs were delineated on each repeat CT scan by a physician.

pCT0 = planning CT
CTV = clinical target volume
D98 = dose in 98% of CTV
D98 objective ≥ 95% (57 Gy)
Spinal cord objective ≤ 50 Gy