Paul Scherrer Institut
Center for Proton Therapy
Newsletter #29_09/2023

Dear Reader,

Welcome to the second 2023 edition of our SpotON+ Newsletter. With this issue we are switching to a professional newsletter tool which will hopefully improve your reading experience & interest.

I am pleased to inform you that the first Swiss patient was enrolled in the PROTECT trial [press release]. The oesophageal cancer patient was randomized in the proton arm. Currently, three centers (Aarhus, Leuven and USZ/PSI) are actively accruing patients, and more should be activated in the not too distant future.

I am also happy to present in this edition my team's report on the analysis of NTCPs for salivary gland tumors treated with photons and protons utilizing the Dutch model-based approach (MBA). The MBA has been key in selecting head and neck cancer patients in the Netherlands and an extension of this model to other cancers is foreseen in this country. If anything, our analysis has shown that there is no one-size-fits-all strategy for proton therapy cancer management and that radiotherapy should be individualized in the framework of personalized medicine.

Maradia et al. have published an interesting paper in Nature Physics on higher transmission, reduced treatment times, and ultimately potential improved patient outcomes of patients treated with proton therapy utilizing a momentum cooling technique.

Finally, Smolders et al. incorporated patient-specific information into convolutional neural networks to improve segmentation accuracy in patients treated with an "ADAPT" paradigm.

That being said, I hope that these topics are of interest to you and I stay tuned for the next edition in three months’ time

Sincerely,
Prof. Damien C. Weber,
Chairman Center for Proton Therapy,
Paul Scherrer Institute

Radio-Oncology News

Clinical outcome after pencil beam scanning proton therapy and dysphagia/xerostomia NTCP calculations of proton and photon radiotherapy delivered to patients with cancer of the major salivary glands

Background

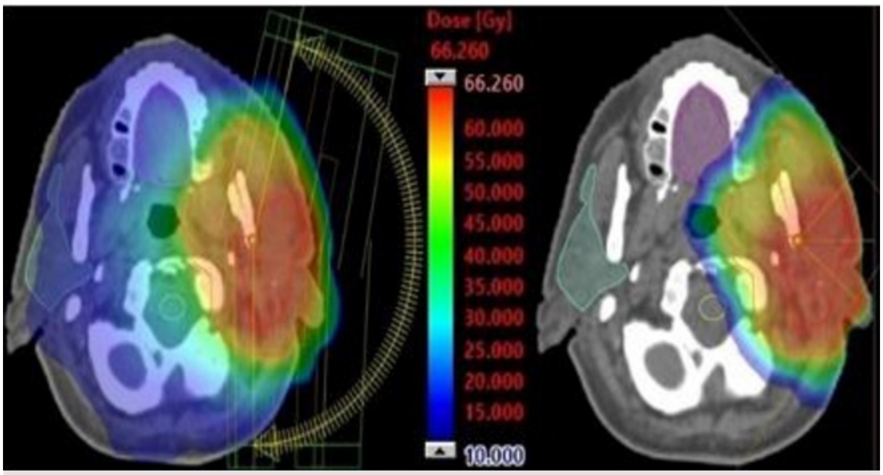
Major salivary gland tumors (SGT) are a heterogenous group of tumors with surgical resection being the treatment of choice. Adjuvant radiotherapy is recommended in patients with advanced or high-grade tumors. Proton therapy (PT) may be of benefit due to the more favorable dose distribution and sparing of organs at risk close to the tumor. Normal tissue complication probability (NTCP) models can help to guide treatment planning in order to minimize the risk of long-term toxicities. the purpose of this study is to report the oncological outcome, observed toxicities and NTCP calculation for pencil beam scanning (PBS) PT delivered to SGT patients.

Methods and materials

We retrospectively reviewed 26 SGT patients treated with PBSPT (median dose, 67.5 GY(RBE)) between 2005 and 2020 at our institute. Most patients had their tumor in the parotid gland (n=20) and main histological type was adenoid cystic carcinoma (n=13). Toxicities were recorded according to CTCAEv4.1. Overall survival (OS), local control (LC), locoregional control (LRC) and distant control (DC) were estimated. For all patients, a photon plan was re-calculated with volumetric arc therapy (VMAT) using 2 (n=23; 88.5%) to 3 (n=3; 11.5%) arcs and 6 MV photon beam data of a Varian True Beam LINAC in order to assess the photon/proton NTCP according the Duch model-based approach (MBA) for H&N cancer.

Results

With a median follow-up time of 46 months (range, 3-118), 5 (19%), 2 (8%), 3 (12%) and 2 (8%) patients presented after PT with distant, local, locoregional failures and death, respectively. The estimated 4 year OS, LC, LCR, and DC were 90%, 90%, 87% and 77%, respectively. Grade 3 late toxicity was observed in 2 (8%) patients. The estimated 4 year late high-grade (≥3) toxicity-free survival was 78.4%. The calculated mean risks after PBSPT and VMAT plans in our cohort for developing Grade 2 xerostomia were 23.4% (range, 19.6-28.7) vs 27.2% (range, 21.9-40.0) resulting in a difference of 3.8%. For Grade 3 xerostomia the corresponding values were 4.7% (range, 2.7-7.5) vs 7.6% (range, 3.8-12.6) resulting in ΔNTCP 2.9%. Accordingly, the calculated mean difference of NTCP-values after PBST and VMAT plans for developing Grade 2 and 3 dysphagia were 8.6% and 1.9%. Not using an upfront model-based approach to select patients for PT, only 40% of our patients met the Dutch eligibility cirteria.



Comparative planning showing a VMAT photon plan (left) and a PBSPT plan (right) of a patient with a parotid tumor. Photon and proton plans were normalized that 95% of the prescribed dose covered 98% of the PTV. Dose range shown 10-66 Gy(RBE)

Conclusions

Our data suggest excellent oncological outcome and low late toxicity rates for patients with SGT treated with PBSPT. NTCP calculation showed a substantial risk reduction for Grade 2 or 3 xerostomia and dysphagia in some SGT patients, while for others no clear benefit was seen with protons, suggesting that comparative planning should be performed routinely for these patients.

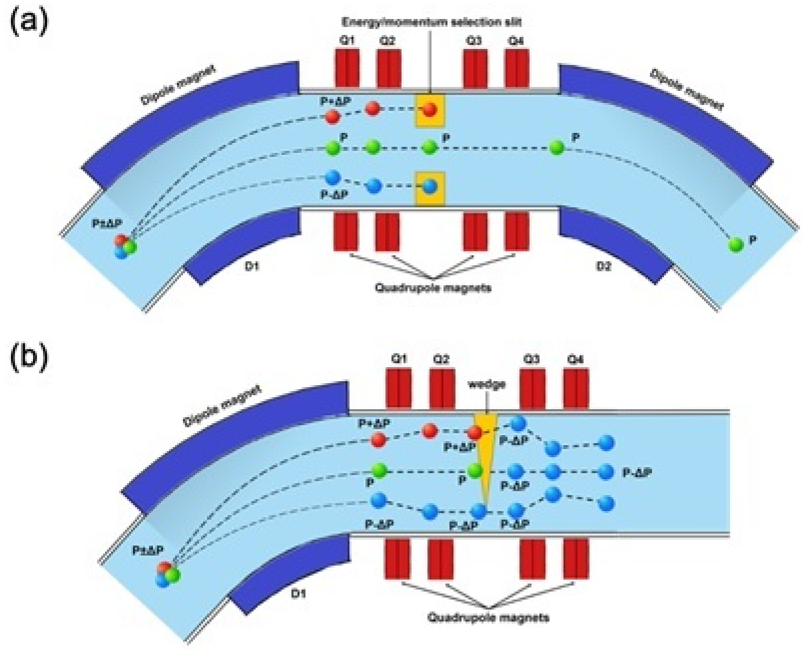
This work has recently been published (Walser and Bachmann et al. 2023)

Physic News

Proton Therapy Gets a Chill Pill: How Momentum Cooling Can Beat Cancer

In our recent study published in Nature Physics (Maradia et al. 2023), we introduce an innovative approach called "momentum cooling" that significantly enhances the transmission of low-energy proton beams in cyclotron-based proton therapy facilities. this breakthrough holds immense potential for improving cancer therapy by enabling higher dose rates, treating moving tumors within a single breath-hold, reducing treatment time, increasing patient throughput, and potentially lowering the cost of the treatment facility.

The proposed momentum colling technique introduces a wedge-based energy selection system (ESS) that replaces conventional slits. By carefully designing the geometry of the wedge, particles with different momenta experience varying thicknesses of the material as they pass through, thereby equalizing the momentum spread of the beam without substantial losses. this leads to improved transmission and the potential for higher dose rates.



(a) The conventional layout of an ESS features a cross-sectional bending plane with an energy/momentum selection slit
(b) The new layout of ESS featuring a momentum cooling which is achieved with the insertion of a wedge.

In a demonstration on an eye treatment beamline, we successfully tested momentum cooling using a polyethylene wedge. By transporting the beam with a momentum spread of ±1.3% up to the wedge, we achieved a remarkable reduction in momentum spread to less than ±0.3%. Consequently, transmission increased to 0.5%, nearly double the original transmission achieved with slits. This corresponds to a significant reduction in treatment time, potentially halving the time required for effective therapy delivery, being able to treat more patients and increasing patient comfort.

This study also explores the design of a compact proton therapy gantry incorporating momentum cooling capabilities. Utilizing advanced beam optics and collimation techniques, we project a substantial increase in transmission for a range of beam energies. Monte Carlo simulations indicate the possibility of achieving almost 100 times higher transmission for a 70 MeV beam compared to conventional facilities.

Furthermore, the ability to achieve ultrahigh dose rates using momentum cooling holds promise for exploring the benefits of FLASH irradiations, which have shown potential for improved normal tissue sparing and tumor control. Additionally, the technique address challenges related to treating mobile tumors affected by breathing motion, while also reducing investment costs associated with facility shielding requirements.

In summary, the momentum cooling technique presents a groundbreaking advancement in proton therapy, providing a path towards higher transmission, reduced treatment times, and improved patient outcomes. This innovation holds great promise for enhancing cancer therapy and offers exciting possibilities for exploring new avenues in particle therapy research and accelerator physics.

Medical-Physics News

Patient-specific neural networks for contour propagation in online adaptive radiotherapy

Background

Anatomical changes as well as set-up uncertainty cause the delivered radiotherapy dose to deviate from the planned dose. This is especially important for proton therapy, as the depth of the Bragg peak depends on the tissue densities along the beam path. Conventional approaches address these uncertainties by introducing margins around the clinical target volume (CTV) or through robust optimization. Unfortunately, this inevitably introduces additional radiation dose to the neighbouring healthy tissue. With online adaptive radiotherapy, a 3D image is acquired each day shortly before delivery and the treatment is reoptimized using this information. This image reduces both the set-up and anatomical uncertainty, alleviating the need for robustness and, hence, enhancing the sparing of healthy tissue.

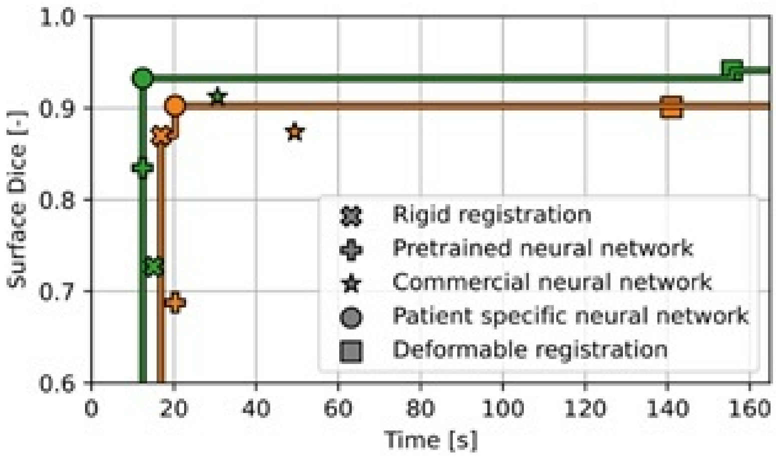
Fast and accurate contouring of daily 3D images is a prerequisite for online adaptive radiotherapy, but the time constraints impede full manual contouring. Current automatic techniques rely either on contour propagation with registration or deep learning (DL) based segmentation with convolutional neural networks (CNNs). On the one hand, registration lacks general knowledge about the appearance of organs and traditional methods are slow. On the other hand, CNNs lack patient-specific details and do not leverage the known contours on the planning computed tomography (CT). This works aims to incorporate patient-specific information into CNNs to improve their segmentation accuracy..

Approach

For 5 patients with lung cancer and 5 patients with head and neck cancer, patient-specific information was incorporated into CNNs by retraining them solely on the planning CT. The models were used to retrospectively contour the 4-9 repeated CTs of each patient and the resulting contours were compared to manually delineated organs-at-risk and CTV. The contour quality was further compared to four other autocontouring methods, namely an in-house pretrained CNN, a commercial DL contouring tool and rigid and deformable registration.

Results

Patient-specific fine-tuning of CNNs significantly improves contour accuracy compared to standard CNNs. The method further outperforms rigid registration and a commercial DL segmentation software and yields similar contour quality as deformable registration (DIR). It is additionally 7–10 times faster than DIR.



Mean runtime versus mean OAR surface dice for the different contouring methods and datasets. The markers correspond to the individual methods and the solid line depicts the Pareto optimal front. Green: lung cancer patients; Orange: head and neck cancer patients.

Conclusion

Patient-specific CNNs are a fast and accurate contouring technique, enhancing the benefits of adaptive radiotherapy. Fine-tuning further allows target volume segmentation, which is not yet feasible with general CNNs.

This work has recently been published (Smolders et al. 2023)

Imprint

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