RAPTOR - LOOP BASIC 13th-17th December 2021 VIRTUAL EVENT

Monday 13 December 2021 - Friday 17 December 2021

Book of Abstracts

Contents

65

Welcome

Corresponding Author: francesca.albertini@psi.ch

66

History of PT

Corresponding Author: parodi.katia@gmail.com

History of PARTICLE THERAPY
75 years after the initial proposition of R.R.Wilson to use protons and even energetic carbon ions for tumour treatment [1], ion beam therapy is still considered an emerging form of advanced external beam radiation therapy, which can offer considerable advantages in comparison to the widely used X-rays. In particular, the physical properties of swift ions in matter may enable a highly conformal deposition of dose (i.e., energy per unit mass) in a well localized maximum, so called Bragg peak, while considerably reducing the burden to surrounding healthy tissue. Moreover, especially for ions heavier than protons, the enhanced ionization density toward the end of the ion paths can cause more efficient tumour cell killing in comparison to conventionally used sparsely ionizing radiation.

This talk will give an historical perspective on the developments of proton and light ion therapy, from the pioneering experience at research institutions able to accelerate heavy charge particles up to suitable energies for the treatment of deep-seated tumors, through the first hospital based facilities established in the 1990s, up to the still ongoing exponential growth of state-of-the-art dedicated facilities.

1. R.R. Wilson, Radiology 47 (1946) 48

Summary:

67

RT / PT basics - clinical perspective

Corresponding Author: damien.weber@psi.ch

68

Current clinical workflow in PT

69

Clinical needs in adaptive therapy

Clinical needs in adaptive therapy
This presentation will provide an overview on the evolution of photon radiotherapy from a clinical perspective. Modern technology permits highly precise dose shaping with a corresponding improvement of normal tissue complications. It also enables new approaches such as extremely hypofractionated treatment courses. This higher precision of the therapy also requires higher precision in imaging and positioning, as smaller margins and a lower number of fractions reduces treatment robustness. Adaptive radiotherapy plays an increasingly central role in this process –the available in-room imaging technology permits a feedback loop over the course of therapy to adapt highly conformal treatment plans to a changing anatomy.

70

RT basics - physics perspective

Radiation is being used for cancer therapy for well over 100 years and due to this long history it is sometimes claimed, it is an old fashioned and outdated form of medicine. Radiation therapy is, however, still around and more vital than ever. The main reason is probably, that radiotherapy is based on physical principles and consequently has always been benefitting from technological progress. Radiation therapy is currently the only treatment modality, which allows for a precise calibration of the treatment device, a mathematical description of the dose to the patient in three dimensions, the possibility to verify that dose in phantoms prior to delivery and in addition to predict outcome based on biophysical models. The mathematical formulation of the whole treatment process and prediction of probabilities for a certain clinical outcome make it unique and offer many possibilities for further improvement. Starting already with the development of Cobalt units, the concept of dose conformation to the target was pursued, which again is based on radiobiological concepts. This line was followed by the introduction of high energy X-rays and later on particle beams, which further improve the dose conformation and today the problem of three-dimensional dose conformation can considered to be solved technically. The next step –following a physical slang –is now to achieve conformality in the 4th dimension, meaning to conform the dose to the target not only in space, but in time. This is done by treatment adaption and makes use of recent developments in radiological imaging technology. For the first time in radiotherapy, it is now possible to use magnetic resonance imaging to continuously visualize the target region, while the treatment is being delivered. This is a dramatic shift of paradigms for radiotherapy and will certainly have an enormous impact on the way radiotherapy is delivered. In addition, the advances in understanding the interactions of radiation with the human body, e.g. with the immune system and based on the specific genome of a tumor, open further options to optimize the use of radiotherapy and arrive with a personalized treatment. In this talk the most important physics principles and developments will be addressed and the connections to the radiobiological and clinical aspects will be outlined.

71

PT Basics –Physics Perspective

Corresponding Author: wolfgang.enghardt@oncoray.de

Particle Therapy Basics –Physics Perspective
The ballistic and radiobiological advantages of proton and light ion beams for external beam therapy, in particular the finite range and the elevated linear energy transfer, respectively, rest upon the Coulomb interaction between the projectiles and the constituents of the targets. While nuclear interactions deliver only a rather minor, but non-negligible, contribution to the dose deposition, they are of high importance for radiation protection and dedicated range measurement techniques in particle therapy. Therefore, the lecture will give an overview on electromagnetic and nuclear interactions of proton and ion beams with matter and their consequences for particle therapy technology.

72

RAPTOR - the science case

Corresponding Author: kristjan.anderle@cosylab.com

RAPTOR - the science case
There are different research venues happening within particle therapy. Some of these are very close to clinical realization, others are only in the laboratory.
This presentation will focus on what differentiates a solution from being ready to be used in the clinic in contrast to experiments.

73

Science Communication

Corresponding Author: yolanda.prezado@curie.fr

Science Communication
Effective science communication must clearly and succinctly describe the context of scientific work, its importance, and how the results differ from opinion, conjecture, or anecdotal evidence. This lecture will provide with general tips and resources to effectively communicate scientific results. Guidance on how to write a paper and successfully present your latest data at conferences will be given. Some hints on how to use some other non-traditional communications channels will be presented.

Summary:

74

Imaging for particle therapy treatment planning

Corresponding Author: christian.richter@oncoray.de

Imaging for particle therapy treatment planning

The lecture will focus on tomographic imaging for particle therapy treatment planning, with special emphasis on the prediction of the stopping power ratio S(PR) as prerequisite for accurate range calculation. This knowledge is valid for both: Treatment planning before therapy start and for plan adaptations. Special emphasis will be on the application of Dual-Energy CT for direct SPR prediction. Furthermore, the pros and cons of MRI will be covered.

75

Treatment planning basics

Corresponding Author: tony.lomax@psi.ch

76

QA basics and impact on ART

77

In-room imaging

Corresponding Author: marco.riboldi@physik.uni-muenchen.de

In-room imaging
The potential of particle therapy to precisely tailor the dose distribution around the target volume needs to account for the intrinsic sensitivity to uncertainties in dose deposition. These peculiar features motivate the use of image guided methods to consistently verify the accuracy in dose delivery. Dedicated in-room imaging methods are therefore required, in order to reduce the effects of uncertainties. The scenario is complicated by the lack of standardized layouts of treatment bunkers, which implies the relatively increased use of custom solutions. Imaging can also be applied to verify the actual delivered dose, representing a valuable opportunity to validate specific protocols and visualize the efficacy of the intended treatment. In this contribution, challenges and opportunities of in-room imaging for particle therapy are overviewed, with a clear focus on research perspectives in the implementation of adaptive treatment protocols.

Summary:

78

Concepts of synthetic imaging

Corresponding Author: bwiney@mgh.harvard.edu

Concepts of synthetic imaging
Basic reconstruction techniques for 3D medical imaging rely on pixelized measurements of a signal, including photon transmission and RF signals. The reconstruction methods convert the signals into a grayscale or color coded 3D map of the human anatomy. Historically, the reconstruction methods have used basic physics and mathematics to provide the analytically reconstructed 3D medical images. In addition to the analytic reconstruction methods, multiple methods have been proposed to map values from one image or data set to another and create a synthetic image. The recent rise of machine learning tools has provided additional methods for the reconstruction of 3D medical images. The departure from the analytic algorithms has allowed for the creation of synthetic 3D medical images in multiple contexts, including DR, CT, CBCT, MR, and PET, and for multiple purposes.

Summary:

79

PT patient perspective

Radiotherapy is proven to be an essential part of cancer treatment. Until now, the vast majority of cancer patients who were treated with radiotherapy, received X-rays and only a limited number of them, receive radiation from high-energy charged particles. This is still the case, despite the fact that Particle therapy (PT) can deliver higher radiation doses more accurate within the tumor burden, reducing unwanted effects on the surrounding healthy tissues, diminishing the adverse effects of traditional radiotherapy and providing a more efficient treatment for cancer patients. This means that, although more expensive, it can also reduce overall health costs in the long run.
However, all those considerable benefits, the number of cancer patients appointed for PT is very limited and the knowledge and solid clinical evidence is still quite scarce. In addition, the selection of patients who are accepted for PT varies among countries. There are some standard indications where all patients are offered PT, e.g. for pediatric patients, but in many the decisions are based on national or local regulations. As PT is currently more expensive than conventional radiotherapy, it is important that we have solid evidence to justify the viability of its use as well, besides the clinical benefit. One major handicap is the cost of the facilities that can generate the radiation necessary to produce PT. Consequently, the number of centers which provide this therapy is still very limited around the world.

Within this lecture we will try to bring the patient perspective forward and identify what the potential increase of the therapeutic ratio in PT use translates into patients'treatment outcomes and quality of life after treatment. In addition, we will present how access to PT results in treatment inequalities within Europe and what is the role of patient advocates in trying to alleviate them.
We will try as well, to briefly present what patients value the most, when undergoing a specific radiotherapeutic treatment. It is high relevant to provide more information on PT and their access, involving patients in medical decision-making, encouraging them to participate in decisions about their cancer treatment. Proper information about the scientific and clinical evidences on how can PT benefit patients, will empower them as co-creators of their own health.

Summary:

81

Time resolved imaging

Corresponding Author: guido.baroni@polimi.it

Time resolved imaging
In the last years, particle radiotherapy has attracted increasing interest for the treatment of moving organs, such as pancreas, liver and lung, and promising outcomes have been obtained with proton and carbon ion radiotherapy. Indeed, particle beams present favourable physical properties, allowing conforming the dose to the target while sparing surrounding healthy tissues, and offer increased radiobiological effectiveness with respect to X-ray radiotherapy. However, thoraco-abdominal tumours are subject to motion due to respiratoration, which causes target displacement and radiological path length changes, resulting in particle dose distribution variations. If not accurately accounted for, these variations can hinder treatment accuracy and efficacy. Different treatment solutions have been proposed, such as breath-holding, respiratory gating, being the optimal solution in terms of patients'compliance and technical effort, and tumour tracking, which is not yet clinically implemented in particle therapy. These treatment solutions however require accurate image-guidance techniques to plan, adapt and verify the treatment, with Computed Tomography (CT) and time-resolved 4-Dimensional (4D) modality being the current clinical standard. In this presentation, we will review the basic concept of time-resolved imaging adopted within the current clinical practice, along with novel time-resolved imaging techniques which could improve respiratory motion quantification and management in particle therapy.

Summary:

82

Advanced Treatment Planning

Advanced Treatment Planning
This lecture will acquaint the participants with various advanced treatment planning concepts. These include multi-criteria decision making in treatment planning, the use of cost functions, and the most recent developments on automated treatment planning. Furthermore, robust optimization and robust evaluation in clinical practice will be discussed, in particular focusing on the robust prescription and reporting of proton therapy plans. Finally, I will introduce online adaptative treatment planning for proton therapy and compare it with robustly optimized treatment plans.

83

Basic of biological models in Particle Therapy (PT) Treatment Planning

Corresponding Author: silvia.molinelli@cnao.it

Basic of biological models in Particle Therapy (PT) Treatment Planning
One of the advantages of light ions in radiation therapy (RT) treatments is their higher relative biological effectiveness (RBE) in creating damage to tumour cells, with respect to conventional RT photons. Treatment planning systems (TPS) must account for this increased efficacy in dose calcula-

tion. RBE depends on several factors including radiation quality, linear energy transfer (LET), tissue type, dose, endpoint [1]. How this is accounted for in TPS significantly affects the dose actually delivered to the patient [2].
Protons are clinically considered to be all and everywhere 10% more effective than photons (RBE = 1.1). This approximation is not always valid, particularly at the end-of-range LET elevation in tissues with a low α/β [3]. Newly available commercial software, providing inhomogeneous RBE calculation according to different models, renewed the discussion on the adequacy of a constant RBE and opened new possibilities on the clinical use of more complex modelling strategies. The topic is still controversial, being all long-term clinical data based on RBE = 1.1 and hardly translatable into a new language. Recent works include in the problem LET distribution and LET dependence of proton therapy efficacy and toxicity [4].
Radiobiological properties of carbon ions demand a 3D RBE modelling in tissues for clinical dose calculation and optimization. All Japanese centres adopted the same mixed-beam RBE model [5] for passive scattering and the modified microkinetic dosimetric model [6], for pencil beam scanning. Conversely, all European centres followed the German experience and implemented the local effect model version-I [7]. Each model in turn contains several parameters, fitted to reproduce in-vitro and in-vivo experimental data, which can be modified to drive the optimization in the desired direction. All models agree on the fact that carbon ions effectiveness increases in the distal part of the spread out Bragg peak (SOBP). Therefore, to obtain a homogeneous RBE-weighted dose distribution in the target, a lower physical dose should be delivered in the distal portion of the SOBP. The question is: "how much more and how much less?"and the answer strongly depends on the model used. Several groups studied dose deviations implied in the used of different RBE models to ease the comparison of clinical results between different centres [2, 8-10]. For the same nominal RBE-weighted dose value, the corresponding physical dose deviates differently along the spread-out and even more outside, in the entrance channel and lateral fall-off regions, with significant implications on clinical outcomes [11-13].
RBE modelling still represents a challenge in prescribing, recording and reporting dose for all light ions used in RT [14]. New TPS provide multi-model calculation and optimization options, which could support the process of future harmonization of PT treatments.

References

[1] Tinganelli W and Durante M. Carbon Ion Radiobiology. Cancers (Basel) 2020.

[2] Mein S et al. Assessment of RBE-Weighted Dose Models for Carbon Ion Therapy Toward Modernization of Clinical Practice at HIT: In Vitro, in Vivo, and in Patients. Int J Radiat Oncol Biol Phys 2020.

[3] McNamara A et al. Modelling variable proton relative biological effectiveness for treatment planning. Br J Radiol 2020.

[4] Engeseth GM et al. Mixed Effect Modeling of Dose and Linear Energy Transfer Correlations With Brain Image Changes After Intensity Modulated Proton Therapy for Skull Base Head and Neck Cancer. Int J Radiat Oncol Biol Phys 2021.

[5] Kanai T et al. Examination of GyE system for HIMAC carbon therapy. Int J Radiat Oncol Biol Phys 2006.

[6] Inaniwa T et al. Reformulation of a clinical-dose system for carbon-ion radiotherapy treatment planning at the National Institute of Radiological Sciences, Japan. Phys Med Biol 2015.

[7] M Krämer et al. Treatment planning for scanned ion beams Radiother Oncol 2004.

[8] Fossati P et al. Dose prescription in carbon ion radiotherapy: a planning study to compare NIRS and LEM approaches with a clinically-oriented strategy. Phys Med Biol 2012

[9] Steinstraeter O et al. Mapping of RBE-Weighted Doses Between HIMACe and LEM Based Treatment Planning Systems for Carbon Ion Therapy. Int J Radiat Oncol Biol Phys 2012.

[10] Molinelli S et al. Dose prescription in carbon ion radiotherapy: How to compare two different RBE-weighted dose calculation systems. Radiother Oncol 2016.

[11] Molinelli S et al. RBE-weighted dose in carbon ion therapy for ACC patients: Impact of the RBE model translation on treatment outcomes. Radiother Oncol 2019.

[12] Dale JE et al. Brainstem NTCP and Dose Constraints for Carbon Ion RT-Application and Translation From Japanese to European RBE-Weighted Dose. Front Oncol 2020.

[13] Dale JE et al. Optic nerve constraints for carbon ion RT at CNAO - Reporting and relating outcome to European and Japanese RBE. Radiother Oncol 2019.

[14] ICRU Report 93: Prescribing, Recording and Reporting Light Ion Beam Therapy.

Summary:

84

PT perspectives and challenges: clinical

PT perspectives and challenges: clinical
Particle therapy using protons or heavier ions is currently the most advanced form of radiotherapy and offers new opportunities for improving cancer care and research. Ions deposit the dose with a sharp maximum (i.e. the Bragg peak) and normal tissue receives a much lower dose than what is delivered by X-ray therapy. Particle therapy has also biological advantages due to the high linear energy transfer of the charged particles around the Bragg peak. In this presentation we will review the clinical perspectives and challenges of particle therapy with a specific focus on the clinical trials where protons are tested against conventional radiotherapy.

85

The role of Raptor for the democratization of proton therapy .

The role of Raptor for the democratization of proton therapy
The prospects of proton therapy will depend largely on our ability to make this treatment modality affordable for the majority of our patients. One potential solution to achieve substantial cost savings is to get rid of the large and costly gantry by positioning the patient on a flexible chair relative to a fixed proton beam. Raptor can facilitate this approach by providing the following capabilities:

1. Online monitoring of the patient by advanced surface and volumetric imaging.
2. Integration of soft robotics to nudge the patient in the intended position.
3. Rapid determination of the stopping power distribution for different postures.
4. Combination of position and posture corrections with beam spot adjustments.
5. Dynamic re-optimization of the treatment plan.

In this presentation we will discuss the progress made and the challenges that remain in each of these areas, resulting in research questions to be addressed by Raptor. If successful, Raptor will have made a major contribution to the democratization of proton therapy.

86

Good scientific practice

Corresponding Author: stine.korreman@oncology.au.dk

Good scientific practice
As a researcher, it is your responsibility to maintain and adhere to basic principles ensuring reliability and integrity of the research performed. The fundamental principles relate to honesty, responsibility, reliability, fairness, openness, transparency, objectivity, and impartiality. When working in the health sciences, the protection of personal data is crucial.
The lecture will cover the principles and responsibilities related to good research practice in relation to applications such as working with clinical data, collaboration with external partners, publication and dissemination of knowledge.
In the lecture, we will go through relevant guidelines including "THE EUROPEAN CODE OF CONDUCT FOR RESEARCH INTEGRITY", the "SINGAPORE STATEMENT ON RESEARCH INTEGRITY" , and the Vancouver authorship guidelines.
In addition, the lecture will include working with illustrative examples and dilemmas through short exercises.

87

Scripting for data evaluation

Corresponding Author: christoph.bert@uk-erlangen.de

Scripting for data evaluation
Data evaluation is an essential and critical part of any medical study. In the sense of good scientific practice, data evaluation shall be transparent and reproducible also after a long period of time. Well-designed scripting supports this process greatly, by simultaneously evaluating and documenting the evaluation. Moreover, scripts permit to automate and standardize evaluation of complex datasets, facilitating reproducible results also over different scientific studies.
Different methods for scripting will be presented, including basic script languages and options of modern radiotherapy tools

Summary:

88

Perspective on publishing and OA

Corresponding Author: jochen.bihn@lib4ri.ch

Perspective on publishing and OA
Both researchers and society as a whole benefit from freely accessible research findings. In addition, more and more funders and institutions expect their researchers to publish research results Open Access. In this talk, you will get to know the Open Access requirements for scientific publications under Horizon 2020 (-> RAPTOR). You will learn about your options to publish Open Access (green Open Access, gold Open Access) and will be shown how to implement this knowledge in your daily work.

89

Scripting in a modern TPS

Corresponding Author: elin.hynning@raysearchlabs.com

Scripting in a modern TPS
This presentation will give you an overview of scripting in the RayStation treatment planning system. We will talk about why scripting is useful and important, both in an every-day clinic environment and for research purposes. We will discuss how scripting is implemented in RayStation and the benefits of using a well-used programming language. We will also have a look at real-world scripting solutions, from short scripts that automate simple, repetitive tasks to larger projects such as semi-automatic treatment planning and decision-support tools.

90

Monte Carlo dose calculations

Monte Carlo dose calculations
Monte Carlo (MC) methods in radiation therapy have been increasingly important in the last two decades. MC-based dose calculation shifted from being considered a tool for a few to a widespread resource for daily use by medical physics and clinicians. This was the result of a continuous development and benchmarking of the models handling biophysical phenomena of radiation interaction within patients and the enormous speed-up of calculation times. The latter point was largely achieved via porting CPU-based MC codes to the GPU (Graphics Processing Unit). The lecture will focus initially on the fundaments of the MC-dose calculations in radiation therapy emphasizing both the advantages and the limitations of MC dose engines. Clinical and research applications of MC codes will be presented together with the key elements for a successful GPU implementation of the MC.

Summary:

91

Best Practices and Services for FAIR Data Management

Corresponding Authors: martin.spenger@ub.uni-muenchen.de, regina.albrecht@lmu.de

Best Practices and Services for FAIR Data Management
The focus of this presentation is on research data gathered in scientific projects. Research data lay the foundation for publications but can also be of huge benefit for other researchers if they are shared in an appropriate way. Therefore, Research Data Management, plays a crucial role in every scientific endeavor. Basic requirements can be found in the FAIR guiding principles. Data should be Findable –Accessible –Interoperable –Reusable. In this presentation will be addressed, what this means for your data. Helpful resources and tools will be introduced and the role of potential partners, like academic libraries or data centers, pointed out. In this context, the role of data management plans,

metadata, data publication and Open Data will show, how inseparable Data driven research and FAIR are linked."

92

Role of Particle Therapy in Cancer Care. Public Talk zoom link to access the talk: https://lmu-munich.zoom.us/j/96417723332?pwd=NHpLR01Rd2N6

Role of Particle Therapy in Cancer Care
zoom link to access the talk: https://lmu-munich.zoom.us/j/96417723332?pwd=NHpLR01Rd2N6Q1RobWt2bG5lVGNLUT09
More than 250.000 patients have been treated with particle therapy worldwide. The vast majority of patients, i.e. >240.000 for more than 3 decades treated with protons and about 13-15% (>30.000) using carbon ions. The main physical advantages of particle therapy are the dose distribution using the Bragg-Peak resulting in significant reduction of the low to moderate dose volume delivered to normal tissues –thus resulting in fewer chronic side effects - yet high dose conformality in tumor thus allowing higher tumor residual dosages. Some indications are clearly established, for example, in pediatric tumors, skull base tumors, sarcomas and selective Head&Neck cases and eyes. However, the last decades witnessed an extension into frequent malignancies, in particular in breast cancer, lung cancer and gastrointestinal malignancies. Carbon ion therapy is presently still limited to a few centers only. However, there is significant medical evidence for its application in radio-resistant tumors, unresectable disease and also re-irradiation, based on the combination of physical dose distribution advantages with the higher relative biologic effectiveness. The principles of particle therapy as well as present clinical evidence and future aspects will be provided.

Summary:

93

Concluding remarks

Corresponding Author: francesca.albertini@psi.ch

94

VIDEO MAKING WORKSHOP: for RAPTOR ESRs only

The workshop is intended for RAPTOR ESRs only and focuses on the basics of communication to a non-scientific audience and the production of intro films. Final goal is that each ESR produces a film introducing themselves and their work. The workshop consists of 3 group sessions and by individual work assignments:
Friday 17 December 20221 1st session, in-person, Munich.
18 Dec. –18 Jan. 2022 ESRs work on their project in a self-organized manner; feedback loops on

their work
Wednesday 19 January 2022, 4.00-6.30 pm. Second session, online
20 Jan. –15 Feb. 2022 ESRs work on their project in a self-organized manner; feedback loops on their work
Wednesday 16 February 2022, 4-6:30 pm Final session, online

96

Time and self-management

Corresponding Author: antje.knopf@gmail.com

Time and self-management
Sooner or later, every young scientist will realize that good research requires a good approach to time- and self-management. There are two main reasons for that: The complexity of research projects and their often-large time frame. Without good time- and self-management, self-doubt and lack of motivation can easily drain energy and sabotage all planning efforts.
In this lecture, we will look at time- and self-management from a holistic point of view. First, we will review some concrete methods to organize project and track their progress. Attendees will reflect on individual needs they should account for when planning and on personal strengths they can use to carry out their plans. Second, we will look at the root causes of procrastination and writer's block and develop individual strategies to tackle these issues. Finally, everyone will be invited to reflect and visualize his or her personal motivation and his or her goals in order to ensure sustainable, long-term motivation even when times might get a bit rough.
Lesson contents:
• methods & tools for organising a long-term-project
• methods for measuring progress and keeping motivated
• self-management techniques
• root causes of procrastination and writer's block and how to deal with them
• individual reflection of personal motivation and goals

Summary: