SP-0028
Which dosimetric uncertainties in small fields are clinically acceptable for IMRT/VMAT?

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During the last years small field dosimetry (re-)gained importance. Several working groups highlighted its relevance in the context of high precision radiotherapy techniques. Non-conventional linear accelerators that do not support standard reference geometry and the upcoming unflattened photon beams had an impact on upcoming recommendations in this context as well. However, recent audits revealed large uncertainties in small field dosimetry with deviations up to 10% for 2 × 2 cm2 fields, which motivated the present contribution. Clinically used beam models of two TPS (Monaco, ELEKTA and iPlan, BrainLAB) were modified to mimic the large uncertainties in small field output factors. Next IMRT and VMAT treatment plans for prostate and head and neck cancer cases as well as treatment plans for stereotactic brain lesions were generated and calculated with correct and incorrect beam models, respectively. Finally, treatment plans were delivered with an ELEKTA Versa HD linac. Dose calculations were compared with measurements performed with EBT films and a detector array. Effects of uncertainties in small field output factors were less pronounced for IMRT and VMAT plans compared to stereotactic techniques delivered with static fields or dynamic arcs. TPS specific sequencing of IMRT and VMAT had an impact on the final results. The gamma evaluation performed with detector arrays was not able to dissolve uncertainties in small field dosimetry due to the rather large detector. On the other hand single detector signal was sensitive to such uncertainties. Upcoming treatment techniques like dose painting will use small fields more extensively and motivates highest accuracy in small field dosimetry. Published reference data and guidelines including detector correction factors contribute to eliminate gross uncertainties (>5%) in small field dosimetry.

SP-0029
IAEA external audits for advanced radiotherapy - lessons learnt and their relevance for industrialised countries

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The postal dose audit programme for radiotherapy dosimetry operated jointly by the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) has been in existence for over 45 years. To-date the existence for over 45 years. To-date the programme has been audited in 11300 radiotherapy beams in 2200 hospitals in 132 countries has been audited. Several hospitals have improved their dosimetry practices over the years, and the percentage of acceptable results is > 95% at present. The IAEA records suggest that regular participation in audits is associated with higher quality dosimetry than the first participation. It confirms that the dosimetry audit is useful to enhance confidence in radiotherapy dosimetry for both medical physicists and clinicians who need assurance that their patients receive safe and high quality radiation treatment, which is not possible without accurate dosimetry. With the increasing complexity of radiotherapy treatments, basic dosimetry audits are no longer sufficient and more complex audit programmes testing different dosimetry parameters and treatment delivery techniques are required. The first IAEA ‘end-to-end’ audit methodology was developed for 3D conformal radiotherapy. It reviewed dosimetry, imaging, treatment planning and radiotherapy delivery processes following the pathway similar to that of the patient undergoing radiotherapy. The audit was implemented at national levels with the IAEA providing an international thorax phantom (CIRS) and expert advice. National groups conducted the audit at local hospitals through on-site visits. TPS calculated doses were compared with ion chamber measurements for a set of test cases. In Europe, the audit has been carried out in 60 hospitals in 8 countries. About 200 data sets have been collected and reviewed. Suboptimal beam modelling requiring interventions were discovered in about 10% of datasets. In addition, suboptimal beam modelling in TPSs occurred in several centres. Overall, the audit contributed to better understanding of the performance of TPSs and helped to resolve discrepancies related to imaging, dosimetry and treatment planning. Recently, a new methodology has been developed for on-site ‘end-to-end’ audits to review the physics aspects of head and neck IMRT treatments. It uses a dedicated anthropomorphic head and shoulders phantom (CIRS) with a set of contours representing the target volumes and organs at risk. The contours are imported and superimposed on the CT scans of the phantom. The treatment plan is developed and transferred to the treatment machine for the dose delivery. Ion chambers and radiochromic films are used for dose measurements. Comparisons are made between the TPS calculated measured doses. The audit methodology is currently tested within an international study group. For >20 years the IAEA has supported the development of audit methodologies for national audit groups using remote audit tools. Current projects focus on remote IMRT audits involving different audit steps, e.g. small field dosimetry relevant for IMRT. One study compared TPS calculated beam outputs to the published reference data sets. The results showed good agreement (within 1%) between the TPS output and the reference data for field sizes 4×4 cm2 and dose overestimation by TPSs by 2%/3% for field sizes ≤ 3×3 cm2. Auditing methodology was also developed to verify the TPS modelling of small MLC shaped beam profiles with radiographic film measurements for 2×5 cm2 and 2×2 cm2 fields. Relative differences between the profiles at 20%, 50% and 80% dose levels were evaluated. Only 64% beam profiles were within 3 mm agreement between the TPS calculated and film measured doses. This highlights some limitations in TPS modelling of small beam profiles in the direction of MLC leave movements. Such differences can affect patient treatments, especially for stereotactic radiotherapy and IMRT. Another study evaluated MLC performance using pickup tests and confirmed that most MLCs performed as expected. A comparison of gamma analysis techniques was also conducted through a multicentre analysis of a film irradiated with a complex field arrangement. Differences in gamma agreement occurred that were attributed to the differences in film scanning parameters and gamma calculation algorithms. A newest study on remote ‘end-to-end’ IMRT audit is on-going. Overall, the results of these studies demonstrate challenges in TPS commissioning for
small fields and challenges in multicentre comparison of gamma analysis for complex dose distributions.

Overall, the IAEA supports developments of various audit tools for radiotherapy with the audit scope corresponding to the evolving complexity of radiotherapy technology, in order to verify radiotherapy physics practices and improve the quality of treatments delivered to cancer patients in participating countries.

Symposium: Strategies for treatment planning

SP-0030
Comparisons of treatment planning with photons and protons
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This presentation will focus on the main differences between the radiotherapy treatment planning with photons and protons. An important issue in all treatment planning is the dosimetric uncertainties and margins to account for these. Compared to photons, protons have additional sources of uncertainties that should be analysed and understood. Insufficient quantification of margins can have more serious consequences in proton therapy than is the case for photons.

The main advantage of proton beams is the finite range and sharp distal dose fall off in depth, an advantage that often is a contradiction in the sense that the range uncertainty limits the use of this advantage. A second advantage is the ability to, with every single field, give the target volume a higher dose than the surrounding tissue. The sources of range uncertainties are caused by the patient variations in anatomy and the uncertainties in the conversion of CT numbers to tissues with the correct proton interaction properties. The handling of range uncertainties play a critical role in proton planning and has an impact on the entire treatment planning process that differs from photons.

The generic PTV margin recipes used in photon planning, are not adequate in proton planning. Primarily, this is used to account for lateral beam uncertainties. In proton planning, two margins have to be considered, the lateral and the margin in depth i.e. range uncertainty. In principle, these two margins arises from different physical processes. According to ICRU 78 [1] the PTVs are recommended to be used in proton planning for dose reporting purposes. Additional volumes with beam specific margins, have to be used to account for uncertainties in range. Paganetti has suggested margin recipes that is widely used in proton planning [2].

Consequently, the range uncertainty also has an influence on the selection of beam and their entry angles. In this phase of the treatment planning process, proton planning emphasizes other considerations than photons. Robust planning has the potential of mitigate the impact of range uncertainties, aiming for a robust beam path i.e. heterogeneous geometry along the beam path. Likewise, the robustness should be considered during the optimization as well as during the treatment plan evaluation and the comparison with a photon treatment plan to choose the best treatment plan.

The contents of this presentation are based on experiences from the start-up of the first Scandinavian Proton Centre, Skandinonkliniken, where the first patients were treated in late August 2015. Nearly four years before that, in January 2012, we started the Proton School in order to prepare for the clinical start and to train a group of medical physicists, dosimetrists and radiation oncologists in proton planning [3,4].

Thinking protons instead of photons has been the greatest challenge for the group as a whole. How do we achieve the best plan? This includes selecting robust beam angles and thinking about what the protons interact with on its way to the target volume. Discussions about target volumes has been frequent, as the use of them. Delination 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 optimisation structures to provide the best treatment plan.

References

SP-0031
When to re-plan: a practical perspective
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Anatomical changes are important issue during radiotherapy because they could potentially lead to inadequate dose distribution to target and organs at risk (OAR). Radiation induced complications have a significant adverse impact on health-related quality of life. To minimize the risk adaptive radiotherapy (ART) has become state of art of modern radiotherapy. In clinical practice ART is expressed mostly by Image-Guided Radiation Therapy (IGRT) and re-planning, the last is very individualized but should be more unified. Clear guidelines are therefore needed to determine the timing of re-planning, and an increasing amount of information needs to be acquainted, transferred and stored.

There are several indications that anatomic changes are more pronounced in the first half of treatment, and therefore repeated imaging and replanning should be performed in this first time period. The parotid gland was the most studied OAR and showed the largest volume changes during radiotherapy (26% average volume decrease). The average number of radiation fractions delivered between baseline and re-planning CT scans was 15 (+5) fractions which equals 21 (+8) days. It is also well established in the Head and neck (H&N) area that, because of i.e. weight loss and/or tumor shrinkage especially in more advanced stages of cancer (T3/T4, large N+), re-planning improves relapse-free survival and significantly alleviated the late effects. In many dosimetric studies without replanning during treatment, the doses to normal structures were significantly increased and doses to target volume significantly decreased. According to literature replanning frequency increases also with smaller PTV margins.

To answer the question „When to re-plan?” we need to know which sites would most benefit. In regard to literature studies it seems that re-plan would be the most beneficial for tumors of the biggest volume or the nearest proximity of the OAR’s. Still it does not explain „when” should we perform it. Despite of the great amount of reports and analysis further research are needed.

SP-0032
Fully automated treatment planning: benefits and potential pitfalls
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Purpose/Objective: Labor-intensive procedures, such as adaptive radiotherapy, result in an increased workload in the treatment planning department, which can be reduced by introducing fully automated treatment planning. The benefits of automated planning are many: reduction of workload, increased workflow efficiency, and reduction of plan variability. However, a potential pitfall could be loss of