

treatment delivery, optimal clinical outcome and meaningful reporting and comparison of treatments.

In addition to high quality imaging and contouring guidelines, solid knowledge of radiological anatomy is a precondition to achieve best contouring standards. While this subject is recognized as one of the key competencies in the radiation oncology core curricula and training programmes [Eriksen JG, et al. *Radiother Oncol* 2012, www.acgme-i.org], there is limited published data regarding the actual impact of the teaching interventions on contouring skills and the characteristics of the learning curve [Jaswal JK, et al. *IJROBP* 2014, Cabrera AR, et al. *J Am Coll Radiol* 2011, Bekelman JE, et al. *IJROBP* 2009, D'Souza L, et al. *BMC* 2014]. Furthermore, published national surveys among radiation oncology residents and residency program directors indicate that there is room for improvement of training and evaluation of contouring competencies during residency [Jani AB, et al. *Pract Rad Onc* 2015, 12; Jaswal JK, et al. *IJROBP* 2013].

Contouring training should not be viewed as a process limited to the residency and fellowship programs and core-curriculums. In a study evaluating the impact of prospective contouring rounds in a high volume academic centre, 36 % of cases required modification of contouring or written directives prior to treatment planning [Cox BW, et al. *Pract Rad Onc* 2015]. In a study of stereotactic body radiotherapy for lung cancer, the institutional peer-reviewers recommended major and minor changes of delineations in 23 % and 37 % of 472 contoured structures, respectively [Lo AC, et al. *J Thor Onc* 2014]. In view of the rapid developments of imaging and radiotherapy delivery, accompanied by constant evolution and development of new contouring recommendations, the importance of continuous education of the experienced practitioners, mentors and trainers cannot be overemphasized.

Research focusing on site-specific volumetric, topographic and qualitative aspects of contouring variation informs the educational activities in this field. The growing number of published inter-observer studies offers valuable resource to guide the training process. Limiting the learning to didactic and case-based instructions has improved knowledge scores and resident satisfaction in one study. However, this was not translated into improved contouring accuracy [D'Souza L, et al. *BMC* 2014]. In our experience, site-specific curriculum based on intensive sequence of didactic presentations, system-based instructions and hands-on contouring workshops represents an optimal strategy to achieve good learning results [Segedin B, et al. Submitted to *Radiol Oncol* 2016]. Feasibility and effectiveness of similar intensive educational interventions has been confirmed by others [Jaswal J, et al. *IJROBP* 2014].

These favourable early outcomes of teaching cannot be extrapolated on the long-term scale. Further evidence-based characterization of the learning curve is required to quantify the needs for continuous education and identify strategies for long term knowledge consolidation. Relative impact of the individual educational modules and qualifications of trainers on the learning outcome needs to be quantified, taking the tumour-site specific challenges into account. Development of training tools, including e-learning platforms and tools for objective assessment of contouring represent some of the main pre-requisites for future improvements in this field.

SP-0108

Physicist training in 3D dose planning

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New physicists entering in to the speciality of brachytherapy normally undertake a formal training scheme in Medical Physics. Within the specialised field of brachytherapy the depth and breadth of training received can be dependent on the training scheme undertaken, training hospital's expertise in brachytherapy, length of time dedicated to brachytherapy training and the assessment process.

This presentation will summarise the key components of knowledge and experience a physicist should be expected to

receive during their brachytherapy training and cross reference this to example training schemes. Several key questions need to be addressed when reviewing the training needs for image guided brachytherapy: Is additional training still required after completion of the formal training scheme? Are they appropriately focussed on image guided brachytherapy?

It is important that any training gaps are identified and that measures are put in place to ensure that physicists have an understanding across all the components of image guided brachytherapy, have a full appreciation of the uncertainties and limitations within the brachytherapy pathway and of the systems used.

Additional training resources will likely have to be explored to complement the core training schemes. Examples of available training resources will be presented and how they can potentially help facilitate the training and professional development of brachytherapy physicists.

It is important that we ensure that opportunities for physicist training is not restricted and that physicists are allowed to develop their knowledge, understanding and skill set required for the modern image guided brachytherapy era. Training schemes need to continue to evolve and new training resources explored to complement formal training schemes and work based learning.

SP-0109

New avenues for training with e-learning

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E-learning has the potential to deliver educational content to large numbers of learners world-wide. In 2008, Cook *et al* from the Mayo Clinic conducted a meta-analysis of 201 studies of e-learning in the health professions. They found that internet-based instruction for medical professionals is associated with favorable outcomes across a wide variety of learners, learning contexts, clinical topics, and learning outcomes. Internet-based instruction appears to have a large effect compared with no intervention and appears to have an effectiveness similar to traditional methods. In a separate review in 2010, they identified that interactivity, practice exercises, repetition, and feedback improved learning outcomes.

This talk discusses the potential of e-learning for teaching competency in target volume delineation (TVD). A crucial component of such a programme is automated assessment of contours with individualised feedback. The talk will compare conventional and novel methods for creating reference contours for TVD assessment, and conventional and novel metrics for automated assessment of TVD competency in individuals and groups of learners. The talk will also discuss the potential to investigate the impact of different instructional designs (e.g. live lectures, podcasts, annotated clinical cases, interactive demos) on TVD competency using quasi-experimental methodology.

Symposium: Imaging markers for response prediction and assessment

SP-0110

Imaging markers for response prediction: the clinical need

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A variety of therapeutic options are now available to cancer patients. It is recognised that significant biologic heterogeneity exists that may affect a patient's likelihood of response to particular therapies and development of resistance on therapy. To be able to predict whether a patient will respond or not respond to a specific therapy is advantageous in streamlining patient management and minimising the costs of continuing therapy that is not working as well as minimising unwanted side-effects of such therapy.

Imaging currently play an important role in routine clinical care and clinical trials in triaging patients to appropriate management and in monitoring patients on therapy. In terms of treatment assessment it is essential for imaging markers to be consistent, reproducible and validated. Standardized response assessment based on morphological change, such as RECIST 1.1 is well established in the clinical trial setting although its limitations for therapies beyond standard chemotherapy are recognised e.g. immunotherapy, and for which alternative response criteria have been proposed. Computed tomography (CT) remains that most commonly performed imaging modality due to its high spatial resolution and its cost-effectiveness, but positron emission tomography (PET) and magnetic resonance imaging (MRI) have advantages in their capability to image beyond morphology.

Measurement of glucose metabolism, cell proliferation, hypoxia, and vascularisation is now possible in clinical practice as well as quantification of their spatial variation, providing an imaging phenotype that is likely to be more beneficial than simple biomarkers e.g. size in predicting individual patient response to therapy. These imaging methods can also be integrated with genomic and pathological data allowing a comprehensive approach to address the clinical need towards individualisation of therapy in the future.

SP-0111

Response prediction in rectal cancer using PET Radiomics

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In personalized medicine, early prediction of pathologic complete response for locally advanced rectal cancer (LARC) patients is essential to tailor treatment. The standard treatment for LARC patients consists of preoperative chemoradiotherapy (CRT) followed by surgery, with a complete response being observed in 15-30% of the patients after the neo-adjuvant treatment. Overtreatment of complete responders could be avoided if an accurate prediction of pCR is available, by selecting a wait-and-see policy instead of surgery after CRT, and thereby reducing treatment related complications. Further treatment strategies based on the prediction of pCR include a radiotherapy boost after CRT for patients with good response to achieve a higher complete response rate, and additional chemotherapy after initial CRT for the worst responding patients.

In recent years, [18F] fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) imaging has been increasingly used for decision support, treatment planning and response monitoring during radiotherapy. Radiomics (www.radiomics.org;

animation: <http://youtu.be/Tq980GEVPOY>) is a high throughput approach to extract and mine a large number of quantitative features from medical images, characterizing tumor image intensity, shape and texture. The core hypothesis of radiomics is that it can provide valuable diagnostic, prognostic or predictive information. FDG-PET radiomics may therefore facilitate early and accurate prediction of tumor response to treatment to identify LARC patients eligible for a wait and see or organ preserving approach, or patients who may benefit from treatment intensification.

This presentation will focus on the methodology of, and technical challenges in, the development and validation of a predictive PET radiomic model for pCR in LARC patients, illustrated with recent data.

SP-0112

MRI imaging of irradiated liver tissue for *in vivo* verification in particle therapy

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In vivo treatment verification is highly desirable, especially but not only in particle therapy where uncertainties in the particle range can compromise the physical advantage of this treatment modality. Existing measurement techniques for range measurements exploit physical effects, in particular secondary radiation that is produced by the proton beam, for example through activation of positron emitters, or prompt gamma radiation. Also biological effects caused by the irradiation can be used for *in vivo* treatment verification, if a functional imaging method is available to visualize the effect.

One prominent example for biology-driven range verification is an irradiation-induced change in contrast-enhanced MRI of the liver. A strong systematic decrease in uptake of the hepatobiliary-directed contrast agent Gd-EOB-DTPA has been shown in irradiated healthy liver tissue 6-9 weeks after irradiation [1-3] using different treatment modalities (brachytherapy, stereotactic body radiation therapy with photons and protons). The underlying mechanism seems to be based on a pro-inflammatory reaction of the irradiated liver tissue resulting in a downregulation of the Gd-EOB-DTPA uptake transporters and an upregulation of the respective excretion transporters [4].

In a prospective clinical study, carried out at Massachusetts General Hospital in Boston (USA), we investigated whether MRI of the liver can be used for *in vivo* dosimetric verification already during the course of hypo-fractionated proton therapy of liver metastases (5 fractions within 2 weeks). In contrast to the previously found late changes weeks after the end of treatment that were seen in all patients, for the early Gd-EOB-DTPA enhanced MR imaging large inter-patient variations were found. For 10 patients, strong or moderate signal changes were detected for 2 and 3 patients, respectively. For 5 patients no dose-correlated early signal change was found at all. This qualitative scoring was consistent with a quantitative voxelwise dose to signal change correlation. The analysis of additional parameters that could potentially explain inter-patient variations (e.g. dose delivered at time of MRI scans, several timing parameters, liver function parameters and circulating biomarkers of inflammation determined from blood samples taken before and during treatment) revealed no clear correlation or trend with the strength of the signal decrease. Hence, irradiation-induced effects in the liver can be detected with Gd-EOB-DTPA enhanced MRI within a few days after proton irradiation in a subgroup of patients. As all patients possessed a signal decrease in late follow up scans, only the early dynamics of the liver response is influenced by these inter-patient variations. The reason for these large variations in early response is not yet fully understood and needs further investigation.

This presentation will cover a brief overview of biological effects used for treatment verification and will then focus on the irradiation-induced signal change in Gd-EOB-DTPA enhanced MRI of the liver. The hypothesis for the biological mechanism, the available data for late and early MRI signal changes will be presented and open questions will be discussed.