scanner and a state of the art linear accelerator. During the commissioning and implementation phase of the MR Linac a series of programs and methods were developed to replace the traditional pre-treatment plan QA approach. This includes the commissioning of a non Monte Carlo dose engine within a second commercial planning system to perform the independent monitor unit check. A high degree of automation and integration is desirable to enable the operator to perform a comprehensive QA of the new treatment plan within the limited time available. While a strong focus of these checks will be on the dosimetric aspects other issues like contours and data transfer error must not be neglected.
Within this presentation the methods developed at the RMH/ICR to tackle online plan QA will be presented.

SP-0033 QA of on-line Adaptive Radiotherapy: Washington University Experience

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Abstract text
Adaptive radiotherapy (ART) has been a concept for a long time but has become a practicality just in the past few years. This is especially the case for online ART. The online ART has been defined in many different ways and for the purposes of this presentation the online ART consists of 1) Daily volumetric patient imaging, 2) Creation of contours on the images of the day, 3) Creation of a new plan on contours of the day, including full IMRT optimization, 4) Review of the plan, 5) QA with the patient on the table, and 6) patient treatment with the new plan based on the daily anatomy and contours. It is worth noting that the desired time for this entire procedure should not add much time (minutes) to typical radiotherapy treatment appointments. While the main obstacle to practical online ART have been technological limitations, there are also operating paradigms that need to be evolved to enable practical online ART. One of the paradigms that needs to evolve is patient specific QA. While many will equate patient specific QA to IMRT QA, the QA for online ART has many more components. The online ART includes evaluation of daily imaging, contour accuracy, any image registrations or contour propagations, evaluation of clinical and technical integrity of the daily plan, evaluation of deliverability and safety of the daily plan, etc. While most, if not all, of these steps are performed with conventional radiotherapy and offline ART, the unique challenge of online ART is that all of these tests plus the treatment planning process have to be performed in minutes versus hours to days that are used in conventional and offline ART. In addition, during the entire time that planning and QA are performed the patient is on treatment table making any measurement based QA impractical. The needed speed for online ART QA and inability to follow conventional processes mandates reconsideration of conventional patient specific QA paradigms. This presentation is intended to provide systematic analysis of concepts for online ART QA, describe deployment of these concepts in a clinical setting, and description how lessons learned may affect future developments in this area.
Learning Objectives: After this presentation, the audience should be able to 1) Describe systems based approach to design of online ART QA2) Describe practical considerations for online ART3) Understand direction in online ART QA as this procedure becomes more prevalent.

Symposium: Beyond Physical dose

SP-0034 Mathematical Modelling of radiation response in Proton Therapy

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Abstract text
Clinically, the Relative Biological Effectiveness (RBE) of protons compared to photons is 1.1. However, there is considerable variance between the experimental studies informing this value. It has been shown that RBE is not constant but instead depends on many factors, including dose, Linear Energy Transfer (LET) and cell type. Most studies on proton RBE have concentrated on phenomenological modelling based on linear energy transfer (LET) and parameters derived from the linear quadratic model fitted to cell survival. We have taken a different approach, centred on mechanistic mathematical models. Detailed models of the cell and its DNA are constructed in Geant4-DNA where the DNA volume energy depositions, resulting from radiation track-structure, are recorded. Mechanisms of direct and indirect DNA damage are incorporated by simulation and comparison to experimental data in the literature. Predictions of both the position and complexity in DNA damage are then passed to our model of DNA repair, named DaMaRiS, which incorporates both non-homologous end joining (NHEJ) and homologous recombination (HR). Here, predictions are made on the kinetics and fidelity of repair at various time points. We show preliminary results, which integrate mechanistic mathematical models of DNA damage and repair in the Eclipse™Treatment Planning System (TPS). We score the dose and LET in each voxel and, using the previously established correlations, convert the scored parameters into biological predictions, specifically the yield of residual and misrepaired DSBs, which can be anatomically mapped. Predictably, residual DSBs across the LET and dose range dominate the biological outcome. The model shows a slight increase in complex damage with LET, i.e. with depth in the patient. We also predict that the increased LET produces more proximal Double Strand Breaks (DSBs), which increased misrepair events between DSBs. These maps can potentially provide valuable information to the clinician by allowing identification of regions of heightened biological effect (and are a step towards biologically augmented radiotherapy).

SP-0035 Developing metrology support for biologically relevant dosimetry

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Abstract text
A number of radiation modalities require weighting factors applied to absorbed dose to account for the biological effectiveness of the particular radiation quality. Examples include proton and ion beams as well as kilovoltage X-rays [1-3]. Micro- and nanodosimetry have been developed to provide radiation quantities that capture the influence of the stochastic nature of radiation interactions and, hence, the properties of different radiation qualities responsible for their different relative biological effectiveness. The European Joint Research Project BioQuaRT (Biologically weighted quantities in radiation therapy) [4-6], funded within the European Metrology Research Programme [7], created a metrological basis for radiation quantities integrating properties of particle track structure and biological radiation effects (Fig. 1).