

depending on the age of the system and the availability of Radiation Dose Structured Reports (RDSR). The data covers a variety of neuro-interventional and vascular-interventional exam procedures as coded under NIMIS national exam codes. Typical radiation dose metrics include Fluoroscopy Time, Dose Area Product (DAP) and Reference Point Air Kerma (RPAK). More recently the estimation of Peak Skin Dose (PSD) has been added to the suite of dose metrics available within dose tracking software. The aim of this study was to:

- Obtain the distribution of doses per interventional procedure (e.g. Mean, Median, 3rd quartile of Fluoroscopy Time, DAP and RPAK, PSD where available)
- Compare locally determined Dose Reference Levels to published literature
- Compare Peak Skin Dose (PSD) values (where available) with published thresholds for deterministic effects to the skin (e.g. erythema, epilation etc)
- Identify patients who have had single or multiple high dose procedures – for Out-Patient follow-up where appropriate
- Use the collected dose metric data for the optimisation of radiation safety for both patients and staff in an effort to provide continuous improvement within the hospital's radiation safety environment

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Radiotherapy Session 11:25 – 12:55

Benchmarking novel optical fibre sensors for applications in radiation therapy

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Detecting ionising radiation using scintillation light is a long-established technique, yet scintillator-based dosimetry in radiotherapy was not commercially available until recently. Scintillator materials can be organic or inorganic. Organic based scintillator detectors suffer from low light conversion efficiency and Cerenkov light ratio (CLR) coefficient energy dependence. The aim of this study was to characterise novel optical fiber sensors (OFS) based on an inorganic scintillating material for external beam radiotherapy due to the high sensitivity and high light conversion efficiency of inorganic scintillators. The sensor was constructed using a polymethyl methacrylate (PMMA) plastic optical fibre. The core of the PMMA was micro machined to make a cavity with a 700 µm diameter and a 3 mm depth. The cavity was filled with the scintillating material terbium doped gadolinium oxysulphide (Gd₂O₂S:Tb) and then sealed with an epoxy. The scintillation material fluoresces on exposure to ionising radiation and the resultant emitted fluorescent light is detected using a multi-pixel photon counting module. Essential dosimetric properties were quantified, including the repeatability of the OFS system response, linearity of the output signal with radiation doses and dose rate and dose per pulse (DPP) dependency of the system.

Percentage depth dose (PDD) and lateral dose profiles were measured for different field sizes and compared to the commercial W1 plastic scintillator and Monte Carlo simulations using BEAMnrc/DOSXYZnrc codes.

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Using a deep neural network to predict deviations in mean heart dose during the treatment of left-sided deep inspiration breath hold patients

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Purpose We investigated if a deep neural network could be used to predict the change in mean heart dose when a patient's heart deviates from its planned position during radiotherapy treatment. **Methods** Predictions were made based on parameters available at the time of treatment planning. The dose prescription, deep inspiration breath hold (DIBH) amplitude, heart volume, lung volume, V90% and mean heart dose were used to predict the increase in dose to the heart when a shift towards the treatment field was undertaken. The neural network was kept as simple and institutive as possible with a single hidden layer. The network was trained using of 3 mm, 5 mm and 7 mm shifts in heart positions for 50 patients' giving 150 data points in total. The neural network was tested using random cross-validation to evaluate the model's robustness to new data. Results The optimal neural network found was comprised of a single hidden layer of 30 neurons. Based on twenty train/test splits, 94% of all prediction errors were below 0.2 Gy, 97.3% were below 0.3 Gy and 100% were below 0.5 Gy. The average RMSE and maximum prediction error over all train/test splits was 0.13 Gy and 0.5 Gy respectively. **Conclusions** Our approach using a deep neural network provides a clinically acceptable estimate of the increase in MHD, without the need for further imaging, contouring or evaluation. The trained neural network gives clinicians the information and tools required to evaluate what shift in heart position would be acceptable and which scenarios require immediate action before treatment commences.

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Dosimetry assessment of patient-specific 3D printable material for HDR surface brachytherapy

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Purpose: 3D printable material water equivalence was investigated within the range of Iridium-192 source energies. The aim is to validate it for superficial brachytherapy treatments.

Methods and materials: 3D Cheetaflex material (bolus) was examined both in a water tank and with CIRS anthropomorphic phantom, performing an end-to-end test. In water tank, a GafChromic EBT3-V3 film was oriented perpendicular to the source axis obtaining percentage depth dose (PDD) from 7 mm to 30 mm of distance from the source, with and without a bolus 5 mm thick. Two films were oriented parallel to the source at 5 mm and 15 mm of distance and results were compared with TG-43 implemented on Oncentra[®] Brachy treatment planning system (TPS). A set of CT images of CIRS phantom was acquired and a bolus with 7 trajectories (1 cm inter-distance and 5mm from skin) was created. A new CT set of images with bolus and phantom was imported on TPS where a target was

defined and a dose plan was created. Plan was delivered with two films positioned between two different slabs of phantom, at reciprocal distance of 2 cm, orientated perpendicularly to the source axis.

Results: PDDs show a maximum difference of 4.7% (average 2.2%). At 5 mm and at 15 mm, the gamma pass rate is 100% with tolerance 3%/2mm DTA. Results of films placed intra-slabs show a high pass rate (>96%) with tolerances of 2% dose and 1mm DTA.

Conclusion: 3D material investigated is water equivalent at Ir-192 energies and is suitable for superficial brachytherapy.

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Superficial X-ray therapy beam measurements using a liquid-filled chamber array

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Superficial treatment from units such as the Gulmay D3300 investigated in this study are usually measured using a single ionization chamber at the central axis. Dose falls off from the central axis towards the periphery of the field. This falloff is asymmetrical in the anode-cathode axis due to the heel effect. Current clinical practice is to prescribe dose to the central axis, which neglects the varying dose across the treatment field. Therefore, it is important to formulate a methodology to quantify this. This study investigates the viability of the PTW LA-48 Linear Chamber Array with 100 and 140 kVp beam energies with seven applicators by comparing measurements with GAFChromic EBT-3 Film measurements which is validated for use at those beam energies in previous studies. The PTW LA-48 Array has 47 iso-octane-filled chambers in series allowing investigation of off-axis dose. Measurements were taken under 5 mm of liquid water using a PTW MP3 Water Tank. Film measurements were taken under 5 mm of solid water and analysed using FilmQA Pro. Both data sets were made relative to the measured central axis dose and compared. The average percentage difference between measurements for each applicator ranged between $-2 \pm 2\%$ and $1.5 \pm 0.5\%$ for 100 kVp and $-2 \pm 1\%$ to $2 \pm 3\%$ for 140 kVp, where the uncertainty is the standard error. These results show that the PTW LA-48 measurements were comparable to the EBT-3 Film measurements and highlight the potential for liquid-filled chamber arrays to be utilised to investigate off-axis dose for superficial X-ray therapy units.

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Radiobiological modelling of clonogen distribution, hypoxic fraction and tumour size effects on local tumour control of non-small cell lung cancer

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Published clinical data show that hypoxia in human lung tumours can impede the establishment of optimum local tumour control. However, the overall effect of hypoxia on the tumour control probability (TCP) model is not clear. The focus of this project was to assess the influence of radiobiological parameters (the number of clonogens and the hypoxic fraction), as well as some treatment parameters (i.e., the tumour size), on local tumour control of early stage non-small cell lung cancer (NSCLC). A TCP model, based on LQ cell survival concept combined with the Poisson statistic, was established to predict one, two and three years of local tumour control. This TCP model was created using data from seventeen publications of early-stage

NSCLC treated using one of the three radiotherapy modalities: three-dimensional conformal radiation therapy (3D-CRT), continuous hyperfractionated accelerated radiotherapy (CHART) or stereotactic ablative body radiotherapy (SABR). The variations in the TCP with the gross tumour volume (GTV) size, clonogen number and hypoxic fraction were then investigated. This issue was approached by varying the clonogen densities values (between 10^1 and 10^7 cm³), the GTV volume (20–140 cc) and the hypoxic fraction (20–90%). The optimum values used to compute the TCP model were a clonogen density of 10^7 cm³ and a hypoxic fraction of 20%, which were consistent with the clinical outcome values reported in the literature for NSCLC. This radiobiological model has demonstrated the proof of concept that poor local tumour control is strongly associated with the hypoxic fraction and large tumours.

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Testing of auto segmentation to improve the workflow for stereotactic radiosurgery

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Auto segmentation (contouring) is used to improve the efficiency of the radiotherapy workflow. Stereotactic Radiosurgery (SRS) patients often require short patient pathways. The aim of this study was to compare 3 different commercial auto segmentation software packages for SRS. The first software package uses a single contour set from a previous patients CT. The second uses an atlas built from a selection of previous patients CT. The final uses a generic model of a patient and utilises MRI and CT images. These 3 auto segmented datasets, and the original contours that were used during treatment, were assessed by 1 consultant clinical oncologist and 3 medical physicists from the SRS team. 12 contours, across two patients were analysed and ranked on a 3-step scoring system; 1-clinically acceptable, 2-needs small amendments, 3-needs large amendments. DICE coefficients were also performed. All auto generated contour sets required some amendments. Some of the original contours drawn by the physician were ranked as requiring amendments by all reviewers. Two of the auto segmentation tools had a median score of 2 across all the reviewed contours. For the contours that were originally physician approved, the median score was 1, although some of the contours were rated as 2. Statistical analysis indicated no significant difference between software packages 2 and 3 when comparing all contours that were included in both systems. This study demonstrated that our implementation of software packages 2 & 3 could be used to improve the workflow in the department by creating autogenerated structures.

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Imaging Equipment Limited Bursary Competition 14:45 – 15:20

Energy and dose dependence of GafChromic EBT3-V3 film across a wide energy range

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The purpose of this work is to determine the energy and dose dependence of GafChromic EBT3-V3 film over an energy range 0.2