Fig. 2: V95% for CTV-N and PTV-N in two patients. Dose calculation on synCT for all fractions and calculation on sCT at two fractions. F0 is pCT. Anatomical changes are shown as an overlay of CT and CBCT to the right.

EP-2061 Use of CBCT Imaging vs Planning CT Rescans to determine the need for Adaptive H&N VMAT Plans

L. Sarri[1], C. Agnew[1], D. Irvine[1], C. McGarry[1]
[1]Northern Ireland Cancer Centre, Radiotherapy Physics, Belfast, United Kingdom

Purpose or Objective
The aim of this study was to evaluate the use of routine on-treatment imaging (cone-beam CT, CBCT) to correctly identify head and neck patients who experience anatomical changes during their radiotherapy treatment that require the creation of a new adaptive treatment plan. With patient safety paramount, this decision is based upon the dose to the spinal cord.

Material and Methods
13 patients treated with VMAT for head and neck cancer were identified for this retrospective study. All of the patients had a rescan CT at some point during treatment due to potentially unacceptable changes identified on CBCTs. 7 patients required the creation of a new plan, with 3 of these required due to dosimetric changes. A number of metrics related to the patient shape were studied to identify weight loss on the CBCT scans just prior to the rescan CT. The CBCT images and the planning CT scan deformed to the CBCT anatomy were used to calculate the dose to the spinal cord. The information from the rescan CT was considered to be the gold standard for this study.

Results
Whilst a number of the patient shape metrics (SSD, volume of body contour) were found to change over treatment, consistent with patient weight loss, this was not found to indicate the need to create a new plan for the patient (based on the clinical decision). Dosimetrically, almost all of the patients (12/13) were found to have a statistically significant increase in D0.1cc to the spinal cord (-1.8 – 7.2 Gy) between the planning CT and rescan CT. Calculation of the original plan on the CBCT or the deformed planning CT was found to present a viable method for correct identification of patients who required a new treatment plan due to spinal cord doses exceeding the tolerance value of D0.1cc = 45 Gy (see Figure 1). These patients formed a small subset in the group, experiencing large increases of more than 7 Gy to the spinal cord D0.1cc (3/13).
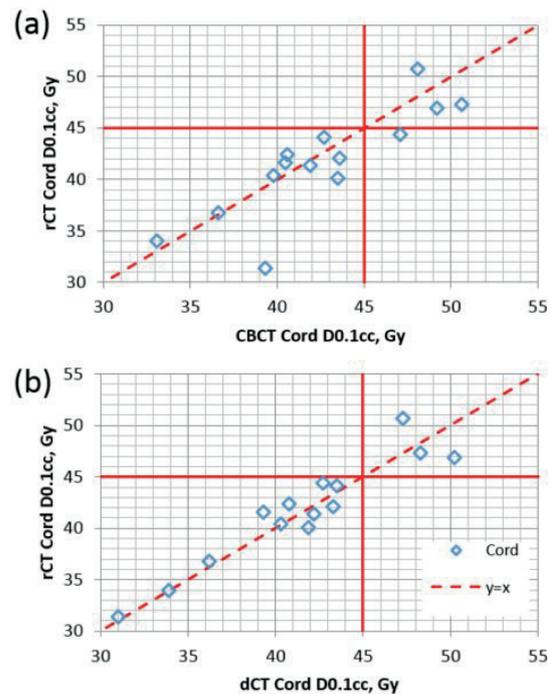

Figure 1: Spinal cord D0.1cc from (a) the CBCT and (b) the planning CT deformed to the CBCT, the dCT, compared to the spinal cord D0.1cc on the rCT (considered the gold standard). The red dashed line indicates the ideal scenario where the dose on the CBCT/dCT is equal to that on the rCT. The solid red lines indicate the 45 Gy tolerance.

Conclusion
This work shows that dose calculations on CBCT and deformed planning CTs provide sufficient information to trigger the acquisition of a rescan CT and an adaptive radiotherapy plan due to potential overdose to the spinal cord. As approximately only half of rescan CTs currently require a new treatment plan to be created, this will reduce the number of unnecessary rescan CTs in this patient group, save resource and staff time, and remove the inconvenience of additional appointments for the patients involved.

EP-2062 Probabilistic scenarios for assessing setup uncertainty in VMAT and IMPT plans for lung cancer

S. Teoh[1], F. Fiorini[1], B. George[1], K.A. Vallis[1], F. Van den Heuvel[1]
[1]CRUK/MRC Oxford Institute for Radiation Oncology, Oncology, Oxford, United Kingdom

Purpose or Objective
To evaluate and compare robustness of intensity modulated proton therapy (IMPT) and volumetric modulated arc therapy (VMAT) for stage III non-small cell lung cancer (NSCLC) for setup uncertainties using probabilistic scenarios.

Material and Methods
Minimax robust (MM) and planning target volume (PTV) optimised IMPT and VMAT nominal plans (D_{nom}) were created to a prescribed dose of 70 Gy in 35 fractions and compared in 10 patients. Assessment of setup uncertainties was done using a probabilistic method whereby a fractionated treatment course was simulated, summed (D_{sum}) and compared to D_{nom}. For every plan, a set of 35 shifts from the isocentre was generated by random sampling from a Gaussian distribution with the population systematic and random errors. Three treatment-course simulations were done for each plan.

Acceptable robustness criteria for the target were: dose degradation of 5% or less to 98% of the clinical target volume (CTV) compared to D_{nom} and a minimum dose of 66.5Gy covering 99.9% of the CTV. For fraction dose distributions (D_{frac}), plans were considered acceptable when at least 90% of the fractions were within the above criteria. All organs-at-risk (OARs) constraints were required to be met for nominal and simulated plans. Voxel-wise dose simulation repeatability of the target was analysed using Bland-Altman plots and Pearson correlation co-efficient to see if a single simulation was representative.

Results

A total of 3150 fraction doses were simulated for setup uncertainties robustness analysis. All D_{sum} met both robustness criteria for the target. For D_{frac}, out of 30 simulations (3x10 patients), 30, 25 and 30 met the CTV $D_{98\%}$ criteria and 30, 9 and 29 met the CTV $V_{66.5Gy}$ in VMAT, PTV and MM-IMPT plans respectively. Whilst VMAT plans showed superior target coverage robustness, 2 VMAT D_{nom} plans did not meet lung constraints. Additionally, out of 30, 3 VMAT, 5 PTV-IMPT and 3 MM-IMPT D_{frac} plans failed to meet OAR constraints. Compared to VMAT, IMPT plans deliver significantly lower mean lung dose, lung V_{5Gy}, V_{20Gy}, heart V_{5Gy} and maximum dose to the spinal cord (p<0.05). Overall 7, 3 and 8 out of 10 VMAT, PTV- and MM-IMPT plans respectively were considered acceptable at the prescription dose. Comparison of dose within the CTV at voxel level showed excellent correlation between each simulation for VMAT, PTV-IMPT and MM-IMPT (r=0.89-0.97, p<0.001).

Conclusion

Although all summed plans met the target robustness criteria for setup uncertainty, fraction doses showed differences in plan qualities, in particular for PTV-IMPT plans. Overall, MM-IMPT plans showed comparable robustness to VMAT plans. PTV-IMPT should be avoided for treatment of lung cancer. Probabilistic scenarios is a feasible method for analysing robustness of stage III NSCLC VMAT and IMPT plans.

EP-2063 An audit of adaptive radiotherapy in a large centre

R. Chuter[1], S. Brown[2], P. Whitehurst[1], J. Handley[1], C. Faivre-Finn[2], M. Van Herk[3]
[1]The Christie NHS Foundation Trust, Christie Medical Physics and Engineering CMPE, Manchester, United Kingdom
[2]The Christie NHS Foundation Trust, Clinical Oncology, Manchester, United Kingdom
[3]University of Manchester, Manchester Cancer Research Centre, Manchester, United Kingdom

Purpose or Objective

All patients considered to exceed on-treatment imaging tolerances are referred to physics for assessment against the original plan objectives. If the original objectives are not met the patient is rescanned and planned. This audit was undertaken to assess the extent to which replans were necessary by tumour site with the intention to inform and prioritise future adaptive workflows for photons and protons ensuring that resources and research is focussed on the tumour sites where it is most required.

Material and Methods

A retrospective audit of all queries requiringg physics input in 2016 were analysed. These were categorised according to the nature of the request with CBCT related queries further divided into 4 categories; anatomical change, moves/shifts, bolus position verification and other CBCT related queries. These were then split according to tumour site in order to demonstrate the problems encountered across different sites.

A further retrospective analysis over 4 years of the Pinnacle 9.10 (Philips Radiation Oncology, Andover, USA) plan files was undertaken to investigate which sites

required repeated planning. The data was analysed using an in-house python script to separate the plans by treatment site and whether they had been re-planned.

Results

In 2016 physics assistance was requested on 3,840 occasions out of the ~110,000 fractions treated in that period. Of these 43.5% of requests were for cone beam CT (CBCT) review. Within this group anatomical change was the main reason for the CBCT review (54.1%). Lung was the dominant tumour site and accounted for 39.2% of CBCT reviews and 41.5% of CBCT reviews related to anatomical change (see Figure 1 (a)). This was followed by head and neck tumours (31.9% and 31% respectively).

The results of the 4 year analysis of Pinnacle plans (excluding breast) shows that overall 1.9% of all cases receive a replan. The percentage of replans per site is shown in Figure 1 (b). For each site the percentage of replans is shown in Figure 2. This varies site by site with bladder patients most frequently requiring plan adaptation with 4.3% needing a replan, while 2.6% of lung patients require a replan.
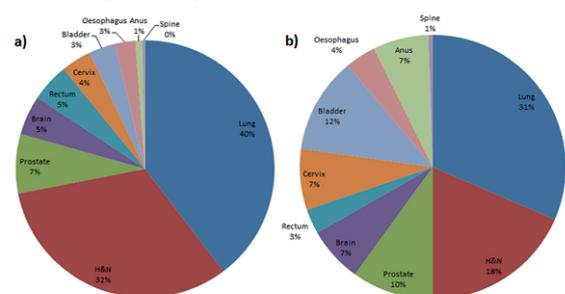

Figure 1 – a) The percentage of patients requiring physics attention for CBCT review and b) the percentage of patients that had a replan by site
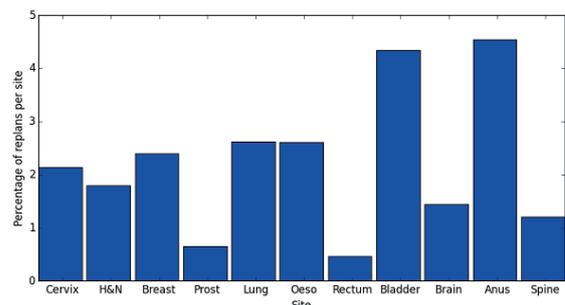

Figure 2 - The percentage of patients that need a replan by site

Conclusion

This audit demonstrates that ~40% of adaptive assessments on CBCTs are for lung patients with anatomical changes. Despite this only ~30% of all replans are lungs. A similar situation is true for H&N plans which take up 32% of CBCT adaptive assessments but only result in 18% of replans. Our replan rate of 1.9% agrees a previous study[1], stating that <5% of patients are likely to need a replan.

This work will aid the development of improved IGRT protocols reducing the number of plans that are referred for adaptive assessment thus improving the treatment workflow and allowing resources to be directed where they are most needed. It will also inform the workflow design of new technology such as PBT and the MR-Linac.

Reference - [1] Rowbottom C, The Practical "costs" of adaptive radiotherapy, ESTRO 35, 2016, SP-0394

EP-2064 Intra- and inter-fractional motion in radiotherapy of rectal cancer quantified using MRI and CBCT

C. Skinnerup Byskov[1], L. Nyvang[1], A. Harbøll[2], A. Schouboe[2], E.M. Pedersen[3], C.J.S. Kronborg[2], O. Casares-Magaz[1], P.R. Poulsen[1], K.L.G. Spindler[2,4], L.P. Muren[1]