Material and Methods: By using a CIRS 062 phantom, conversion curves (Hounsfield Unit, HU, to pel ) for two different Varian CBCT models and for head and pelvis protocol were measured. Diffusing material was added to the phantom to simulate the typical dimensions of the anatomical districts. A dosimetric analysis was then performed for CIRS phantoms and patients treated for H&N and prostate cancers, by comparing dose distributions calculated on the same CBCT using different HU-pel conversion curves. For each case, the plan-CT and CBCT images were registered rigidly. A VMAT plan was generated on the plan-CT and transferred to the CBCT. The dose was calculated on the CBCT without heterogeneities corrections, using the plan-CT conversion table and using the CBCT site-specific conversion tables. The distributions were compared to the reference distribution (Dref) with 3D gamma analysis, Dref being the dose calculated on the plan-CT using its proper conversion curve. For each comparison the net disagreement was calculated, i.e. the percentage of points that exceeded gamma criteria without taking into account discrepancies due to registration errors (DTA = 2mm for phantoms, 3 mm for patients).

Results: For the CIRS phantoms, the CBCT conversion curves gave good results for dose calculation: mean net disagreement for gamma criteria DO= 1% was lower than 1%. For the pelvis region, the best results were obtained without applying heterogeneity corrections to the calculation. The dosimetric discrepancies with respect to Dref were few and mostly below 2% of the local dose. For H&N patients, calculations with the CBCT site-specific conversion curves showed the smallest discrepancies with Dref. On average, 0.4% of the points showed discrepancies larger than 1%.

Conclusion: The differences between the results found for phantoms, pelvis and H&N patients highlighted the importance of careful evaluations for each anatomical region. The error introduced by calculating the dose on a CBCT is acceptable for ART. CBCT dose calculation could be used to monitor the dose distribution due to the lack of scattered radiation or patient shoulders in case of H&N treatment. This affects dose calculation in case of H&N treatment. Further investigations are necessary to map the reason for the differences between image series acquired with these machine types as a step towards implementing deformable image registration using CBCT.

Material and Methods: Characterization of kV- and MV-CBCT for personalized adaptive treatment therapy on RayStation TPS

Purpose or Objective: Modern treatment therapy, with the combination of intensity modulated fields, dose escalation and small margins, is unthinkable without equipment that facilitates IGRT. Hence, the latest generations of linacs are equipped with modern kV and MV detectors, with enhanced image quality and precision. RayStation TPS exploits this development further, making it possible to use these image series to execute personalized adaptive treatment planning, by using the acquired CBCT during treatment. Our goal with this project is to characterize the geometrical and dosimetric data of different CBCT types from different machines (Elekta XVI, Varian TrueBeam OBI and Siemens Artiste kView).

Material and Methods: Using CatPhan phantom, planning CT with a Philips BigBoard Brilliance, Head&Neck protocol were acquired on imported PET CPCT. The advantage of using CatPhan is, that it has both geometrically known and accurate measures, and inserts with known CT numbers. CBCT series were acquired by using Head&Neck protocols. The captured image series were then imported to RayStation, where, after rigid image registration, all the characteristics of the CBCT images were investigated, and doses recalculated on the CBCT image series.
Results: For GTVs the median DICEs were 0.88 and 0.63 for RH and H, respectively, while for parotid gland were 0.94 and 0.82, and for spinal cord were 0.94 and 0.88, respectively. Although dose differences on GTVs show the median variations within 1% with minimal values up to 8%, TCP values were 63.7%, 69.7% and 61.9 % for planned, RH and H approach, respectively. Moreover, the average NTCP for homo-lateral parotids it was 36 %, 46 % and 34 %; while for contra-lateral parotids was 28%, 36% and 27% based on planned, RH-based and H-based accumulated DVHs, respectively.

Conclusion: RH strategy generates structures well in agreement with ones manually contoured, supporting the goodness of generated deformation matrix, resulting an appropriate strategy to perform dose tracking in HN cancer patients eligible for ART. Home-made tools/routine, as developed in this work, are mandatory to evaluated results and permit the adoption of a dose tracking strategy.

Purpose or Objective: Pre-requirement for adaptive RT for LACC. Delivered dose determination in large organ deformations: Deformation algorithm. Clinical evaluation includes clinical target volume (CTV) coverage for patient with locally advanced cervical cancer (LACC).

Material and Methods: Between June and September 2015 five consecutive LACC patients were scanned with empty and full bladder conditions for treatment planning purposes. Primary CTV was delineated in both scans creating an internal target volume (ITV) concept and the distance between the tip of the uterus was measured. Primary ITV and lymph node CTVs were expanded with 10 mm margin to generate the planning target volume (PTV). Advanced treatment planning technique (VMAT or IMRT) were used for delivering a total dose of 45 Gy in 25 fractions with daily online correction CBCT. On every CBCT the 1) current position of the primary CTV were delineated and 2) the planned dose matrix were co-registered and eventually transposed to CBCT rigidly. Using the Mirada RTx (version 1.6.2, Mirada Medical, Oxford, United Kingdom) between the planning CT and a CT acquired on CBCT a “CTV-guided” deformation (using the RBF-RPM algorithm) matrix were generated to deform the dose matrices from CBCT to the planning CT. The dose parameters on the initial CTV were estimated on a single fraction basis (worst and average) and summed dose basis compared to the reference plan value.

Results: The average tip movement of the uterus was 2.2 cm (range 0.5-5.7 cm). A total of 118 CBCTs were eligible to perform the CTV delineation and the dose matrix transformation (rigid CT to CBCT, deformation CBCT to CT). Visual verification of each individual deformation grid were considered as clinically plausible and smooth (Figure 1). The changes in CTV-V95% were -4.7% (range [-7.0,-3.62], -0.3% [-1.4, 2.2]) for the single fraction worst and mean, while for the summed actual delivery -0.6% [-3.7, 1.76]. Deviation of CTV-D95% resulted in -2.7 Gy [-5.8, -1.1] and -0.4 Gy [0.9, -0.2] for the single fraction worst and mean, while for the summed actual delivery -0.5 Gy [-2.1, 0.1].

Conclusion: Using VMAT/IMRT for LACC treatment in combination with ITV concept and 10 mm margin provides a safe treatment option in the presence of large daily organ deformation. The dose accumulation using the RBF-RPM algorithm is feasible and provides a powerful tool to evaluate delivered dose not only to CTV but also to organs at risk. This methodology allows an environment to test various adaptive strategies (e.g. library of plans based LACC radiotherapy) and CTV to PTV margins in a safe retrospective manner.

Electronic Poster: Physics track: CT Imaging for treatment preparation

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An empirical post-reconstruction method for beam hardening correction in CT reconstruction
B. Yang1, H. Geng1, W.W. Lam1, K.Y. Cheung1, S.K. Yu1
Hong Kong Sanatorium & Hospital, Medical Physics and Research Department, Happy Valley, Hong Kong SAR China

Purpose or Objective: Beam hardening artifacts in X-ray computed tomography is caused by the polyenergetic spectrum of X-ray source. In this abstract we describe an empirical post-reconstruction method which removes the artifacts successfully.

Material and Methods: Our proposed post-reconstruction method has similar approach as a well-known correction method first developed by Joseph and Spital (J&S). Our method also requires prior knowledge of the X-ray spectrum and consists of three stages of correction. The first step is a so-called soft tissue correction which determines the equivalent length of soft tissue Te by solving the non-linear equation:

\[ Pi = \sum \exp(-\mu(s)\rho(s)Te) \]

In the second step, this image is segmented into soft tissue Ts and high density Tb (e.g. bone) region by setting a threshold. Different from J&S, we consider \( \mu(s)\rho(s)Tb \) as part of the density map of high density region and calculate the projection data:

\[ Bi = \sum \exp(-\mu(bj)\rho(s)Tb) \]

The third step applies the soft tissue correction again by solving the non-linear equation:

\[ \exp(-\ln(Pi)+\ln(Bi))=\sum \exp(\mu(s)\rho(s)Tb) \]

, therefore a density map \( \rho(s)Tb \) is reconstructed. The final image will be the sum of \( \rho(s)Ts \) and \( \rho(s)Tb \). We created a 128 x 128 pixel numerical phantom which was a circular phantom consisting of water, four small regions containing bone and a small region containing fat. For validating the robustness of the method, we also replaced the four small regions with those containing aluminum and titanium. The projection data consisted of 140 radial samples and 100 angular samples over 180 degree from a 100 kVp parallel X-ray beam.

Results: The results of the post-reconstruction method for the phantom containing bone, aluminum and titanium are shown respectively. Within each figure, top left is the true phantom image; the middle is the direct filtered back projection (FBP) result with no correction; the top right is the post-reconstruction result; the profile plot is sampled at the center of phantom. For the cases of bone and aluminum, the beam hardening artifacts are removed successfully. Even in the most challenging case of titanium, the artifacts are suppressed greatly. Compared with the results using method from J&S, the density values of reconstructed high density