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Gold seed markers in prostate bed image-guided radiotherapy

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Purpose/Objective: This study aimed to investigate the magnitude of interfraction prostate bed motion and delineate reasonable CTV-PTV margins in situations where image-guided localization is performed using an analysis of bony anatomy landmarks or gold seed fiducial markers and in situation where image-guidance is applied more sparsely and patient set-up is done according to patient's skin marks.
Materials and Methods: Thirteen prostate cancer patients, who had been implanted four gold seed fiducials into their prostate bed, were imaged daily by cone beam CT (CBCT) before radiotherapy. In total, 466 CBCT images were analyzed and total position error, set-up error and prostate bed motion were measured by analyzing the position of gold seed fiducials and locations of bony anatomy landmarks. Systematic and random errors were calculated and CTV-PTV margins were determined for the situation where 1) the fractions are delivered according to patient's skin marks, 2) the IGRT is performed for the first three treatment fractions, whereas the rest of the fractions are delivered according to patient's offset skin marks, and 3) the IGRT is executed daily and the localization is based on bony anatomy landmarks.
Results: CTV-PTV margins were 4.9 mm in the left-right (LR) axes, 8.0 mm in the superior-inferior (SI) axes and 7.4 mm in the anterior-posterior (AP) axes when the localization was done aligning to skin marks (i.e. without the IGRT). If imaging was performed on the first three treatment fractions and the rest of the fractions were treated according to patient's offset skin marks, the margins were 2.4 mm, 6.5 mm and 6.6 mm in the LR, SI and AP axes, respectively. If daily IGRT was performed and localization was done by bony anatomy landmarks, margins were 1.4 mm, 5.9 mm and 5.9 mm in the LR, SI and AP axes, respectively.
Conclusions: Daily pre-treatment CBCT can reduce CTV-PTV margins for 72%, 26% and 20% in the LR, SI and AP axes, respectively. Prostate bed motion seems to have a relatively more significant impact to the SI and AP margins when compared to set-up error, which has more important role in the LR margin. The alignment of bony anatomy landmarks on daily basis does not reduce margins significantly hence it is reasonable to use imaging more sparsely in that case. In daily IGRT either the use of CBCT or the gold seed fiducial localization seems profitable.

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Impact of motion in advanced paediatric abdominal radiotherapy.

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Purpose/Objective: Advances in radiotherapy technology have sought to mitigate the effects of patient movement, organ motion and anatomical deformation on the efficacy of treatment delivery [1]. The irradiation of abdominal tumours such as Neuroblastoma in paediatric patients presents a challenge to deliver an adequate dose to the target dose whilst minimising dose to surrounding tissues. The majority of the published data for motion for abdominal organs have been acquired from the adult population [2][3]. Paediatric data is limited to one article on 4DCT on 20 free-breathing patients and a second evaluating CBCT for 9 patients under general anaesthesia [4][5].
References available on request.
Materials and Methods: The radiotherapy database was reviewed to extract those paediatric patients that were treated for abdominal tumours with Intensity Modulated radiotherapy with Cone Beam CT (CBCT) verification during treatment for 2011/2012. The CBCT scans were then 'co-registered' to the vertebral bones of the reference helical planning CT within the ECLIPSE v10.0 planning system (Varian Medical Systems) in order to demonstrate soft tissue motion relative to the planning CT. In ECLIPSE, both kidneys were then re-delineated from the matched dataset onto the reference planning scan. In addition, areas of bowel gas were re-delineated in the same fashion. The re-delineated volumes were compared for changes in 'apparent' volume and centre of mass. The dosimetric effect of these changes was also calculated.
Results: Six paediatric patients were able to be included in this review with a total of 31 CBCT scans. Each patient had at least one CBCT acquired per week. All patients demonstrated 'apparent' kidney volumes different from the planning ct. Range of kidney volume change (All CBCTs): [-0.3% (±5.2) to +27.0% (±14.0)] . Maximum Centre of Mass change vector: [+0.9cm (±0.3cm)]. The principal direction of kidney motion is in the cranial-caudal direction as described by other authors. All patients also demonstrated large variations in bowel gas volume and distribution. Anatomical positional variations and bowel gas changes led to changes in delivered dose to Organs at Risk.
Conclusions: Highly conformal plans based on a helical CT in this patient cohort may not be able to deliver the planned dose due to the variations in anatomy described. Methods to characterise the motion such as 4dCT or limit the motion such as abdominal compression should be considered. Interventions such as those used in the adult practice to reduce the impact of bowel gas should be evaluated for suitability in this population. Reduction in bowel gas will improve CBCT image quality. Linac-based CBCT verification strategies must also be investigated to reduce potential dosimetric variation.

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Calculation of the dose of the day using an in-house validated deformable registration algorithm

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Purpose/Objective: Validate an in-house deformable registration algorithm in order to calculate the 'dose of the day' and assess the need to replan head and neck (HN) patients, by deforming a planning CT (pCT) to match the daily CBCT scan.
Materials and Methods: Data from 3 HN patients treated in our clinic was used in this study. These patients considerably changed shape throughout their treatment and therefore required replan midway. Therefore, in addition to the pCT and weekly CBCTs, a rescan CT (rCT) was also available. We register the pCT to a CBCT using an open-source deformable registration algorithm developed at our institution (NifTK). Two tests were performed to assess the quality of our registrations: (i) structures delineated in the pCT were warped and compared with contours manually drawn by the same physician on the CBCT and (ii) dose calculations for the same IMRT plan on the deformed CT and rescan CT (rCT) were compared. The structure set used on the first test was a mixture of bone and soft tissue structures, such as vertebras and neck muscles, which can be seen unequivocally on the pCT and CBCT. Since the rCT and following CBCT are acquired 5-7 days apart, they do not represent the same geometry. To minimize errors in the dose calculation due to inaccuracy in representing the real geometry, we actually registered the pCT to a simulated CBCT, obtained from deforming the real CBCT to match the rCT. This simulated CBCT is a better representation of an ideal dataset, in which the rCT and CBCT would have been acquired at the same time. The dose distributions were compared using dose-difference (DD), gamma analysis (γ), target coverage (using isodose surfaces) and DVHs.
Results: The warped structures showed a good agreement with the manually drawn ones, with more than 90% of the warped surface pixels being distanced less than 2mm off the manually drawn ones. The dose distributions were compared within a region of interest that contained the rCT body that received dose plus a 5mm margin. The dose to critical structures, such as parotids, brainstem and spinal canal, was also assessed. The mean DD value was less than 1% of the prescribed dose and 92.6% of the voxels have a DD less than 2% of the prescribed dose. The gamma analysis of the dose distributions passed with 96-98% of the voxels agreeing within 2% DD and 2mm distance-to-agreement (DTA). The 95% isodose surfaces were shown to have a mean dice similarity index (DSI) and overlap index (OI) of 0.959 and 0.971 respectively. DVHs were found to be in good agreement for the brainstem, spinal cord and parotids curves. The relative error estimating the absolute dose to the brainstem and spinal canal is 4.20% and 0.35% on the deformed dataset.
Conclusions: Our preliminary results indicate that pCT to CBCT deformable registration can be used to estimate the 'dose of the day'. The structures of interest warped from the pCT can be used to compute daily DVHs. This strategy has potential clinical use to evaluate the need for a replan without significant increased workload to the clinic.

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