Proffered paper

Treatment of prostate cancer

539 oral

INTERIM RESULTS FROM A RANDOMISED TRIAL COMPARING THE BLADDER VOLUME CONSISTENCY ACHIEVED WITH TWO BLADDER-FILLING PROTOCOLS IN PROSTATE CONFORMAL RADIOTHERAPY.

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Purpose: As a consequence of more conformal treatment techniques in prostate radiotherapy, dose distributions are increasingly conformed to target volumes and become more sensitive to treatment uncertainties, such as organ motion. Hollow organs present difficulties because of their variation in volume and position according to differences in filling. The optimal bladder-filling instructions for prostate patients remain to be determined. The aims of this trial are to compare the current institutional bladder-filling instructions (1080ml H20, 30 mins delay - Arm A) to instructions that might be less demanding on patients (540ml H20, 30 mins delay Arm B) in terms of consistency of bladder volume achieved during radiotherapy treatment; acute GU and GI toxicity; patients' satisfaction and quality of life; and staff satisfaction.
Materials: n = 220 radical prostate patients. Bladder volume measurements are obtained using the BladderScan^{TM} Instrument (BVI), immediately prior to obtaining the planning CT scan and verification and approximately twice during each week of treatment. The bladder volumes obtained during treatment are compared with the BVI volume obtained at the planning CT scan.
Results: Interim analysis on the first 50 patient to complete RT found that the CT bladder volumes were significantly less than the treatment volumes for both arms (Arm A(6 cups) p=0.02; Arm B(3 cups) p=0.001). Verification bladder volumes were not significantly different from treatment volumes for both arms (Arm A, p=0.12; Arm B, p=0.98). Treatment bladder volumes were relatively consistent for individual patients on both Arms. Toxicity showed no significant difference between both Arms, except for dysuria, where the incidence was higher in Arm A. Median comfort scores are significantly higher (more comfortable) for patients in Arm B, p=0.026. A possible reason for this inconsistency between planning CT, verification and treatment bladder volumes may be due to a pre-hydration letter that is sent to patients prior to their CT appointment. This letter requests patients to pre-hydrate i.e. to drink approximately 2/3 l of H2O daily, for 3 days prior to their planning CT appointment. This may have resulted in the patients having large bladder volumes at time of CT and subsequently smaller volumes at time of verification and treatment. Patients no longer receive any pre-hydration instructions prior to appointments.
Conclusions: Our initial results showed that patients are not achieving consistent bladder volumes between planning CT and treatment. Changes on treatment from planning CT bladder volume have dosimetric consequences that may impact on normal tissue complication probability. The change in hospital policy to remove the pre-hydration letter may result in increase consistent between planning CT and treatment. Results from this further analysis will also be available for ESTRO 27.

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CONFORMAL PROSTATE RADIOTHERAPY:HOW HAS THE ROUTINE USE OF CONE BEAM CT INFLUENCED CLINICAL PRACTICE?

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Purpose: To analyse the impact of the introduction of routine cone beam CT (CBCT) off-line imaging protocols in prostate radiotherapy and identify factors to help select at planning which patients may benefit from CBCT instead of or in addition to MV portal imaging.
Materials: A retrospective review of the CBCT images of 32 patients receiving conformal prostate radiotherapy (55Gy in 20 daily fractions). Patients received information on diet and some received regular laxatives prior to treatment. CBCTs were acquired off-line fractions 1-3 and then once weekly (6 planned CBCT/ patient). Images were reviewed by a clinician with a treatment radiographer. Bone and CTV set up errors (SUEs) were recorded every fraction and population averages calculated. AP rectal diameters were measured at the superior, isocentre and inferior planes. Interventions included isocentre shifts (if systematic CTV SUEs > 5mm), giving patient further diet advice or laxative. Fybogel (bulking agent) was prescribed if random changes in rectal distension seen. The intervention rate was assessed.
Results: Using CBCT the mean CTV population SUEs were < 3mm in all directions. AP displacements accounted for 90% of CTV SUEs with 76% seen in the anterior direction. CTV SUE exceeded bone SUE for 59% of patients.In total 226 CBCTs were acquired (192 planned) resulting in 86 changes in patient management. 75% of imaged fractions resulted in intervention. The intervention rate was greater for treatments including seminal vesicles vs. prostate alone. If bony SUEs only had been used only 19% of patients would have required an intervention. The population mean AP rectal diameter at the isocentre was 4.2cm. Larger rectal diameter was not directly proportional to larger CTV SUE but differences in diameter > 1cm between superior, isocentre and inferior levels were associated with greater CTV errors. Sagital rectal shapes at planning scan were categorised into Pyramid, Inverse Pyramid, Diamond, Hourglass and Regular. Inverse pyramid and diamond shapes were associated with greater CTV SUEs and could be used at planning to identify those patients who would benefit most from CBCT.
Conclusions: The workload and intervention rate increased with CBCT compared to standard 2-D approaches but did allow more accurate treatment delivery. Patients who may benefit from CBCT imaging can be identified at planning scan by the size and sagital shape of the rectum. Treatments to the prostate and seminal vesicles are subject to more error than prostate alone and also may benefit from CBCT imaging.

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PROSTATE ROTATION DETERMINED FROM DAILY IN-ROOM COMPUTERISED TOMOGRAPHY (CT) IMAGES.

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Purpose: To determine the rotation of the prostate in the sagittal, transverse and coronal planes using implanted fiducial markers and in room computed tomography (CT) images.
Materials: Daily in treatment room CT (Siemens Primatom^{TM}) images (mean number per patient = 34) of 3.0mm slice thickness and pitch 1.5 (512 X 512 matrix, 50cm FOV) were acquired for 10 patients during their radiotherapy treatment for prostate cancer. Each patient had 3 fiducial markers implanted into the prostate apex and left and right lobes. The CT scans were evaluated after correction of the patient position to $\leq$2.0mm of the planned position. The coordinate locations of the 3 markers were identified relative to the centre of volume (CoV) coordinate of the prostate contour. Each patient's data set was assessed individually. Where possible the marker in the apex of the prostate was used as the pivot point of rotation along each axis. The coordinates of the other 2 markers in the corresponding dimension (eg. for rotation along the sagittal plane the AP and SI coordinates are required) were averaged and the degree of rotation was calculated using trigonometry. Prostate rotation was computed 1) relative to the planning CT scan and 2) relative to the average rotation found in the first 5 fractions (n= 6 including the planning CT scan).
Results: A total of 341 CT images were evaluated. The group systematic rotational error was 7.8° in the sagittal and 3.8° and 0.9° in the transverse and coronal planes respectively. This error was reduced to -1.4° and -2.1° in the sagittal and transverse planes respectively when the average rotation of the first 5 treatment fractions was used as the reference. Rotation in the coronal plane increased from 0.8° to -3.3°. For 2 patients, the rotation in the sagittal plane varied by more than 30° from planning CT and in 4 patients the rotation in this plane was $\leq$5.0°.
Conclusions: Considerable rotation of the prostate exists. Information from a single CT scan does not adequately reflect prostate rotation during a course of radiation. A systematic correction based on the average of the first 5 fractions reduced the rotation error of the prostate for subsequent treatment fractions. Adapting the treatment plan to reflect this could potentially increase precision and save time between image acquisition and treatment delivery due to complex corrections that may be required at each treatment session.

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DOSIMETRIC ANALYSIS OF TREATMENT PLAN DEGRADATION AFTER LARGE SHIFT CORRECTIONS DURING IMAGE-GUIDED RADIATION THERAPY (IGRT) FOR THE TREATMENT OF PROSTATE CANCER.

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Purpose: The use of image guided radiation therapy (IGRT) to correct for day-to-day systematic setup errors is essential to minimize the dose variation

to the treatment target. Many studies have previously shown these variations with and without IGRT correction. We now investigate the dose variations to the surrounding normal structures after IGRT correction. With regards to large shifts of the isocenter, the initial intensely-modulated radiation therapy (IMRT) calculations may no longer be applicable because IMRT delivers precise amounts of dose with small segmented fields based on fixed anatomical locations.
Materials: IGRT CT scans from prostate cancer patients treated with external beam IMRT were compiled and examined. Our IGRT system is comprised of a linear accelerator with an in room diagnostic CT-on-rails attached to the same treatment table. Patients with final shift corrections ranging in magnitude from 5mm to 15mm in the anterior / posterior direction were reviewed. Results were analyzed to determine the variations between the initial treatment plan calculations versus the original treatment plan superimposed and recalculated on the daily IGRT CT scans with the appropriate shift implemented.
Results: Even with large shift corrections (10mm or more), neither the PTV coverage nor mean dose to the PTV was significantly affected with the largest difference being 2 3%. In addition, the coverage to the prostate gland did not change significantly regardless of the resulting shift magnitude from IGRT. However, rectal dose was significantly affected with mean dose differences ranging from 15 25% in severe cases. These differences also increased as shift magnitude increased and were additionally magnified with large changes in treatment planning parameters such as depths and effective path lengths. These existing changes were random and non-specific to any one single parameter, but the overall dosimetric variations for the rectum were significantly affected, particularly with shifts greater than 10mm in the AP/PA direction.
Conclusions: The positional changes of the target, normal tissue, and differences in beam parameters taken individually do not cause significant breakdowns in the original treatment plan, but these changes taken as a whole and compounded, result in dramatic DVH degradation. To our knowledge, this is the first report of dosimetric degradation of initial treatment plans to the surrounding normal structures after IGRT corrections. These changes in dosimetry may be critical, especially when clinicians have based their estimates of current or future side effects/complications on the initial treatment plan DVH. As such, with large shifts to the isocenter and positions of normal tissues surrounding the target, mere IGRT isocentric corrections may not be adequate and further consideration for some type of re-planning maybe needed.

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RADIOTHERAPY WITH SIMULTANEOUS INTEGRATED BOOST AS A TREATMENT FOR PROSTATE CANCER WITH A MAGNETIC RESONANCE (MR) DETECTED INTRA-PROSTATIC LESION (IPL): A PLANNING STUDY OF IMAT VERSUS IMRT.

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Purpose: To compare 4 different planning techniques for patients with localized prostate cancer presenting with a MR-detected IPL.
Materials: This planning study involves 12 patients. All of them had a MR or MRI-spectroscopy detected IPL. For treatment planning, the following anastructs were delineated on CT-images: 1. IPL, CTV (prostate + seminal vesicles). 2. rectum, sigmoid colon, bladder and femoral heads. The PTV was created with a 4 mm isotropic margin around the CTV. The plans were optimised by GRATIS®(Sherouse Systems Inc.chapel hill,NC,USA) in order to achieve a median dose on the IPL, CTV and PTV of 86, 78 and 76 Gy respectively, given that the maximal dose on the rectum did not exceed 76 Gy. For each patient, 4 different planning techniques and 2 different photon energy levels (6 and 18 MV) were compared, resulting in 8 treatment plans. We compared 3 IMRT techniques with SB-IMAT. The IMRT plans consisted of 3 (0°-116°-244°; IMRT_3), 5 (0°-45°-90°-225°-270°; IMRT_5) or 7 fields (20°-70°-120°-170°-210°-260°-310°; IMRT_7). Dose volume histograms were used to compare treatment plans. Physical and biological (NTCP) endpoints (see Table) were evaluated using a mixed model ANOVA and post-hoc Scheffe tests. Planning technique and photon energy were used as fixed factors. Patient ID was used as a random factor.
Results: There was no significant difference between 6 and 18 MV photons for the same planning technique. For CTV and IPL Dmin, Dmed and Dmax were significantely higher for IMAT compared to the IMRT plans (p<0.0001). The absolute gain in Dmin was ≥1 Gy for CTV (77 vs. ≤76 Gy) and IPL (84 vs. ≤83 Gy). The absolute gain in Dmed was ≥3 Gy for CTV (84 vs. ≤81 Gy) and ≥2 Gy for IPL (88 vs. ≤86 Gy). For PTV, Dmed and Dmax were superior with IMAT, with an absolute gain of ≥2 Gy (p<0.0001). The rectal volume receiving 10, 20, 30, 40, 50, 60 and 65 Gy was significantely lower with IMAT (p<0.0001), resulting in a drop of NTCP of ≥2 % (4% vs. ≥6%). The same was noticed for all physical sigmoid endpoints (p<0.0001). The bladder volume receiving 30, 40, 50, 60, 65 and 70 Gy was significantly lower with IMAT (p<0.0001). For the femoral heads there were no differences.
Conclusions: The use of IMAT resulted in opposite effect on relevant dose indices for targets (higher doses) and OARs (lower doses) suggesting an improved therapeutic index for IMAT.

	targets			
	CTV	PTV	IPL	
Dmin	x	x	x	
Dmed	x	x	x	
Dmax	x	x	x	
	organs at risk			
	rectum	sigmoid	bladder	femoral heads
V10	x	x	x	0
V20	x	x	x	0
V30	x	x	x	0
V40	x	x	x	0
V50	x	x	x	0
V60	x	x	x	0
V65	x	x	x	0
V70	x	x	x	0
V75	0	0	x	0
Dmax	0	0	x	x
NTCP	x	0	0	0

544 oral

ROUTINE USE OF ANO-RECTAL DOSE SURFACE MAPPING IN EXTERNAL BEAM RADIOTHERAPY OF THE PROSTATE

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Purpose: The size and spatial distribution of regions of the ano-rectal wall (Awall and Rwall) exposed to low dose external beam irradiation predict for late toxicity (1). An endorectal balloon (ERB), used for many years now in our department, is capable of producing a favorable dose distribution with less Rwall damage compared to treatment without an ERB (2). The purpose of this work is to describe and demonstrate the use of Rwall dose surface maps (DSM) and dose surface histograms (DSH) in order to correlate them to Rwall damage as observed in follow-up endoscopy.
Materials: Patients undergo a CT-scan and are treated with a daily inserted 100 cc air-filled ERB. In the Pinnacle treatment planning system, the physician delineates the standard regions of interest (femoral heads, bladder) plus both the Rwall (inner and outer Rwall) and the anal wall (Awall) (inner and outer Awall). After treatment planning the required dose data from the Pinnacle plan are exported to home-made software (Radiation Dose Viewer (RDV)) that is used for the construction of DSMs. Both 2D and 3D images of the dose distribution on the Rwall and Awall surface can be produced. The 2D-map can be exported to Excel in table format for later usage. The rectum is virtually folded open and the dose to the inner rectal wall is displayed two-dimensionally (fig 1a). The rectum is virtually divided into multiple mucosal areas for comparison with endoscopic mucosal assessment at follow-up. DSHs of the Rwall and Awall can be produced by exporting the Pinnacle plan to the Computational Environment for Radiotherapy Research (CERR) (fig 1b). Regular follow-up with endoscopy is performed to correlate late Rwall damage with Rwall DSM (2). An Excel spreadsheet has been developed that allows for an automatic update when new patients or data are entered into this prospective study.
Results: With the inserted ERB the delineation of the Rwall and Awall is easy because of the introduced air cavity. A trained research technologist is able to construct the DSM and DSH for each patient, within 30 minutes. So far, Rwall dose maps and DSHs have been constructed for 150 patients and compared with mucosal damage assessment during follow-up.
Conclusions: RDM and DSHs are now standard in our daily prostate radiotherapy practice. Trained technologists are capable of constructing these visual tools. Our set of patient data is steadily growing and will be correlated to the observed Rwall damage scored by endoscopy to provide more insight into late anorectal toxicity.References: 1. Tucker et al. IJROBP 2006; 64:1255-64. 2. van Lin et al IJROBP 2007; 67:799-811

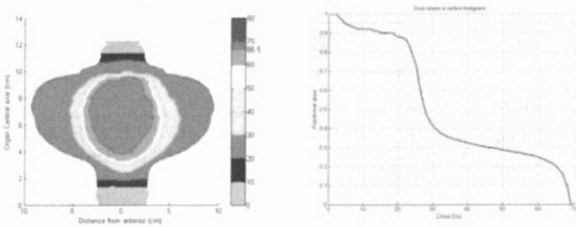

Fig.1 2D Rwall and Awall dose surface map (a), and ano-rectal dose surface histogram (b)

Symposium

Reliability of IGRT

545 speaker

RELIABILITY OF THE BONY ANATOMY IN IMAGE-GUIDED STEREOTACTIC RADIOTHERAPY

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Current standard for verification of patient positioning is electronic portal imaging using the therapeutic megavolt x-ray beam. Image quality and especially soft-tissue contrast is limited as result of the high x-ray energy. Consequently, the bony anatomy usually serves as surrogate for the actual target unless radio-opaque markers are implanted into or near the target. Since recently, in-room kilo-voltage volume imaging is available offering high spatial resolution combined with improved soft-tissue contrast making pre-treatment verification of the target position itself possible. In high precision radiotherapy of cranial and extra-cranial lesions, so-called "frameless" stereotactic radiotherapy has been described: the stereotactic system of external coordinates is replaced by image-guidance. For some indications a fixed relationship between the target and the bony anatomy has been demonstrated. Image-guidance matching the bony anatomy is consequently reliable. However, internal mobility independent from the bony anatomy has been described especially for intra-pulmonary targets and targets located in the upper abdomen. In such cases, image-guidance targeting the lesion itself has been shown to significantly increase accuracy of treatment.

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IMAGE-GUIDED VERIFICATION WITH AN EPID IN CINE MODE

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Purpose: During conventional radiotherapy, the location of the patients' anatomy, particularly the tumor, while the treatment beam is on is of primary importance. This becomes especially relevant in treatment sites where large intra-fraction motion has been observed (upper abdomen and thorax). We have demonstrated a method for monitoring the target during irradiation with beam's-eye-view (BEV) imaging, and then using the intra-fraction data to retrospectively calculate the delivered dose. This can be done in between each fraction and the cumulative treatment dose updated daily. If discrepancies are seen between planned and delivered, the treatment may be altered such that the delivered distribution converges with the plan. Method and Materials: The radiotherapy target is visualized daily during radiotherapy by collecting the exit radiation with an electronic portal-imaging device (EPID) in cine mode. In between each fraction, the location of the target in the treatment images is compared with the reference position from simulation. The in-treatment target positions are introduced in the treatment planning software as sub-fields representing equal fractions of the original fields' monitor units. The dose distributions from each of the sub-fields are summed to calculate the dose delivered each day. This distribution is updated daily to provide the cumulative delivered dose distribution. Results: The target position during radiotherapy has been recorded and the dose-volume histograms (DVH) for the planned and delivered distributions have been calculated for several patients. Delivered doses to target and critical structures are generated for each fraction and cumulatively. Using the cine EPID method, we have discovered several cases of unexpected, non-periodic intra-fraction motion. Note that this in-treatment monitoring is implemented independently of the setup procedure. Therefore, not only is the cine EPID method compatible with IGRT, but also it provides an important, independent verification of the target position during radiotherapy. Conclusion: The cine EPID method can be used to ensure the reliability of IGRT. The delivered dose is calculated using the information contained in BEV images acquired during irradiation. By calculating the dose actually delivered to the target, we can assess our treatment procedures as well as more accurately report clinical results.