

Results: The Group 1 vs. Group 2 mean prostate D90, V100, V90, and V80 were 91 vs. 99 ($p < 0.001$), 86 vs. 89 ($p < 0.002$), 90 vs. 94 ($p < 0.001$), and 94 vs. 97 ($p < 0.001$). Variance analysis showed a statistically significant reduction in the ranges of the D90, V100, V90 and V80 in favor of Group 2. The number of patients with a D90 $< 90\%$ in Group 1 vs. Group 2 was 15 patients vs. 1 patient ($p < 0.001$). There were no statistically significant differences in the urethral or rectal dosimetric outcomes between Group 1 and Group 2.

Conclusions: Changing from a pre-plan to a real-time dosimetry technique to perform PPIB by the same implant team in a consecutive series of patients resulted in better and more consistent prostate dosimetric outcomes. No significant changes were seen in the urethral or rectal dosimetric outcomes.

Author Disclosure: R.A. Hsi, Bard Urological, D. Speakers Bureau/Honoraria; T. Okura, None; E. Garver, None; H. Parsai, None; P. Cho, None; D. Jacobs, None; J. Corman, None.

2292 A Comparison of Dosimetric and Biological Effective Dose (BED) Parameters for the Prostate and Urethra Using Cs-131 and I-125 for Prostate Brachytherapy

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Purpose/Objective(s): Cs-131 is a new isotope available for prostate permanent seed implant (PPI). As compared to I-125, the physical half-life of Cs-131 is shorter (9.7 days) and, the average energy comparable (29 keV). We compare urethral doses between Cs-131 and I-125 PPI based on the urethra D30 (dose (Gy) to 30% of the contoured urethra).

Materials/Methods: We randomly selected eight patients with manually planned prostate brachytherapy cases previously implanted with I-125 and, re-planned these patients manually with Cs-131. We also re-planned each patient with both Cs-131 and I-125 using Inverse Planning Simulated Annealing (IPSA), with identical prostate and urethra optimization parameters for both isotopes. The prostate and urethra were contoured on trans-rectal ultrasound images with no margin applied for PTV.

I-125 IPSA plans were produced with the same activity used at time of actual implant and, a prescribed dose of 144 Gy. All Cs-131 were based on the specifications and recommended activity as provided by Isoray© and, a prescribed dose of 115 Gy. All plans met prostate dose-volume criteria of V100 $> 90\%$, V150 $\leq 65\%$, D90 $> 100\%$, and V200 $\leq 30\%$. The BED (Gy₂) for the prostate was calculated as described by Stock et al. This BED formula was also used to calculate the urethra BED according to the urethra D30. For both tissues the α/β was assumed to be 2. The urethra D30 and urethra BED were normalized according to the maximum prostate BED achieved by either isotope for each patient. All comparisons where the difference was $> 3\%$ were considered clinically significant.

Results: Prostate volumes ranged from 20.7 cc to 51.4 cc. For the IPSA plan comparison, prostate BED values in each case (8/8) were higher with I-125 as opposed to the Cs-131. The median prostate BED was 187 Gy₂ (181–190) for I-125 and 177 Gy₂ (170–181) for Cs-131. The urethra D30 was consistently lower using Cs-131 vs. I-125 (median 147 Gy (143–149) vs. 178 Gy (172–179), respectively). As such, the urethra was spared by a median of 30 Gy (28–33) with Cs-131. However, the median urethra BED was comparable for Cs-131 vs. I-125 (192 Gy₂ (184–194) vs. 189 Gy₂ (183–190), respectively). In all cases, Cs-131 IPSA plans yielded a greater homogeneity index by a median of 10% (5–15).

For the manual plan comparison, Cs-131 resulted in comparable prostate BEDs as compared to I-125. The median prostate BED was 191 Gy₂ (180–192) for I-125 and 193 Gy₂ (186–200) for Cs-131. However, urethra D30 was lower for Cs-131 vs. I-125 (median 152 Gy (138–154) vs. 188 Gy (180–193), respectively). As such, the urethra was spared by a median of 37 Gy (6–50) with Cs-131. Based on the urethra BED, Cs-131 yielded a comparable median BED to I-125 (202 Gy₂ (178–244) and 199 Gy₂ (191–203), respectively). The homogeneity index in 3/8 Cs-131 manual planned cases was improved as compared to I-125.

Conclusions: When comparing absolute urethra D30s, Cs-131 spares the urethra relative to I-125. However, in accounting for dose rate by calculating the urethra BED, this benefit is no longer apparent. These data highlight the difficulty in determining the true biologic dose to the prostate and urethra when comparing different isotopes and treatment planning approaches (IPSA vs. manual).

Author Disclosure: J. Pouliot, None; A. Sahgal, None; J. Chen, None; B. Pickett, None; I. Hsu, None; M. Roach, None.

2293 A Novel Method of Image Guided Radiation Treatment of Prostate Cancer Using a Quasi-Adaptive Margin and Evidence Based Isocenter Shift

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Purpose/Objective(s): In our practice, localized prostate cancers are treated by radiation via a combination of Image Guided Radiation Therapy (IGRT) followed by the conventional Intensity Modulated Radiation Therapy (IMRT). The rationale is that in the first phase using IGRT, daily movements of the prostate can be measured. This allows us to predict a “global mean shift”, which defines the positioning of patient for the second phase; and the variance of daily displacements for each patient, which is incorporated into the posterior margin, which we called a “Quasi Adaptive Margin”. The theoretical basis of this technique is described in this study. Clinical application of this evidence-based isocenter shift technique is described in companion abstract.

Materials/Methods: Based on standard statistics theory, a margin M to ensure 95% dose coverage on CTV with 95% confidence limit for individual patients can be prescribed as $M = t(n-1) * sd(n)/\sqrt{n} + 0.7 * sd(n) + 2 \text{ mm}$ where sd is the standard deviation of the n shift samples. $t(n-1)$ is a correction factor to achieve 95% confident limit for different sample size with t being 2.57, 2.23 and 2.13 for 5, 10 and 15 shifts, respectively. The number 2 is the additional margin applied to compensate for the uncertainty in IGRT. This formula was tested for three patient groups: the first group consists of 284 patients who underwent 5 IGRT fractions, no BB shift was used; the second group consists of 114 patients, each underwent 10 IGRT fractions, one BB shift was used for fractions 6–10; the third group consists of 54 patients, each underwent 15 IGRT fractions, two BB shifts were used for setup for fractions 6–10 and 11–15, respectively.

Results: In general, the margin is reduced with the increased number of IGRT fractions. The use of 15 IGRT fractions would reduce the margin to below 10 mm for 90% of the patient population whose shift uncertainty is less than 6 mm. The shift uncertainty was

found to be 6.0, 4.4 and 3.4 mm for the three patient groups who underwent 5,10,15 IGRT fractions and 0,1 and 2 BB shifts, respectively. Correspondingly, the margin would be reduced to 8.2, 6.3 mm from 13.1 mm for the second and the third patient groups.

Conclusions: We have successfully implemented the concept of “quasi-adaptive margin” and “evidence based isocenter shift” in prostate irradiation to account for the random and systematic setup uncertainties for our prostate patients. We have shown that by performing a sufficient number of IGRT procedures (but not for the whole course of >35 fractions, which is very time and resource consuming), the patient positioning can be accurately reproduced on a daily basis, and the issues of underdosing the target or overdosing the normal adjacent tissues are addressed adequately.

Author Disclosure: Z. Gao, None; J. Wong, None; S. Merritt, None; M. Uematsu, None; C. Cheng, None.

2294 On-line Prostate Localization Using Radiopaque Markers and an Electronic Portal Imaging Device: Analysis of Seed Migration and Interfraction Gland Rotation

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Purpose/Objective(s): During external-beam radiation therapy, radiopaque gold marker seeds are increasingly being implanted in the prostate for verification of the position of the gland. In doing so, it is assumed that the markers remain rigidly stationed, do not migrate and that there is no significant rotation of the gland. Only a few modest-sized studies have previously investigated prostate rotation. In this study, we assess marker migration and the magnitude of interfraction rotation in a cohort of 151 consecutive prostate cancer patients treated between 1997 and 2005.

Materials/Methods: We reviewed the records of all patients undergoing external-beam radiation therapy for prostate cancer who had three prostatic markers (two in the base and one in the apex) implanted transrectally between 1997 and 2005 at the University of California, San Francisco. Using an amorphous silicon electronic portal imaging device, pairs of orthogonal portal images (AP and lateral) were obtained daily during the treatment regimen. The marker positions in the portal images were compared to reference positions on digitally reconstructed radiographs (DRRs). In this study, the three-dimensional coordinates of the three markers were reconstructed using both the daily portal images and the DRRs for each day of treatment and the intermarker distances (IMDs) were determined. The magnitude of marker migration was assessed by the IMD time trend. In addition, interfraction prostate gland rotation was analyzed along the three principle axes (left-right [LR], superior-inferior [SI], and anterior-posterior [AP]) using the aforementioned DRRs and portal images with a three-dimensional reconstruction algorithm utilizing a least-squares curve fitting method created with in-house software.

Results: For the 151 patients treated between 1997 and 2005, there were a total of 4077 days of treatment. The mean standard deviation (SD) of the IMD differences was 0.95 mm (range 0.1–5.3 mm). This is similar to the findings of our previous smaller study and to the estimated precision of the system (approximately 1.5 mm). To date, 86 of the 151 patients have been analyzed for gland rotation. For the 6720 interfraction prostate rotations analyzed, the random SD around the LR axis was 5.4° (systematic SD, 5.8°), 2.1° (systematic SD, 3.3°) around the SI axis and 2.4° (systematic SD, 3.6°) about the AP axis.

Conclusions: Accurate and reliable on-line verification of prostate position can be obtained using three intraprostatic radiopaque gold markers during external-beam radiation therapy. Although seed migration appears to be of little concern, interfraction rotations of the prostate are not trivial. In some instances, large rotations were observed around the LR axis which may have resulted in significant deviations from the planned dose distributions. This study, performed on a large number of patients, provides statistical information to study how rotations of the prostate could be taken into account when designing external-beam treatment plans.

Author Disclosure: M.W. Lometti, None; N. Kased, None; A. Jackson, None; M. Aubin, None; O. Morin, None; J.L. Speight, None; I.C. Hsu, None; A.R. Gottschalk, None; J. Pouliot, None; M. Roach III, None.

2295 Hypofractionated Simultaneous Integrated Boost Tomotherapy in Localized Prostate Cancer: Preliminary Toxicity Results

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Purpose/Objective(s): To report early toxicity results of a phase I-II study using a moderately hypofractionated simultaneous integrated boost (SIB) approach delivered with Helical Tomotherapy (HT).

Materials/Methods: Between January 2006 and January 2007, 40 patients with localized prostate cancer (PC) were treated with HT; data on acute toxicity were available. Different CTVs were defined: CTV1: Pelvic nodes (N); CTV2: 2/3 cranial portion of seminal vesicles (SV); CTV3: lower third of SV; CTV4: prostate; OP: overlap region between PTV4 and rectum. Different doses to each PTV, according with a grouping risk based on NCCN criteria, were delivered in 28 fractions: low risk: 56 Gy, 61.6 Gy and 71.4 Gy for PTV2-4 respectively; intermediate risk: 51.8 Gy, 61.6 Gy, 65.5 Gy and 74.2 Gy for PTV1-4 respectively; high risk: 51.8 Gy, 65.5 Gy for PTV1-2 and 74.2 Gy for both PTV3 and PTV4. For all patients the dose to OP was limited to 65.5 Gy. The values of 2 Gy equivalent dose (EQD2) were chosen in order to deliver a treatment which has to be at the same time safe and effective enough for clinically reasonable α/β values ranging from 1.5 to 10. For PTV1-4 definition, the same margins used at our Institution for 3DCRT were applied (LR: 0.8 cm; PA: 0.8 cm; CC: 1 cm; 1 cm in all directions for N) even if patients were repositioned every day by MVCT image-guide taking prostate motion into account. Inverse planning optimisation was performed on the HT planning station; rectum, bladder, femoral heads + femurs (FH), penile bulb (for 19 selected pts with MRI imaging available) and intestinal cavity (in 10 pts underwent N irradiation) were considered as OARs. For all patients, set-up was assessed before each fraction through MVCT image guidance. Clinical and treatment data, including dose-volume histogram (DVH) were reviewed. Gastro-intestinal (GI) and genito-urinary (GU) signs and symptoms were evaluated according to the RTOG toxicity scales. The median follow up time was 257 days.

Results: Of the 40 pts, 15 (37.5%) presented G1, 7 (17.5%) G2, and 1 (2.5%) G3 acute GU toxicity respectively. The median time to toxicity was 27 days and 22 days respectively for G1 and G2/G3 sequelae. Rectal G1 toxicity (mainly proctitis) occurred in 15