commercially available rectal retractor blade (RR); vaginal packing (P) and an intravaginal Foley balloon (FB). All three methods were used in all patients. The first application was performed with the RR and the following two applications were randomly assigned to P and FB. All patients received a CT scan with bladder and rectal contrast and orthogonal X-rays following each application. Dose-volume parameters (D_{2cc}) for rectum, sigmoid, small bowel and bladder were collected for each fraction. The sign test and Wilcoxon signed rank test were used to compare if the ratio of doses or absolute difference in dose were significantly different among the three methods.

Results: Twelve patients and 46 CT scans were available for analysis. One patient was unable to have rectal retraction using RR. The mean age (SD) of the patients was 46 (8). The median dose (min, max) in cGy to the rectum using RR, FB and P were: 131 (102, 165), 208 (124, 243) and 211 (149, 298) respectively. There were significant differences in absolute dose to the rectum, sigmoid and small bowel observed using RR compared to FB (median differences -55 cGy, $p = 0.010$; -53 cGy, $p = 0.003$; and -58 cGy, $p = 0.012$, respectively). No differences in dose to the rectum or sigmoid was observed between the packing and Foley balloon methods. There were no significant differences in bladder dose between methods.

Conclusions: The rectal retractor significantly reduced the dose to rectum, sigmoid and small bowel compared with Foley balloon and packing. In patients treated under conscious sedation the rectal retractor method provides the best rectal sparing. For patients unable to undergo treatment using the rectal retractor, no significant differences in rectal or sigmoid dose were observed when comparing the other two techniques. Therefore, the Foley balloon method of rectal retraction is a reasonable alternative to vaginal packing.

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The Changing Nature of HDR Brachytherapy for Cervix Cancer: How the Clinical Target Volume Affects the Historical Prescription Dose

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Purpose/Objective(s): Magnetic resonance (MR)-based treatment planning in cervix brachytherapy has seen a shift in the way that treatment is prescribed and also to some extent the actual dose prescribed. The purpose of this study was to evaluate the changing nature of cervix brachytherapy dosimetry in a single centre with the introduction of MR-based treatment planning.

Materials/Methods: The treatment records of 69 patients treated with curative intent for cervical cancer and receiving HDR brachytherapy treatment were reviewed retrospectively. 41 patients were planned using computed tomography (CT)-based images only and optimized and prescribed based on traditional Point A doses. 28 patients were planned using MR-based brachytherapy with a HR-CTV contoured on each plan. Dose was optimized to the high-risk clinical target volume (HR-CTV) and prescribed to the 100% isodose in these patients. Both CT and MR- based plans were assessed for Point A dose and doses to organs at risk (OAR) including the bladder and rectum with additional HR-CTV dose assessment for MR-based brachytherapy plans. Both ICRU-38 point doses and GEC-ESTRO recommended volumes ($D2_{cc}$ for OAR and D_{100} and D_{90} for HR-CTV) were considered and biological equivalent doses for 2 Gy fractions (EQD_2) using the linear quadratic (LQ) model with an $\alpha/\beta = 3$ for OAR and an $\alpha/\beta = 10$ for target dose were determined.

Results: The average volume of the HR CTV in this study was below published volumes at 21 ($\pm$ 9) cm^3. Due to these small volumes, Point A dose dropped on average by 4.8 Gy ($p<0.0008$) from CT-based plans. The overall mean rectal dose reduced from 75.2 Gy (CT) to 67.7 Gy (MR) for the ICRU point and 74.5 Gy (CT)to 67.7 Gy (MR) D2cc dose. The overall mean bladder dose reduced from 98.0 Gy (CT) to 92.6 Gy MR) for the ICRU point and 105.9 Gy (CT)to 89.9 Gy (MR) for the D2cc dose. Each reduction was statistically significant ($p <0.01$) with the exception of the bladder ICRU dose. Average Point A doses for MR-based brachytherapy treatment plans were closer to, and correlated with, those of HR-CTV D_{100} (29.5 Gy) rather than the HR-CTVD_{90} (48.4 Gy), with a significant difference between Point A and D_{90} doses.

Conclusions: Current recommendations are the traditional prescription dose at Point A to become the dose given to the HR-CTV D_{90},. For small HR-CTV (20 cm^3 and below) this leads to a reduction in Point A dose of up to 30%. The authors suggest basing prescription doses on the HR CTV D_{100} or D_{98} in these instances until larger follow-up studies (eg. EMBRACE) are completed. Effectively this provides a 'dose escalation' to the HR-CTV whilst minimising the differences between historical prescription points that have robust and well-known treatment outcomes. For HR-CTV volumes above 20 cm^3, the recommendation of prescribing to the HR-CTV D_{90} appears appropriate.

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Bone Complications After Pelvic Radiation Therapy: Evaluation With MRI

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Purpose/Objective(s): To assess the incidence, distribution and magnetic resonance imaging (MRI) findings of pelvic bone complications after external beam radiation therapy (EBRT).

Materials/Methods: The medical charts of 345 patients who received pelvic EBRT and had a minimum follow-up of 6 months between October 2009 and June 2013 were retrospectively reviewed. Of the 345 patients, 122 who underwent MRI during follow-up were included. Primary endpoint was cumulative incidence of bone complications. Median EBRT dose was 45 Gy (range, 45-60) in 1.8 Gy fractions using 18 MV photons. Three-dimensional conformal radiotherapy (3DCRT) with a four-field box technique was used in all patients. Target volumes and organs at risk were contoured according to the guidelines. Thirty-two patients (26.2%) had previous surgery. Concurrent chemotherapy (weekly cisplatin and/or continuous 5FU infusion) was administered in 97 (79.5%) patients. The MRI images were retrospectively reviewed by two radiologists. Insufficiency fractures were noted as high signal intensity on T2 weighted images and the fracture line having low signal intensity on T1 weighted images. The cumulative incidence of pelvic bone complications were investigated using Kaplan-Meier Method. The time of onset was defined as the time when a pelvic bone complication was detected on MR images following EBRT.

Results: Male-to-female ratio was 99/23, and mean age was 57 years (range, 32-87). Diagnosis consisted of cervical (65.6%), rectal (18%), bladder (10.7%), and endometrial cancer (5.7%). Pelvic bone complications and focal red marrow changes were identified in 38 patients (31.1%). Pelvic insufficiency fracture was diagnosed in 17 patients (13.9%, with a total of 64 lesions) and radiation osteitis was diagnosed in 5 patients (4.1%, with a total of 13 lesions) and avascular necrosis in one (0.8%) patient. Focal red bone marrow changes were observed in 15 patients (12.3%). Median time to pelvic bone complications was 25 months (range, 2-45). The 1-, 2-, and 3-year cumulative complication incidence were 22%, 41%, and 49%, respectively. All patients developed multiple fractures. Insufficiency fractures included sacral ala, sacral body, ilium acetabulum, pubis, lumbar spinal vertebra, and femoral head. Radiation osteitis was observed in sacral ala, ilium, and pubis. Pain in the pelvic area was developed in seven patients with pelvic insufficiency fracture, and none of the patients with radiation osteitis developed pain. No patient was biopsied to confirm the insufficiency fracture to prevent an overt fracture.

Conclusions: Radiation-induced pelvic bone complications are not uncommon, and knowledge of characteristic imaging patterns is essential; especially in order to rule out bone metastases, and to avoid inaccurate and over treatment.

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Variation in High-Dose-Rate Brachytherapy Dose Contribution Among Pelvic Lymph Node Groups in Locally Advanced Cervical Cancer

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Purpose/Objective(s): The standard treatment for locally advanced cervical cancer (LACC) is concurrent chemoradiation therapy followed by brachytherapy. However, there is institutional variation of the optimal radiation prescription dose to metastatic pelvic lymph nodes (LNs) in LACC. Previous work from our group showed high dose rate (HDR) brachytherapy contributed about 7% of the total Equivalent Dose in 2-Gray Fractions (EQD2) of external beam radiation therapy (EBRT) and HDR brachytherapy. Due to the location in the pelvis and subsequent distance from the implant, LN groups receive differing amounts of brachytherapy contribution. In this study, we investigate a hypothesis that there is variation in HDR brachytherapy dose contribution among anatomical pelvic LN groups in LACC.

Materials/Methods: Twenty-one patients with 45 positive pelvic LNs (9 common iliac (CI), 15 external iliac (EI), 12 internal iliac (II) and 9 obturator (Ob) LNs) treated in two institutions from Oct 2007 to Aug 2011 were included in this retrospective analysis. All patients received EBRT to the pelvis with a supplemental boost to the involved pelvic node, plus HDR brachytherapy. Pathologically involved LNs were contoured on the planning EBRT image as well as the 4 to 5 brachytherapy planning images. The mean received dose of each LN from the EBRT and brachytherapy plans was recorded and EQD2 was calculated. A one-way Analysis of Variance (ANOVA) test was performed to determine if the mean brachytherapy EQD2 was significantly different among 4 pelvic LN groups.

Results: The average prescribed doses from the EBRT, including the initial pelvic fields and boost contribution to CI, EI, II and Ob LNs, were 54.60Gy, 54.53Gy, 53.15Gy and 54.42Gy respectively. The average prescribed HDR doses to International Commission on Radiation Units and Measurements (ICRU) point A were 26.83Gy, 27.84Gy, 29.79Gy and 28.49Gy accordingly. The average dose delivered to CI, EI, II and Ob LNs were 53.19Gy, 55.14Gy, 53.26Gy and 55.10Gy (EBRT), and 2.65Gy, 4.31Gy, 5.46Gy and 5.77Gy (HDR) respectively, with the corresponding EQD2 of 52.26Gy, 54.36Gy, 52.42Gy and 54.42Gy (EBRT), and 2.36Gy, 4.00Gy, 5.09Gy and 5.47Gy (HDR). The HDR contribution to CI, EI, II and Ob LNs was 4.10%, 6.93%, 8.83% and 9.48% of the total EQD2 (EBRT+HDR, 57.69Gy) of all LN groups respectively. There was a statistically significant difference in brachytherapy EQD2 among the 4 pelvic LN groups ($p < 0.05$), with the Ob LN receiving the most dose.

Conclusions: Our study highlights the 4.1% to 9.5% variation in brachytherapy dose contribution of the total EQD2 among pelvic LN groups. This difference in HDR contribution needs to be considered when prescribing EBRT boost dose to each pelvic LN group for the optimal therapeutic total dose.

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FDG-PET Can Predict Overall Recurrence and Disease-Free Survival After Definitive Irradiation and MRI-Guided Adaptive Brachytherapy in Uterine Cervix Cancer

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Purpose/Objective(s): Modern treatment advances gained significant improvement on local control and survival for uterine cervical cancer. Nevertheless the lack of a predictive assay enabling upfront identification of patients more likely to be cured is still a challenge. Upfront identification of chances of cure could aid treatment selection and intensification as the set-up of personalized follow-up schedule after treatment. Purpose of our analysis was to correlate FDG-PET metabolic activity data with clinical outcome to treatment, for a single institution population of patients treated with radiotherapy (RT) for cervix tumor. Our hypothesis is that metabolic data can predict clinical outcome.

Materials/Methods: We evaluated 78 patients treated between 2006 and 2012 for locally advanced cervix carcinoma. Before RT each patient underwent a pre-treatment FDG-PET-CT (PET-pre) as part of staging and treatment planning procedure. About 2 months after treatment with definitive external-beam RT including MRI-guided brachytherapy, patients underwent to clinical re-evaluation (including FDG-PET-CT, MRI, Gynaecological examination). Patients underwent regular follow-up every 3 months for the first 2 years, and six-monthly thereafter until 5 years of follow-up. Recurrence patterns were separately recorded as local, regional and distant, and globally analysed as overall recurrence. Recurrence patterns and survival outcome over time were used to define overall recurrence free (ORFS) and disease free survival (DFS). Disease free survival included data on cause-specific death. Univariate analysis was addressed for correlation between either RFS or DFS and: FIGO stage, presence of bulky disease (BULK), Age, Overall treatment time (OTT), SUV maximum (SUVMAX) and mean (SUVMEAN) and metabolic volume (MV) values at PET-pre. Significant variables were evaluated at multivariate analysis.

Results: Overall recurrence free survival: At univariate analysis FIGO [HR 1,69 (1,26-2,28) p = 0.000], OTT [HR 1,05 (1,02-1,09) p = 0.003] and MV [HR 1,02 (1,01-1,03) p = 0.000] were significant. At multivariate analysis (c-index = 0.77) only MV remained significant [HR 1,02 (1,01-1,03) p = 0.004]. (c-index = 0.74). Disease free survival: At univariate analysis FIGO [HR 1,79 (1,33-2,42) p = 0.000], OTT [HR 1,05 (1,02-1,09) p = 0.004] and MV [HR 1,02 (1,01-1,03) p = 0.000] were significant. At multivariate analysis, only MV remained significant [HR 1,02 (1,00-1,03) p = 0.006]. (c-index = 0.77). Determination of MV threshold significantly discriminating for DFS was also addressed.

Conclusions: In addition to FIGO and OTT FDG-PET metabolic activity data are predictive for overall recurrence and survival outcomes after primary treatment. These findings need to be confirmed in prospective datasets.

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Effectiveness of Bisphosphonate Against Radiation-Induced Decrease of Bone Mineral Densities in Irradiated and Non-irradiated Bone After Pelvic Radiation Therapy in Patients With Uterine Cervical Cancer

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Purpose/Objective(s): We have recently reported in IJROBP that radiation therapy (RT) to pelvis in patients with uterine cervical cancer significantly decreased the bone mineral density (BMD) of irradiated bone (lumbar vertebra 5: L5). Furthermore, non-irradiated bone (lumbar vertebra 2-4: L2-4) in pre-menoposal patients also decreased after RT via the decrease of estradiol. The aim of this study was to prospectively investigate the effectiveness of bisphosphonates against radiation-induced decrease of BMD after pelvic RT in patients with uterine cervical cancer.