non-contrast scan and the oral contrast enhanced scans was measured in three dimensions. Based on the assumption that the target organ positions in the CT scans are but one sample of a random distribution that occurs during treatment, CTV margins were calculated following the ICRU Report 50 and a CTV expansion model to account for a variable gastrointestinal distension and a typical set-up error of 5mm (1 SD). Both oral contrast enhanced protocols were evaluated as planning scans.

Results: The analysis of the kidney position in the positive-contrast CT study (medium fluid volume) demonstrated a significant shift of the left kidney in the caudal direction ($p=0.001$) and a slight shift of the right kidney in the cranial direction ($p=0.01$). The evaluation of parts of the target volume revealed significant positional changes of the pancreatic tail and corpus in the caudal direction ($p=0.01$). The SMA at 15 mm and 30 mm from origin demonstrated a displacement to the right ($p=0.05$). The average displacements clustered around relatively small changes around 3 to 4 mm, but the magnitude of organ translations varied between patients. Organ displacement was, in general, larger in the negative-contrast protocol (high fluid volume). Maximum caudal displacement was 18 mm for the pancreatic tail and 15 mm for the pancreatic corpus. The right-sided shifts of the SMA reached 16 mm and 20.2 mm. A significant translation to the right ($p=0.02$) was also found for the pancreatic head, which is located in close anatomic relation to the SMA. For the left kidney, an additional posterior shift ($p=0.001$) was noted. Larger deviations from the mean in the negative-contrast planning CT protocol generally resulted in larger CTV expansions. The differences were slight and varied between 1% and 7%.

Conclusion: The translations can represent a systematic error, because the CT protocols stand for the special setting under which a planning CT in pancreatic cancer may be employed in conformal therapy. The CTV margins defined in this study may help to assess the adequacy of the margins currently in use and may provide a basis for further studies on organ motion and ways of modifying treatment margins.

1068 Abdominal Organ Motion and Deformation: Implications for IMRT

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Purpose: Organ motion during delivery of intensity modulated radiotherapy may be problematic. An improved understanding of the magnitude and direction of organ motion during respiration, as well as quantifying the degree of organ deformation may lead to selecting the appropriate strategy for mitigation of these effects, whether through gating or other means. The purpose of this study is to quantify the motion associated with abdominal tumors and estimate the degree of organ deformation. Approaches on how to use such organ motion data in treatment planning are also developed.

Materials and Methods: Patients with abdominal tumors and radio-opaque clips were selected for study. Routine imaging studies for treatment planning include conventional and CT simulation. During conventional simulation, fluoroscopic image data were recorded digitally over several breath cycles in both AP and lateral views. Clip coordinates were extracted from these projection views. During CT simulation, volumetric image data were taken under three conditions: during continuous light respiration, and near the maximum and minimum tidal lung volumes. At the time of CT simulation, radio-opaque markers were also placed on skin. The radio-opaque clip positions were digitized using GE Advantage Windows software. The pancreas was outlined on all three CT studies using standard 3D treatment planning software. Center of mass motion was extracted from serial organ contours. The volumes were inspected interactively to judge degree of deformation qualitatively. The medial axis (centerline) of the pancreas was defined for these pancreatic volumes to quantitate distortion. To estimate the perturbation of dose volume histograms for a specific plan and DMLC sequence, a target's eye view is used. In this reference frame, the observer sees the lateral translation of the MLC vanes plus a cranio-caudal movement due to respiration. A calculation of the effective fluence pattern is then used in the inverse planning system to estimate the DVH.

Results: Degree of organ motion is clearly patient dependent. Typically, center of mass anterior / posterior movement of the pancreas is on the order of 5-7mm. Cranio-caudal displacement ranged from 16mm to <5mm, with individual radio-opaque clips in the same patient showing movement differences at a given time of 4-5mm. Motion along the lateral axis (R/L) is small, on the order of 2-3mm. From digitization of clips in CT studies, coordinates of multiple clips and skin surface markers were generated at inhale / exhale conditions. These data are in general agreement with fluoroscopic studies in the same patient. Three-dimensional transformations to bring these fiducials into best alignment showed clip position differences suggestive of local organ deformation. Volumes of the pancreas during different scans was within 5% of each other. Medial axes for the pancreatic tail were quite similar, but differences between inhale and exhale scans showed distortion of the organ in the AP direction closer to the head.

Conclusion: Movement of radio-opaque clips indicates non-uniform motion in different portions of the organ. Lateral motion is small; most motion is in the cranio-caudal and anterior / posterior direction. Analysis of the exhale / inhale CT scans shows organ deformation. The tail of the pancreas moves less than the center. In patients with a Whipple resection, the head/ moves less than the center. Estimates of the centerline of the pancreas indicate a modest degree of deformation. Dose volume histograms to the CTV with and without the perturbing effects of motion will be presented.

1069 The Unequal Internal Motion of the Clinical Target Volume (CVT) for Rectal Cancer

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Purpose: To study the internal motion of CTV and rectum as well as the influence of bladder filling on the position of CTV and to formulate guidelines for the conversion of CTV to PTV for the use of intensity modulated radiotherapy.

Materials and Methods: The CTV was defined by standard target volume definitions obtained from the literature. Ten patients (7 postoperative, 3 preoperative) with rectal cancer had CT scans obtained for planning and during treatment (55 CT scans total). All patients were given oral contrast, placed prone on a rigid foam cradle with a cut-out area for small bowel exclusion.

CT scans were registered using pelvic bones. CTV, rectum and bladder were outlined. The anterior margin of the CTV was measured on each CT slice in the middle of the anterior edge of sacrum to coccyx. The anterior and posterior margin of the rectum was measured on an identical method. Left and right margin of the rectum were measured from the lateral bony pelvis. On each slice, motion of CTV or rectum was calculated by subtracting the distances of the CT scan of each patient divided by the mean of the patient. To measure the motion of the CTV between the patients, the CT slice that encompassed the anus was set as the zero slice and the standard deviation (SD) was calculated. Maximal influence of bladder filling was examined with the CT scan with lowest and highest bladder volume of each patient and the anterior-posterior distance difference of the two CTVs was measured as well as the length of the difference in cranio-caudal direction.

Results: A typical CTV consisted of an anteriorly oriented concave shape (upper part) in the superior pelvis and a conical shape (lower part) in the inferior pelvis. Motion of the CTV was very unequal. In the upper part of the CTV, no motion was seen because it is defined around the common iliac vessels and the anterior margin is placed at least 0.5 cm anterior from the anterior bony sacral wall to include the sacral lymphatic vessels. Only the anterior margin of the lower part of the CTV moves because it includes a small part of bladder, prostate, uterus or vagina. Posterior and lateral borders are defined by the bony pelvis or common iliac artery, so these borders do not move. Motion of lower anterior margin of the CTV and rectum are shown (Table). The largest anterior CTV motion (8 mm, 1 SD) was seen at 9 cm above the anus. The rectum moves more anterior than posterior. The motion is partially due to bladder filling. Bladder filling displaces the anterior margin of CTV with 7 mm (average) and over a 2.5 cm cranio-caudal length (average).

Conclusion: Due to the complex shape of the CTV, an unequal motion of the CTV was observed. Only the anterior margin of the lower part of the CTV moves with a SD of 3 to 8 mm. The design of the PTV should not just include adding a blanket correction in all dimensions and locations from the CTV but should include an 8 mm extra margin at the lower anterior margin. However, because the bladder moves the CTV daily, the design of PTV could also be individualized based on multiple CT scans obtained early in the course of treatment.

Cranio-caudal distance from anus (cm)	Rectum (1 SD, mm) Anterior	Rectum (1 SD, mm) Posterior	Rectum (1 SD, mm) Right lateral	Rectum (1 SD, mm) Left lateral	CTV (1 SD, mm) Anterior
1	4	4	2	2	3
3	4	6	3	2	4
6	6	4	6	7	6
9	11	2	9	5	8

1070 MR-Assisted Quantification of Prostate Movement under Systematic, Artificial Bladder Filling for 3D Treatment Planning

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Purpose: In radiotherapy treatment planning the knowledge of organ movement in the area of the treatment fields is of great importance. These movements are considered when delineating the planning target volume. For the position of the prostate and the seminal vesicles the filling of the bladder is an important factor. The aim of this study was to evaluate the interdependencies between bladder volume and the deviations in the target point and the treatment portals for external beam treatment.

Materials and Methods: For six probands axial, T2* weighted MRI images were acquired using an open MRI scanner. After positioning the proband on the table of the scanner in the supine treatment position 20 ml of Furosemid were injected intravenously to invoke a fast filling of the bladder. The probands were instructed not to move and to continue the examination as long as possible. The total examination time was between 40 and 50 minutes. Between four and six series of 22 images were acquired for each proband while the bladder volume increased continously.

The MRI series were imported in a 3D treatment planning system and bladder, prostate, and seminal vesicles were delineated. The volumes of the contours were calculated automatically by the system. To exclude marginal movements of the proband between the series a landmark matching was performed and the contours of the prostate (incl. seminal vesicles) were imported in the third series of each proband. In this series a ventral and a lateral treatment field was defined. In a first step, the deviation of the target point for the different contours of the prostate and seminal vesicles were evaluated. Therefore each contour was determined as the target volume and the target point was automatically located in its center. In a second step, the change in the shape of the treatment portals for the different volumes of interest (VOI) were analysed. Here, the target point was set in the center of the prostate incl. seminal vesicles of the actual series (third series of each proband). The ventral and lateral treatment portals were adapted to each VOI and the borders of the resulting irregular fields were evaluated.

Results: The mean volume of the bladder increased from 49 ccm (21 to 98 ccm) to 417 ccm (297 to 623 ccm) with a mean ratio of 10.1. The mean volume of the prostate including the seminal vesicles was 68.9 ccm (54.5 to 87.5 ccm), with no significant change with the volume of the bladder.

For the location of the target point a movement in the anterior-posterior direction with increasing bladder volume was found. The mean deviation between the first (empty bladder) and the last series (full bladder) was 4.9 mm (2.9 to 6.1 mm). In the other directions (lateral, cranio-caudal) no significant movements were found.

The borders of the irregular fields for the lateral treatment portals also moved in anterior-posterior direction. The posterior field contour moved a mean distance of 8.2 mm (3 to 13 mm), while the anterior field contour only moved a mean distance of 4.7 mm (2 to 11 mm). There were no significant changes for the cranio-caudal direction. Also for the ventral treatment portals no significant changes were found.

Conclusion: We could demonstrate a systematic ventro-dorsal organ movement of the prostate and the seminal vesicles under continous, artificial bladder filling using MRI. No significant movements of the prostate and seminal vesicles in lateral or