Poster: RTT track: Motion management and adaptive strategies

PO-1013 Library of plans and CTV-PTV margins for VMAT irradiation of cervical cancer

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Purpose or Objective
In December 2012, a library of plans (LoP) methodology for cervical cancer was developed and implemented in our clinic to deal with variations of cervix-uterus position and shape caused by variations in bladder volume. A LoP consists of several VMAT plans corresponding to full bladder volume, empty bladder volume and intermediate bladder volumes. Based on improved motion management due to LoP, it was hypothesized that the clinically used CTV-PTV margin of 1 cm left-right and 2 cm in other directions could be reduced. The aim of this study was to investigate to what extent the CTV-PTV margin with VMAT irradiation of cervical cancer could be reduced with the use of LoP.
Material and Methods
Twelve cervical cancer patients, treated with 46 Gy in 23 fractions, were included in this retrospective study. Before planning CT (pCT) simulation, three fiducial markers were placed in the top of the vagina or cervix. For each patient intermediate CTV structures were constructed from manual CTV delineations of the cervix-uterus on a full and empty bladder pCT in combination with an algorithm that utilizes Robust Point Matching for interpolation. Intermediate CTV structures were generated with a maximum distance of 1 cm between CTV structures. The number of CTV structures within the library depends on the maximum distance between the manual CTV delineations of the cervix-uterus on the full and empty bladder pCT (Figure). Two CTV-PTV margins were applied: A) 1 cm left-right and 1.5 cm in other directions, B) 1 cm isotropic. Subsequently, three observers, radiation therapists with plan selection experience, selected the most appropriate CTV out of the library for each CBCT of each patient. The observers verified for each CBCT if the uterus and cervical markers were in- or outside of the PTV corresponding to the selected CTV, for margin A as well as margin B.

Max distance between CTVs full and empty bladder pCT (cm)	# CTVs
≤ 0.5	1
> 0.5 and ≤ 1.5	2
> 1.5 and ≤ 2.5	3
> 2.5 and ≤ 3.5	4
> 3.5 and ≤ 4.5	5
> 4.5 and ≤ 5.5	6
> 5.5 and ≤ 6.5	7
> 6.5 and ≤ 7.5	8
> 7.5 and ≤ 8.5	9

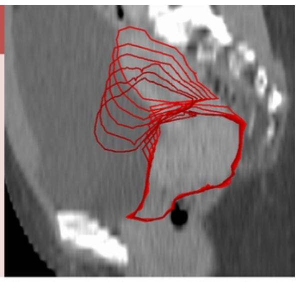

Figure. The number of CTV structures within the library depends on the maximum distance between the manual CTV delineations of the cervix-uterus on the full and empty bladder pCT (table). Intermediate CTV structures were generated with a maximum distance of 1 cm between CTV structures (sagittal view, full bladder pCT).

Results
For each patient, 23 pretreatment CBCTs and 7-11 post treatment CBCTs were included. For margin A, in 8% of the pretreatment and 15-17% of the post treatment CBCTs the top of the uterus was outside the PTV. For margin B, in 14-16% of the pretreatment and 25-26% of the post treatment CBCTs the top of the uterus was outside the PTV. For margin A, the cervical markers were always inside the PTV. For margin B, the cervical markers were outside of the PTV in 1-2% of the pretreatment and 2-3% of the post treatment CBCTs.
Conclusion
The clinically used CTV-PTV margin of 1 cm left-right and 2 cm in other directions that is used for VMAT irradiation of cervical cancer could be reduced with the use of LoP, provided that the geometry of cervix-uterus with respect to the PTV is carefully monitored. Concluding, in order to reduce the CTV-PTV margin to a uniform 1 cm, a combination of a LoP strategy and a traffic light protocol to monitor outliers is advised.

PO-1014 Target volume motion during anal cancer IGRT using cone-beam CT

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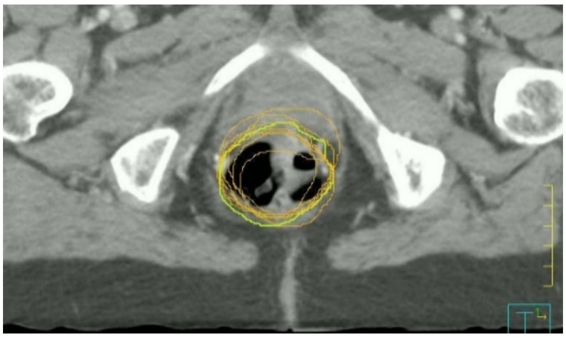
Purpose or Objective
Image guidance during anal cancer radiotherapy allows visualisation of soft tissue and the potential to re duce the margin applied to generate the PTV. In order to safely reduce planned PTV margins it is essential to understand the internal motion of the target volume to be treated to avoid a geographical miss and thus under dosage to the tumour. There is a paucity of published literature regarding an IGRT protocol and the internal target volume motion for anal cancer radiotherapy. At best there are a handful of studies that have investigated this area within rectal cancer. We prospectively analysed the setup data based on bone match for a cohort of anal cancer patients receiving radical radiotherapy using cone-beam CT (CBCT). Using this data we investigated and report the inter-fractional motion of the anal GTV for the same cohort of patients.
Material and Methods
20 patients with stage T1-4 N0-3 anal cancer were prospectively treated with radical radiotherapy using IMRT. All patients received 28 fractions of radiotherapy. CBCTs were acquired for the first 3 fractions and weekly thereafter as a minimum. A total of 196 CBCT images were acquired with 8 CBCTs as the minimum per patient. Each CBCT was exported to the treatment planning system with positional correction and registered with the planning CT. Retrospectively, the GTV of the anal canal tumour was localised again on the planning CT (as defined by the documented digital exam and multi-modality imaging) and all the CBCTs. The GTVs were localised by the same gastrointestinal clinical oncologist. To reduce bias the original planning GTV, CTV and PTV were absent. Similarly the CBCT GTV's were delineated in one session per patient to reduce variation in GTV contours caused by a time lapse. Volume data for all GTVs were collected. To measure CBCT GTV displacement compared to the planning CT all CBCT GTV's were collated into a single GTV contour. The maximum displacement was then measured in the anterior (A), posterior (P), superior (S), inferior (I) and lateral directions (R and L).
Results
The anal GTV volume size for the planning CT and the mean CBCT GTV volumes are reported in table 1 for all individual cases and for the whole group. The mean CBCT GTV volume was larger than the planning CT for the whole group analysed together. Large variations in the CBCT GTV were observed for some of the cases. Figure 1 shows the planning CT GTV in yellow and all the CBCT GTVs in orange. The maximum displacement between the planning CT GTV and the CBCT GTV envelope are also reported in table 1 for all individual cases and for the whole group. Some of these displacements were in the order of up to 2 cm.

Case	Planning CT GTV (cm³)	Volume size for all CBCT GTVs (cm³)		Maximum displacement between planning CT GTV edge and CBCT GTV envelope (cm)					
		Mean	Std Dev	Anterior	Posterior	Superior	Inferior	Right	Left
1	14.1	20.0	2.8	-0.5	1.4	-0.5	-1.0	0.7	-1.0
2	17.3	18.3	1.8	-0.9	0.0	0.8	-0.5	0.2	-0.3
3	139.7	135.2	19.4	-0.3	0.5	0.5	0.0	-0.3	0.0
4	16.0	21.7	2.1	-0.8	0.8	0.5	-0.3	0.3	-0.1
5	23.7	27.4	5.4	-0.3	1.3	0.5	-0.5	0.3	-0.5
6	22.8	33.8	6.3	-1.5	0.4	0.5	-0.3	1.1	-1.0
7	29.2	31.3	2.5	-0.8	0.1	0.8	-0.5	0.2	-0.7
8	160.0	152.7	14.7	-0.5	0.7	0.3	0.8	0.2	-0.1
9	66.4	60.0	7.3	0.5	1.1	-0.5	-1.3	0.8	-1.3
10	26.6	31.6	3.2	-1.2	0.5	0.0	-0.5	-0.1	-0.6
11	188.5	168.8	29.6	-0.3	0.4	0.5	0.0	-0.4	0.0
12	55.6	66.5	4.1	-0.7	-0.2	0.8	-0.5	0.2	-0.1
13	14.4	16.0	1.7	-0.3	0.8	0.5	-0.8	-0.1	-0.4
14	12.8	18.8	2.3	-0.7	1.5	0.0	-0.3	0.2	-0.2
15	78.7	76.2	11.3	0.2	1.3	1.0	0.3	0.8	-1.1
16	49.9	50.1	6.8	-0.7	1.0	0.3	0.0	0.5	-0.1
17	111.3	125.9	12.7	-0.6	-0.8	0.5	1.0	-0.6	1.4
18	35.6	45.2	6.4	-1.2	1.1	0.0	-1.0	0.8	-0.5
19	45.6	59.6	31.1	-0.7	0.2	0.3	-2.0	1.2	0.0
20	14.7	18.8	2.2	-0.9	0.7	0.8	0.3	0.5	0.0
mean	56.1	58.9	8.7	-0.6	0.6	0.4	-0.4	0.3	-0.3
stdev				0.5	0.6	0.4	0.7	0.5	0.6



Conclusion
This study shows there are large displacements within the anal canal internal motion and caution should be applied when considering margins applied to the GTV. Further in depth study within this area is required when developing an IGRT protocol based upon soft tissue matching.

PO-1015 Dosimetric comparison of the breath-hold based and conventional radiation therapy of lung cancer.

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Purpose or Objective
The breath-hold (BH) based radiation therapy (RT) is one of the motion management options for a moving tumor with a beneficial feature of increased lung volume. This additional feature can reduce the volume of normal lung irradiated by radiation and thus the radiation treatment related toxicities. In this study, we evaluated dosimetric properties of the BH based RT compared to those of the conventional free-breathing (FB) based RT of lung cancer.
Material and Methods
Five patients with lung cancer received Deep Inspiration Breath-Hold (DIBH) respiratory training and then CT scan. The CT scans in DIBH were acquired following one FB scan and one 4DCT scan in cine-mode. In case the motion of the target volume in 4DCT scan is greater than 1 cm, a series of 6 scans in DIBH was acquired. A three dimensional conformal treatment plan was generated for each CT scan, giving each patient both FB and DIBH plan using the Pinnacle RTP system for photon plan and corresponding proton plans were generated by using RayStation. The prescription dose for all five patients was 60Gy. The dose-volume characteristics of the total lung volume were compared in order to evaluate the dosimetric benefits, and the conformity index (CI) and homogeneity index (HI) were calculated as a treatment plan quality index.
Results
In average, the total lung volume was increased by 27.2 % and the CTV volume was decreased by 22.1 % in DIBH. For photon plans, CI was improved by 20 % with DIBH but HI was not significantly different. The dosimetric parameters of lung volume were improved in DIBH: Dmean(Gy)(6 in FB and 4.8 in DIBH), V5(%) (25 in FB and 21 in DIBH), V10(%) (15 in FB and 11 in DIBH) and V20(%) (9 in FB and 7 in DIBH). For proton plans, CI and HI were not significantly different between BH and DIBH. The dosimetric parameters of lung volume were improved in DIBH: Dmean(Gy)(3.2 in FB and 2.7 in DIBH) , V5(%) (11 in FB and 10 in DIBH), V10(%) (8.6 in FB and 7.4 in DIBH) and V20(%) (6 in FB and 5 in DIBH).
Conclusion
DIBH provides an advantage to lung sparing by increasing total lung volume and reducing the normal lung volume in high-dose region. Therefore, DIBH could be recommended for the patient with tumor motion of >1cm. In addition, since the dosimetric difference in terms of CI between FB and DIBH in photon plans is larger than that in proton plans, DIBH could be considered in photon radiotherapy.

PO-1016 Impact of CBCT based IGRT strategies on margins in IMRT of gynecological tumors after hysterectomy

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Purpose or Objective
Several studies have investigated the vagina wall or vaginal cuff movement during post-operative radiotherapy of gynecological tumors, using fiducial markers (FM) to quantify the interfractional vaginal motion and derive proper CTV tot PTV margins. The aim of this study was to assess the accuracy of FM registrations on Cone beam CT and investigate the impact of different IGRT strategies on the margins for the CTV(vagina) and the electively treated lymph nodes(LN).
Material and Methods
18 patients treated postoperatively for gynecological cancer were selected for this study. On 369 out of 441 (83,7%) CBCT's the interfractional vagina motion was measured by performing two registration methods
1) Soft Tissue (ST) registration using a 3D shaped Region of interest based on the CTV and a grey value registration algorithm.
2) Fiducial Marker registration using a 3D shaped region of interest on the CTV and a chamfer match algorithm optimized for fiducial markers.
In 14.3% of the FM registrations and in 11.8% of the ST registrations a manual adaptation was performed to obtain a visual validated accurate registration. If that was not possible due to loss of markers during RT, shape deformation or poor CBCT quality, the results were excluded from analysis (16,3%). The results of both registration methods were compared using linear regression analysis to assess marker registration accuracy. Because ST registration was expected to be more representative for measuring the entire vagina motion than FM (as they are generally placed in the tip of the vagina), ST registration was used as golden standard. Using these motion measurements and online performed bony anatomy (BA) based corrections, the impact of BA and FM based IGRT strategies on the CTV to PTV margins for the CTV(vagina) and the CTV(LN) were evaluated.
Results
Linear regression analysis shows a good agreement between the two registration methods in measuring the