result in any significant under-dosing of the target, the observed differences showed that the rectum broke our institutional DVCs during treatment. This is important data required to evaluate the robustness of institutional procedures for the planning and delivery of patients' treatments.

PO-0901

Investigation of a fast CBCT protocol for supine accelerated whole breast Irradiation

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Purpose or Objective: Acceleration in breast cancer treatment might become the new standard. As fraction dose rises, the importance of correct positioning increases. CBCT is time consuming and uses (low dose) radiation. Increasing interval between positioning and actual treatment reduces precision. We therefore investigated a CBCT technique with lower dose and faster acquisition.

Material and Methods: Both standard and fast pre-treatment CBCT imaging (STAND and FAST) were performed on XVI Elekta ® in a 5-fractions supine and whole breast irradiation scheme (5 x 5.7 Gy). The main difference between protocols was gantry speed (Table 1). Central dose was measured with PTW equipment in a CTDI32 phantom. High resolution (HR) and contrast were measured on a Catphan Phantom. Breast contour appearance was assessed on a polystyrene breast phantom. Fifteen clinical CBCT-images for three patients to which FAST or STAND was randomly assigned, were blindly scored by a skilled oncologist. A three-level answer had to be formulated regarding visibility of 1) *all* clips, 2) *entire* breast contour, 3) lung/thorax wall edge and 4) excision cavity. Answers were decoded: 0: *Not at all*; 1: *Yes, but only with guidance of reference CT*; 2; *Yes clearly, without reference CT*.

Results: FAST operated at only 53% and 61 % of dose and time of STAND. A low HR (3 lp/mm) was the same for FAST and STAND. Contrast was assessed for STAND through visibility of the largest (15mm) 1% contrast nodule. For FAST, no nodules could be distinguished. There was excess-tissue on cranial and caudal CBCT breast phantom slices, but to the same extent in STAND and FAST. In mid position, breast edge was sharp and coincided with reference CT.
The Patient study reflected a difference in the overall low soft tissue contrast for the two protocols. The excision cavity was never scored 2, more 1 for STAND and more 0 for FAST and was less visible with higher breast density (patient 3). Breast contours showed step-wise artifacts near inframammary and axillary folds for both protocols. Lung/thorax wall edges were scored 2 and 1 but the dependency was larger for patient anatomy than for scan protocol. All clips were visible: the rather poor HR is however sufficient. Streak artifacts due to beam hardening and undersampling were apparent in both protocols (Figure 1).
Even though the noisy and artifact-rich appearance of the images, effect on clinical decision making for registration is minimal. The stepwise artifacts appear very localized and are easily corrected for in the observer's mind. Additional information by outer breast contour and lung-thoracic wall edge compensates for this. Distinction between real artifacts and excision cavity can be done by comparison with reference CT. Clips are always visible and of special importance in high density and/or voluminous breasts.

Figure 1: a) STAND CBCT image with step-wise artifacts (arrow 1); b-c) STAND mid and caudal breast phantom image sets (green-purple representation), tissue excess (arrow 2); d) STAND CBCT image with streak artifacts (arrow 3) and clip (arrow 4); e-f) FAST CBCT and reference CT image of the same patient with boost CTV volume (red) where visibility of excision cavity was scored 1.

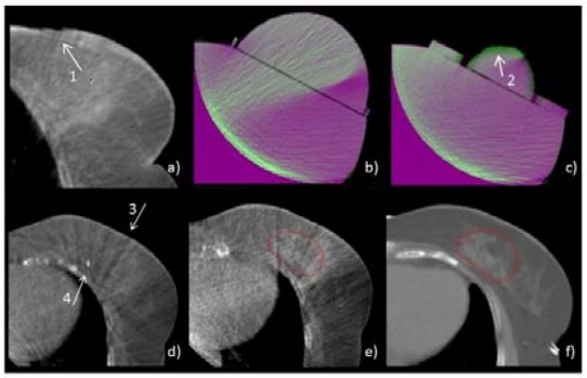

Table 1: Standard and fast pre-treatment CBCT imaging protocols

	STAND		FAST	
	left	right	left	right
*Protocol parameters**				
Acquisition angle [degrees]	205	200	205	200
gantry speed [degrees/min]	180	180	360	360
N° of frames	376	367	188	183
Dose and Time measurements				
Dose Length Product[£] [mGy.cm]	30.7	35.1	16.1	19.0
CBCT-acquisition time [s]	79	76	49	45

* *all: 120kV; mA/frame=20; ms/frame=32; 5.5 frames/s*
£ *Dose Length Product: dose measured over 10 cm long pencil chamber @ central hole of CTDI32 phantom*

Conclusion: FAST allows the oncologist to register breast CBCT. However, with high density or voluminous breasts, clips are recommended with the use of FAST.

PO-0902

Improving frameless intracranial stereotactic setup with 6DOF couch using two pre-treatment CBCTs

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Purpose or Objective: The primary goal of this study was to evaluate the residual inter-fraction positioning errors of our intra-cranial frameless stereotactic treatment following a six-degree of freedom (6DOF) correction based on automatic bone anatomy matching. A secondary goal was to evaluate the intra-fraction motion.

Material and Methods: Since the implementation of the stereotactic program at our centre, 13 patients were treated with frameless intra-cranial fractionated radiotherapy on a Varian TrueBeam STx linear accelerator. All patients had a planning CT scan with an immobilization system that comprised of a CIVCO head cup, customizable pillow and thermoplastic shell. To guide setup, nose to forehead pitch was calculated using CT information and reproduced at treatment using a digital level. Roll was measured as the difference in height at the level of the anterior ear notch and reproduced at treatment using the in-room lasers. Two pre-treatment CBCTs were acquired; the first to correct using 6DOF bone anatomy matching the initial inter-fraction positioning error and the second to assess the residual inter-fraction error post 6DOF correction. Since our initial experience with the first 3 patients, revealed residual inter-fraction setup errors greater than 1mm, the residual inter-fraction setup error post 6DOF correction was measured and corrected prior each treatment for all remaining 10 patients. Due to the technical limitations of Varian's 6DOF couch (i.e. maximum 3 degrees pitch and roll), the correction of the residual inter-fraction error was carried out using 4DOF automatic bony anatomy matching (i.e. excluding pitch and roll due to 3degree limitation). A post-treatment CBCT was acquired to determine the intra-fraction motion using 6DOF bone anatomy matching.

Results: Datasets from 10 patients were obtained for a total of 705 CBCT scans – the first 3 patients were excluded from the study due to changes in methodology partly through treatment. The mean 3D vector of residual setup error post first correction (6DOF) was 0.7 ± 0.4 mm (mean ± SD) and the maximum 3D vector was 2.2mm. The mean 3D vector of residual setup error post second correction (4DOF) was 0.2 ± 0.1mm and the maximum 3D vector was 0.8mm. The mean 3D vector of intra-fraction motion was 0.4 ± 0.2mm and the maximum 3D vector was 1.3mm.

Conclusion: Incorporating a second correction pre-treatment significantly reduced the residual inter-fraction setup error from 0.7 ± 0.4 mm to 0.2 ± 0.1mm. The intra-fraction motion for this cohort of patients was twice as large as the residual inter-fraction setup error. Efforts are currently underway to reduce this intra-fraction motion by focusing on improvements to the immobilization system.

PO-0903

IGRT for a highly conformal VMAT-technique for simultaneous treatment of the breast and lymph nodes

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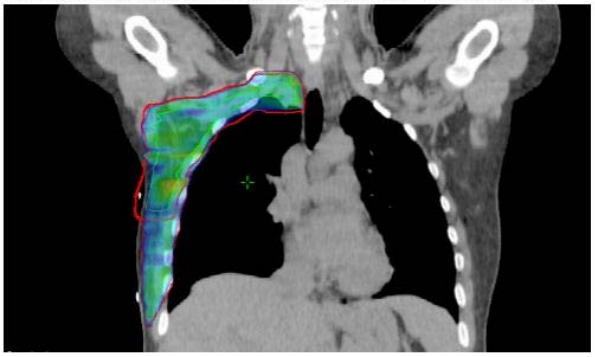
Purpose or Objective: Recently we introduced an improved hybrid treatment planning technique for breast with simultaneous irradiation of axillary and supraclavicular lymph nodes (level I-IV). This technique combines tangential open fields with VMAT (RapidArc®, Varian Medical Systems) and results in a highly conformal coverage of the lymph node region, with a steep dose fall-off towards esophagus and thyroid. The purpose of this study is to evaluate the validity of this conformal planning technique, with the required setup and image guidance.

Material and Methods: Ten patients were included, of which 8 were treated in Free Breathing and 2 were treated in Deep Inspiration Breathhold. Fractionation was 16 x 267 cGy for both elective breast and lymph node regions. PTV-margin of level I-IV lymph nodes is 5 mm to the medial direction and 8mm for all other directions (image 1). Daily online setup was performed on bony anatomy with 2 orthogonal kV-images and subsequent verified with medio-lateral MV field imaging. At the level of the PTVnodes setup deviation up to 3mm was allowed in lateral direction, in all other directions and for the humeral head 5mm was allowed. At the first 3 fractions and weekly a CBCT was acquired for verification of the PTV-coverage of the lymph nodes. All CBCT's were used offline for analysis of the reproducibility of level I-II nodes, level III-IV nodes, humeral head and bony anatomy. All 160 fractions were used for evaluation of the efficiency of the setup and imaging procedure.

Image 1: 95% dosewash: $CTV_{nodes\ level\ I-IV}$ (green) $PTV_{nodes\ level\ I-IV}$ (thick red) and PTV_{total} (thin red)



Results: A t-test showed a significant relation between the position of the humeral head and all the nodes in cranio-caudal direction (p=<0.001) and for level III-IV also in lateral direction (p=0.01). Repositioning was required in 31 fractions (19%). This was reduced to 19 fractions (12%) by excluding 1 patient with positioning problems. Based on the CBCT's, we found that only in 2% of all cases, an off-set of the humeral head less than 8mm lead to a deviation of the nodal PTV of more than 5mm. Analysis of the CBCT's also showed that the remaining average setup error for level I-II nodes and level III-IV nodes was less than 2mm in all directions with SD of max 1.6mm in AP direction (Table 1).

Table 1: Residual setup error of the lymph nodes and humeral head after bony anatomy match on 2 orthogonal kV-images

	Level I-II lymph nodes				Level III-IV lymph nodes				Humeral head			
	vrt(mm)	lng(mm)	lat(mm)	Rot(dgr)	vrt(mm)	lng(mm)	lat(mm)	Rot(dgr)	vrt(mm)	lng(mm)	lat(mm)	Rot(dgr)
MEAN	0,19	0,14	0,14	0,8	0,17	0,15	0,13	0,6	0,31	0,23	0,22	1,8
SD	0,16	0,13	0,09	0,6	0,15	0,15	0,09	0,5	0,32	0,15	0,19	1,9
MIN	0,02	0,00	0,01	0,1	0,01	0,00	0,01	0,0	0,31	0,23	0,22	1,8
MAX	1,26	0,90	0,52	3,8	0,82	0,74	0,38	2,3	1,77	0,66	0,88	8,3

Conclusion: The positioning of the lymph nodes level I-IV can be well addressed by the position of the surrounding bony anatomy and the humeral head. For the adequate treatment of both the lymph node regions and the breast, two orthogonal kV-images and MV field imaging are sufficient.

PO-0904

Bladder changes assessment using daily cone-beam computed tomography

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Purpose or Objective: Late genitourinary (GU) and gastrointestinal (GI) toxicities are the main dose limiting factors prostate radiotherapy plans. However, no predictive models, and consequently, no consensus guidelines have been reported for GU toxicity. One possible explanation is that the plan dose-volume histogram (DVH) is not representative of the accumulated bladder dose throughout the treatment given variability in bladder filling status, motion and set-up uncertainties. Modern image guidance techniques, in particular the use of cone beam computed tomography (CBCT), facilitates reconstruction of the accumulated dose. The aim of the study was to compare planned with accumulated dose and volume data for the bladder with the latter assessed from daily CBCT imaging and deformable image registration (DIR).

Material and Methods: Eight subjects presenting with RTOG GU Grade 2+toxicity were selected from a cohort of 287 patients treated for prostate cancer in 2006-2013. Prescribed dose was 81Gy in 45 fractions. The 8 subjects were each matched to 3 patients without GU toxicity by the following criteria: pretreatment GU symptoms (IPSS score), age ± 5y, risk group (low, intermediate, high), whole pelvis vs. prostate, and use of neoadjuvant ADT. Treatment required adherence to a full bladder and empty rectum protocol. Daily CBCT was used for patient realignment and to assess bladder and rectal filling status. Dose from planning CT was rigidly registered to CBCT using recorded daily shifts followed by bladder contour propagation from plan CT to the first day CBCT and then to the remaining CBCTs using an intensity-based deformable image registration (DIR) algorithm. Bladder contours were corrected manually and the accumulated D10 and D20 (defined as the highest dose received by a volume up to 10 and 20 cm3 of the bladder, respectively) were compared to corresponding values from the planned DVH. All registrations and DVHs computations were done using MIM Maestro 6.4.4 (Mim Software Inc. Cleveland, OH, US).

Results: In the analyzed patients, the bladder volumes in the daily CBCTs were found to vary between 62% and 256% of that from the planning CT, with a mean difference in volume ranging from 63% to 20%. Differences in the compared DVH were also observed where D10 was ±2.7%, and D20 ±11.2% of the corresponding planned metrics.