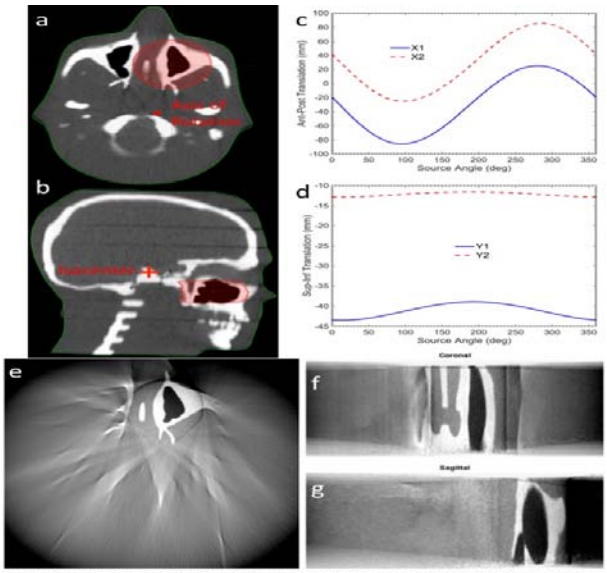
Material and Methods: A four-blade dynamic kV collimator was developed to track a VOI during CBCT acquisition. The system is controlled using a Raspberry Pi computer placed within the linac gantry. The current prototype is capable of tracking an arbitrary volume defined by the treatment planner for subsequent CBCT guidance. During gantry rotation, the collimator tracks the VOI with adjustment of position and dimension. CBCT image quality was investigated as a function of collimator dimension, while maintaining the same dose to the VOI, for a 20 cm diameter cylindrical water phantom with a 9 mm diameter bone insert centered on isocenter. Dose distributions for various anatomical sites were modeled using a dynamic BEAMnrc library and DOSXYZnrc. The resulting VOI dose distributions were compared to full-field distributions to quantify dose reduction and localization to the target volume. X-ray tube current modulation was investigated in combination with the VOI approach, using digitally reconstructed radiographs to estimate tube pulse width for each CBCT projection. The technique was evaluated in Developer Mode on the linear accelerator.

Results: Measurements show contrast increase by a factor of 1.3 and noise reduction by a factor of 1.7, for VOI CBCT, and thus an increase in contrast-to-noise ratio (CNR) by a factor of approximately 2.2. Depending upon the anatomical site, dose was reduced to 15%–80% of the full field value along the central axis plane and down to less than 1% along the axial planes. The use of tube current modulation allowed for specification of a desired signal-to-noise ratio within projection data. For approximately the same dose to the VOI, CNR was increased by a factor of 1.2 for tube current-modulated compared to unmodulated VOI CBCT.



(a-b) CT volume of the ATOM head phantom in the Eclipse treatment planning system, with the volume-of-interest to be imaged in red, isocenter marked with a cross. (c) X- and (d) Y-blade translations as a function of beam central axis angle (using the Varian IEC coordinate system) calculated from the DICOM structure using MATLAB. (e-g) Reconstructed volume-of-interest.

Conclusion: The VOI CBCT approach allows imaging of a planner-defined volume, offering both image quality improvement and reduction of imaging dose for the patient.

OC-0160

Growth and oedema related shifts of brain metastasis treated with stereotactic radiosurgery

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Purpose or Objective: Stereotactic Radiosurgery (SRS) has emerged as a treatment of choice for many cancer patients with brain metastasis. Most institutes use linac-based irradiations with multiple days between imaging and irradiation and a subset of patients is treated with fractionated SRS. So far, the geometrical uncertainties induced by such time intervals have not yet been quantified. Therefore, we investigated the growth rates of different tumour entities, the effect of oedema and the use of steroids on possible tumour shifts to estimate the effect on the tumour dose.

Material and Methods: Thirty-six patients were included, equally divided over lung-, breast- and melanoma cancer patients. Patients receiving systemic cytotoxic treatment 3 months prior to the diagnostic MRI were excluded, except for breast cancer patients on hormonal therapy that started more than 6 months prior to the diagnostic MRI. All patients had undergone a diagnostic and a radiotherapy planning MRI of which the T1w+contrast sequences were registered with the planning CT scan for target definition on both scans. Consensus was reached for all delineations by two radiation oncologists. The median time between the two MRI scans was 18 days (range 6-54). For all tumour delineations, the volume, radius (assuming spherical tumours) and Centre of Mass (CoM) were calculated. Growth rates were determined from volumetric or radial increase per day between the MRI scans. CoM differences between scans served as a measure for tumour shifts that can be caused by oedema (-clearance) and/ or anisotropic growth. Oedema was scored only if an experienced radiologist diagnosed peritumoural oedema on the diagnostic MRI.

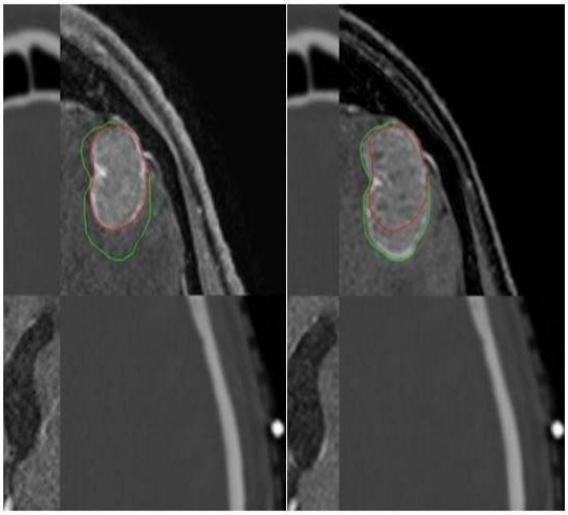

Image 1: Delineations on diagnostic (left) and plannings MRI (right), both registered on planning CT.

Results: Table 1 shows the results for tumour growth and tumour shifts. The highest growth rate in radial increase is seen in large melanoma tumours (0.07 mm/day (SD 0.02) , *p*=<0.01). Large heterogeneities in growth rate are seen in tumours of both small and large brain metastasis of lung cancer patients (small: mean=7%/day, SD=10%, range=0%-26%, large: mean=3 %/day, SD=6%, range=-1%-15%). In this lung group, three patients showed shrinkage; all three started steroids after diagnostic MRI. Large tumour shifts (mean=1.7 mm) and variability (SD=1.0 mm) were observed in the patient group with oedema receiving steroids (whereby the growth rate of tumours in these patients was not different).

Table 1. Growth rates and shifts of brain metastasis

Tumour	Small n=6 Volume planning MRI (cc)	Growth rate % volume/day (SD)	Growth rate mm/day (SD)	Large n=6 Volume planning MRI (cc)	Growth rate % volume/day (SD)	Growth rate mm/day (SD)
Melanoma (n=12)	0.21-1.29	5 (2)	0.05 (0.02)	1.32-8.41	3 (1)	0.07 (0.02)
Breast (n=12)	0.37-1.69	5 (1)	0.05 (0.01)	2.05-5.75	2 (1)	0.03 (0.04)
Lung (n=12)	0.11-1.97	7 (10)	0.04 (0.03)	2.68-8.29	3 (6)	0.03 (0.09)

Shift factors	CoM shift (mm) (SD)	p*	Growth rate (mm/day) (SD)	p*	CoM shift + growth rate (mm/day) (SD)	p*
Oedema and steroids (n=17**)	1.73 (1.02)	p<0.001	0.04 (0.04)	NS	0.15 (0.09)	p=0.002
No oedema and/or no steroids (n=18)	0.53 (0.34)		0.04 (0.02)		0.07 (0.02)	

*Unpaired parametric t-test

**1 patient was excluded because the shift was mainly caused by intratumoural bleeding

Conclusion: Within the limitations of a retrospective study, our results show that the growth and shift of brain metastasis over time can be significant and may vary over patient groups. Given the typical steep dose gradient in SRS treatments (>10%/mm), tumour growths and shifts may have a significant impact on the tumour dose. Therefore, this phenomenon must be considered if the workup and treatment of SRS for brain metastasis is encompassing multiple days.

OC-0161

Renal and diaphragmatic interfractional motion in children and adults: is there a difference?

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Purpose or Objective: One of the factors determining the size of planning target volume (PTV) margins is organ motion. Organ motion is comprehensively studied in adults and paediatric PTV margins are generally based on these data. We hypothesize that adult-based PTV margins are too large for paediatric patients because children and adults differ in body composition. Our aim was to compare renal and diaphragmatic interfractional motion in children with that in adults and to investigate the correlation with age and height.

Material and Methods: This single-centre retrospective study consisted of 35 children and 35 adults who received thoracic/abdominal irradiation between October 2009 and December 2014. The mean age of children and adults was 10.3 years (range 3.1-17.8 years) and 59.9 years (range 34.1-94.0 years) respectively. Mean height in children and adults was 140 cm (range 92-184 cm) and 175 cm (160-203 cm) respectively. According to protocol, abdominal and/or thoracic Cone Beam CT (CBCT) images were acquired for setup verification before radiation delivery. A total of 70 reference CT (refCT) scans, 350 paediatric CBCTs (mean 10; range 5-30) and 476 adult CBCTs (mean 14; range 5-27) were available for registration using Elekta XVI software. In order to assess renal and diaphragmatic motion, each CBCT was registered to its refCT in 2 steps; registration of: 1) the bony anatomy (i.e., the vertebral column), and 2) the left kidney, right kidney and diaphragm separately. For each individual, we assessed organ motion in the left-right (LR), cranio-caudal (CC), and anterior-posterior (AP) directions for the left and right kidney. Diaphragmatic motion was measured in the CC direction only as a surrogate for upper abdominal organ motion. Subsequently, for all organs the mean and standard deviation of the measurements in all directions were calculated and analysed to estimate the group systematic error (Σ) and the group random error (σ). The correlations between organ motion and age and height were investigated using a univariate regression analysis.

Results: Interfractional organ motion in children and adults was different; displacements in children were notably smaller than in adults. Consequently, the estimated group systematic (Σ) and random errors (σ) for the two groups were different (Table 1). Within each group, no correlation was found between organ motion and age or height. Overall, in the CC direction, weak correlations were found between the patient random error, and age and height (Figure 1).

Table 1. The estimated group systematic (Σ) and random error (σ) for children and adults.

	Systematic error Σ (mm) Right kidney LR	CC	AP	Left kidney LR	CC	AP	Diaphragm CC
Children	1.3	3.6	1.8	1.4	3.1	4.0	3.8
Adults	1.9	6.6	3.2	2.1	6.5	2.2	9.9
	Random error σ (mm) Right kidney LR	**CC**	**AP**	**Left kidney LR**	**CC**	**AP**	**Diaphragm CC**
Children	1.0	2.9	1.5	1.5	2.9	2.3	3.7
Adults	1.5	5.0	2.9	1.5	5.0	2.1	4.8

Abbreviations: *AP* anterior-posterior, *CC* cranio-caudal, *LR* left-right

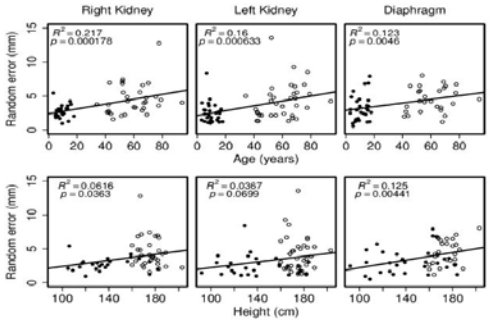

Figure 1. The correlation between the patient random error (mm), and age (years) and height (cm) in children (black dots) and adults (open circles) in the cranio-caudal direction.

Conclusion: Our results show that renal and diaphragmatic interfractional motion in children tend to be smaller than in adults, suggesting that abdominal PTV margins in children could be reduced. The difference in organ motion in the two groups could not completely be explained by age or height, indicating that further research is needed to understand the underlying mechanisms.

OC-0162

Liquid fiducial markers' performance in non small cell lung cancer during radiotherapy

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Purpose or Objective: We developed a new liquid fiducial marker (BioXmark®) for use in image-guided radiotherapy (IGRT). The liquid solidifies into a three dimensional (3D) structure after injection into tissue. A good level of marker's