the PTV in range of 95-115% of the prescribed dose. A DVH was exported for each plan to compare target coverage, conformity and homogeneity indexes.
Results: Preliminary studies investigating the effect of protracting dose relative to acute delivery suggest that when 1000 cGy is delivered over 15+ minutes, cell survival may increase. This study was done, however, on a non-moving target prior to acquisition of the respiratory phantom. Consequently cells need to be irradiated in the moving phantom, and the dose calculation confirmed through OSLD dosimetry. The conformity index ($CI_{95\%}$) and PTV homogeneity index both decrease in gated as opposed to non-gated plans. The improvement in the $CI_{95\%}$ and HI is shown to be dependent on the length of the duty cycle selected.
Conclusions: Though dose optimizations result in very similar dose coverage for gated and non-gated plans, the irregularity of patient respiratory traces implies delivering a precise dose is difficult. This study will provide cell survival results and dosimetric data for three gated and a non-gated plan for 10 patient traces.

EP-1243
Impact of organ motion on dose distribution for 3DRT and intensity modulated techniques
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Purpose/Objective: To evaluate the impact of organ motion on dose distribution for conventional, 3DCRT (three-Dimensional Conformal Radiation Therapy), IMRT (Intensity Modulated Radiation Therapy) and VMAT (Volumetric Modulated Arc Therapy) gated and ungated treatments.
Materials and Methods: A motion phantom (Quasar respiratory phantom, Modus Medical Devices) was used to simulate sinusoidal motion with peak-to-peak 'breathing' amplitude of 2cm and different frequencies (12 and 20 breaths/min), synchronized with Real-Time Positional Management (RPM) System (Varian Medical System, Palo Alto CA). Dose evaluations regarding static, ungated and gated delivery were carried out using EBT2 films. For all treatments a 6MV photon beam was used and 3Gy were prescribed and delivered to the isocenter. For conventional treatments we acquired dose profiles in motion direction for different gating windows. The profiles were compared to those obtained with the stationary phantom delivery in terms of displacements of therapeutic dose levels (95% prescribed dose) and low dose levels (20% prescribed dose). 3DCRT and IMRT treatments were performed in static, ungated and gated mode (40%-70% phase at exhale) whereas VMAT was performed only in static and ungated mode, because this treatment technique is not managed by the accelerator Varian's Clinac DHX. Measured dose distributions in 3DCRT, IMRT and VMAT treatments were compared to those planned using the gamma index with 3mm distance-to-agreement and 5% dose-difference criteria.
Results: As regards conventional treatment, ungated profiles displacements at the 95% and 20% dose levels were 12mm and 15mm respectively. Gated profiles showed an asymmetric enlargement according to target position with respect to the gating window: range shifts at the 95% and 20% dose levels were from 4 to 29mm and from 8.5 to 25.6mm respectively. In static dose distributions the percentage of points passing the gamma criteria, for all treatments, was 92%. The dynamic measurements showed a gamma agreement of 30-33% for all ungated treatments and of 70-74% for gated 3DCRT and IMRT delivery. Respiratory motion resulted in significant dose blurring, which led to an enlarged beam penumbra at the field edge and thereby underdosing of the target and overdosing of surrounding areas. This effect was reduced by gated delivery although dose distribution enlargement was still observed due to the residual motion inside the gating windows.
Conclusions: The profile analysis in the conventional treatment suggests that dose blurring could be reduced by applying asymmetric expansion margins to the CTV according to gating window. Experimental evidence suggests that, if a significant organ motion is involved and a respiratory management system is not used, modulated intensity techniques should be avoided, because planned dose distribution is not longer representative of delivered dose.

EP-1244
Evaluation of setup errors in a randomised study using CBCT & kVkV imaging for prostate radiotherapy
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Purpose/Objective: Prospective assessment of setup errors using 3D cone-beam CT (CBCT) and stereoscopic kV imaging using fiducial markers for image registration.
Materials and Methods: 23 patients underwent prostate ± seminal vesicle radiotherapy with 3 fiducial markers (1/23 had 5 markers). Each patient was randomised to start treatment on one of 2 linacs with different imaging systems, one with OBI (linac 1), the other with ExacTrac (linac 2), and then alternate weekly. Only OBI imaging is considered here. Prior to each fraction on linac 1, a CBCT was acquired, followed immediately by a pair of orthogonal stereoscopic kV images (kV/kV) using Varian OBI (v1.4 & 1.5). kV images were automatically matched online using marker match software (including couch/yaw rotation), and translations applied prior to treatment. 318 of 375 CBCTs acquired were available to match, and were matched offline – first to stable pelvic bony anatomy (for couch/yaw rotation) and then manually to an average position of all markers for the translations. Setup results were compared between CBCT and kV image matches in each orthogonal direction. The imaging methods were considered equivalent if the difference between setup errors were <2mm in each direction in 90% of cases.
To aid comparison, patient population systematic and random errors were also calculated, and imaging isocentre coincidence (with mechanical linac isocentre) was obtained from analysis of regular QA results.
Results: 207 of 318 fractions (65%) gave a difference in setup error <2mm in all directions. Average difference (CBCT – kV/kV) was 0.3mm. Population systematic and random errors, and imaging isocentre accuracy are shown in table 1.

(mm)	Population systematic errors			Population random errors			Imaging isocentre coincidence with linac isocentre			
	L/R	S/I	A/P	L/R	S/I	A/P	L/R	S/I	A/P	3D
kV/kV	2.0	2.1	4.9	2.5	2.8	3.3	-0.1 ± 0.4	-0.1 ± 0.4	0.6 ± 0.5	0.9 ± 0.4
CBCT	1.9	2.1	5.2	2.4	2.7	3.2	0.2 ± 0.4	0.3 ± 0.4	0.4 ± 0.5	0.8 ± 0.4

Table 1: Population systematic and random setup errors, and isocentre accuracy for orthogonal kV, and CBCT imaging. Results are expressed in orthogonal patient axes: left/right (L/R), superior/inferior (S/I) and anterior/posterior (A/P).
Conclusions: 35% of fractions showed setup error differences ≥2mm between orthogonal kV and CBCT that could be due to the subjective nature of the manual CBCT matching, and may be affected by the different matching methods used for couch rotation. In terms of isocentre accuracy and patient population random and systematic errors, CBCT and orthogonal kV modes showed similar results. If the same method for matching CBCTs offline can be performed online, this gives the flexibility to choose between setup using CBCT or orthogonal kV imaging without losing setup accuracy – depending on preference of gaining additional soft tissue information or faster setup with lower imaging dose.

EP-1245
Gated Rapidarc using KV intrafraction verification for liver stereotactic treatment
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Purpose/Objective: We report the results of motion management during gated rapidarc treatment using implanted fiducial markers and a novel application, Intrafraction Motion Review (IMR, Varian medical systems) allowing simultaneous KV/MV utilization.
Materials and Methods: Eight liver cancer patients with implanted fiducial markers were treated using the gated RapidArc technique with a Varian Novalis Truebeam linear accelerator. The fiducial markers (1 to 3) were implanted inside or close to the tumor target before treatment simulation. For patient simulation, three to four 4D computed tomography (CT) scans were acquired using Real time Position management (RPM) system to study the reproducibility of liver motion. During the treatment planning, the internal target volume (ITV) was outlined. The PTV was created by adding a 5 mm margin from the ITV. In the same stage, the fiducial were marked in

the exhalation phase. Before the treatment delivery, the RPM block was put on patient's abdominal surface and the gating signal was generated by the RPM system. Then, the patient's position was set based on cone beam computed tomography (CBCT) compare with ITV. During the treatment, kv images were acquired at each exhalation phase of the breathing cycle and the positions of the fiducial markers were compared with their expected positions. We reported here for the five first fractions the differences between expected and real fiducial position, treatment planning parameters such as the prescription, conformity index $CI_{PTV} = (V_{ITV95\% (cc)} / V_{PTV (cc)}) * (V_{ITV95\% (cc)} / V_{iso95\% (cc)})$, homogeneity index $HI_{PTV} = (D_{2\%} - D_{98\%}) / D_{median}$ and the number of Monitor Unit (UM) per Gray. The treatment delivery parameters such as kv images acquired per fraction, the fraction's time and the room occupation's time were also mentioned.
Results: For the eight PTV patients, the average (±SD) conformity index was 0,93 ± 0,02 and homogeneity index was 0,09 ± 0,02. Average MU/Gy was 147 ± 25.

Table 1: Treatment delivery characteristics

Fractions	1	2	3	4	5
Fraction's time (min)	53	30	20	24	24
Room occupation's time (min)	59	36	26	30	30
Average kv images [range]	34 [9-56]	32 [7-60]	36 [12-56]	40 [28-74]	34 [18-48]
Average SI deviations [range] (mm)	1,00 [0-5]	0,79 [0-5]	0,81 [0-4]	1,06 [0-6]	0,91 [0-5]

Maximum deviation in the Superior-Inferior (SI) direction during the intrafraction ranged from 4 mm to 6 mm.

Conclusions: The average gating errors measured were small compare with the 5 mm margin added to the ITV to create the PTV. However, regarding to maximal error, this additional margin is suitable to treat the tumor with no misses due to the liver motion.

EP-1246
Tracking of hepatic lesions: Correlation between the movements of target and fiducials during breathing cycle
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Purpose/Objective: The liver is a mobile organ that undergoes many movements and deformations during the respiratory cycle. Nowadays, the majority of hepatic lesions treated on CyberKnife® are tracked using the Synchrony® respiratory tracking mode, using internal markers. The movements of the target are considered identical to those of the internal markers. As part of a quantification of uncertainties associated to this type of treatment, it is essential to check the correlation between the movements of target and fiducials.
Materials and Methods: The method is based on the analysis of patient data. A 4D PET-CT exam was performed for three patients treated for hepatic lesions on CyberKnife®. The exams were divided in several temporal respiratory phases, and a threshold of target detection (identical for each breathing phase) was arbitrarily determined for the segmentation, which was performed on the PET images in Oncentra MasterPlan® (*Nucletron*). The target contours were copied to the CT images. A registration, based on fiducials, was performed for each CT phase and thus of each target contour, to the primary CT phase. The similarities of target contours of each phase to the primary phase were quantified by means of indicators, such as overlap percentage and dice. The registration of contour volumes and the calculation of the different indicators were encoded in MatLab®.
Results: The method was applied to three patient data sets for which the distance between the fiducials and the lesion varies from 0.3 to 5.4 cm. The three cases studied met the recommendation for a maximum of 6 cm. Before applying our method to the patient data sets, the movements amplitude of target and fiducials between the different respiratory phases was evaluated. For the three patients, the movements of the center of mass (COM) of fiducials and target are the lowest in the x (left-right) and y (dorsoventral) direction, with a mean variation of 1 to 4 mm and a maximum variation of 2 to 8 mm. The movements in the z-direction (craniocaudal) are more important regarding mean and maximal amplitudes (up to 15 mm). The movements are globally low, but we observe that the COM of the volume of interest does not exactly follow that of the fiducials.
This observation is confirmed by the calculation of indices for comparison of different phases. Indeed, for certain phases, the coverage between two phases is better when not transforming the target contours. Note that the dice index is the best in all cases studied, when monitoring is done on the COM of the target, illustrating the correctness of MatLab ® code and providing a potential tracking method that provides better results.
Conclusions: The movements of the target seem to differ from that of the internal markers, during the respiratory cycle. In cases where the correlation between the target movements and fiducials movements is low, the possibility of using the target center of mass to improve the monitoring should be considered. The benefit of correcting the tracking by the application of a function relating the location of the target relative to the center of mass of internal markers is to be evaluated.

EP-1247
Simulating intra-fraction prostate motion using random walk and conditional Gaussian based Gibbs sampling models
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Purpose/Objective: Intra-fraction prostate movement is one of the reasons why the treated volume in radiotherapy is enlarged by adding treatment margins. Understanding the characteristics of prostate motion may allow for smaller treatment margins and adequate motion management strategies. The purpose of this study was to investigate if a model could be created that could be used for simulation of intra-fraction prostate motion.
Materials and Methods: A dataset of prostate motion traces during 548 radiotherapy fractions (mean length 607 seconds) for 17 patients was used. The motion traces were set to start at origin at the beginning of the trace and analysed to determine general patterns, average step lengths and directional frequency. We proposed four random walk models and a statistical model for simulating the prostate motion; (#1) random walk with the step lengths being the average of observed step lengths, (#2) random walk with the step lengths sampled from the distributions of observed step lengths, (#3 and #4) the same models but with simulated transient motion, and (#5) conditional Gaussian-based Gibbs sampling. The transient motion was simulated by short-lived large displacements in the superior and anterior directions. The observed traces were filtered with an averaging filter prior to being used for input to the proposed models. The number of simulated traces in each model was the same as the number of observed traces. The simulated traces were evaluated with respect to change in the average position and variance of the position over time.
Results: In the observed traces two main types of motion were identified; slow and drifting motion, mainly towards the inferior and posterior directions, and rapid and large, mainly transient, motion in the superior and anterior directions. The simulations done with random walk models #1 and #2 were unable to recreate the rapid increase of the observed variance. However, the average positions agreed reasonably. Increased agreement was achieved when transient motion was added to the models (models #3 and #4, figure 1). Using a conditional Gaussian-based Gibbs sampling, the least difference between simulated and observed traces was observed. The average error between simulated and observed traces was 0.07, 0.14, 0.12, 0.15, and 0.04 mm for model #1 through #5, respectively. The standard deviation of the difference in variance between simulated and observed traces was 0.47, 0.30, 0.25, 0.25, and 0.11 mm for model #1 through #5, respectively, showing the superiority of the Gibbs sampling model and the improved agreement with the observed variance using added transient motion in random walk models.