19 Gy for LADCA ($V_{19GyLADCA}$) in hypofractionated schedule. Quantitative statistical analysis of plan dose differences were generated. Maximum heart distance (MHD) was defined as the maximum distance between the anterior cardiac contour and the posterior tangential field edges. In order to correlate each measure of cardiac dose with MHD a linear regression model was used. Statistical level significance was set with a p-value <0.05.

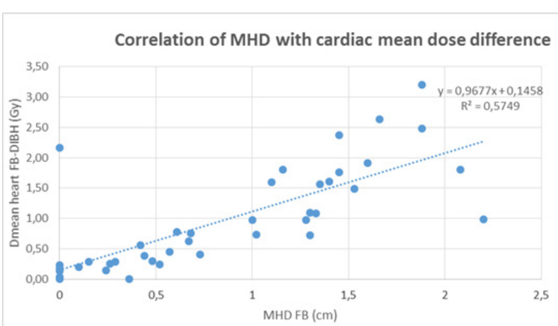
Results

A statistical significant reduction of cardiac and pulmonary doses was achieved using DIBH technique compared to FB plans (Table 1) maintaining an equal coverage of planning target volume (PTV). A positive correlation was found between MHD and mean heart dose reduction (Fig.1).

Table 1

Organ	Technique	Mean dose (Gy)	SD	Mean difference dose (Gy)	p-value	Mean dose reduction (%)
Heart Dmean	FB	2.25	1.27	0.98	0.0000	43.5
	DIBH	1.27	0.65			
Heart Dmax	FB	39.61	12.57	19.09	0.0000	48.2
	DIBH	20.52	16.17			
LADCA Dmean	FB	13.39	10.02	8.39	0.0000	62.7
	DIBH	5.00	5.69			
LADCA Dmax	FB	39.17	11.04	20.29	0.0000	51.8
	DIBH	18.88	14.97			
Mean Lung Dose	FB	7.82	2.76	1.16	0.0354	14.8
	DIBH	6.66	2.02			
		Mean volume (%)		Mean difference volume (%)		Mean volume reduction (%)
Lung left V20Gy	FB	13.56	5.70	2.35	0.0390	17.3
	DIBH	11.21	4.20			
Lung left V30Gy	FB	11.52	5.58	2.18	0.045	18.9
	DIBH	9.34	3.83			
LADCA V20Gy	FB	27.64	27.72	21.93	0.0025	79.4
	DIBH	5.71	15.98			
LADCA V19Gy	FB	20.25	19.02	18.14	0.0004	89.6
	DIBH	2.11	5.54			

Fig.1



Conclusion

Our study confirms literature data about DIBH technique advantage in terms of reduction of cardiac and pulmonary doses for tangentially treated left sided breast cancer patients. Further research is warranted to evaluate potential long-term clinical implications of these relevant dosimetry results.

EP-1949 Heart position reproducibility in deep inspiration breath hold radiotherapy for lung cancer

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Purpose or Objective

Heart dose has been linked to both increased mortality (McWilliam 2017) and cardio-vascular toxicity (Wang 2017) in patients with locally advanced non-small cell lung cancer (NSCLC), treated with modern chemo-radiotherapy. Residual setup errors, with tumour position closer to the heart than planned, had negative impact on overall survival (Johnson-Hart 2018).

We have shown, that treating this patient group in deep inspiration breath hold (DIBH) is well tolerated, improves image guidance and, in majority of patients, facilitates reduced dose to the heart (REF XXX).

The purpose of this study was to assess the reproducibility of the heart position between the consecutive DIBHs.

Material and Methods

Patients participating in a single institution DIBH radiotherapy trial (2015-2017) were included. Voluntary DIBHs were supported by use of an optical marker system and a visual feedback of the patient's DIBH level. The patients underwent three consecutive DIBH CT scans as part of the imaging for radiotherapy planning. DIBH CT no. 2 and no. 3 were rigidly registered on DIBH CT no.1 with focus on the heart. In 15 patients, all registrations were repeated after two months to evaluate the uncertainty of the manual registration process.

The positional variations of the heart position were compared to previously evaluated variations in position of the peripheral tumour (T) and the lymph nodes (N).

Results

In total 60 patients were available for the analysis.

Mean ± standard deviations (SD) in the heart position between the DIBH CTs were 0.3±1.2 mm in left-right (LR), -0.1±1.3 mm in anterio-posterior (AP) and 0.0±2.0 mm in cranio-caudal direction (CC). Over 90% of the deviations were < ±3mm (Figure 1). Intra-observer variation of the manual registration was 0.8mm in LR, 0.7mm in AP and 1.0mm in CC direction.

Heart-to-T position deviations were (mean±SD): 0.1±1.4 mm in LR, 0.3±1.8 mm in AP and -0.4±1.8 mm in CC, with 79% of deviations < ±3mm. Heart-to-N position deviations were 0.2±1.2mm in LR, 0.2±1.4mm in AP and -0.1±1.4 mm in CC direction, with 90% of deviations < ±3mm (Figure 1).

During the image registration process, differences in heart circumference of >1cm were observed in some patients, despite reproducible lung volume and chest elevation (Figure 2).

Largest heart position deviation was in the CC direction and may only in part be explained with higher observer uncertainty in this direction. It was possibly a result of cardiac motion, its impact on image quality and heart deformations between the consecutive DIBHs.

Figure 1 – Box & beeswarm plot of variation in the heart position between consecutive DIBHs (top panel), and differences between the position of the heart and the peripheral tumour (middle panel) and between the heart and the lymph nodes (bottom panel). Thick line represents the median, box the 1st & 3rd quartile, whiskers are set at the 1.5 times interquartile range of the lower and upper quartiles. Points above and below the whiskers are considered outliers (deviating more than 2.7SD from the median).

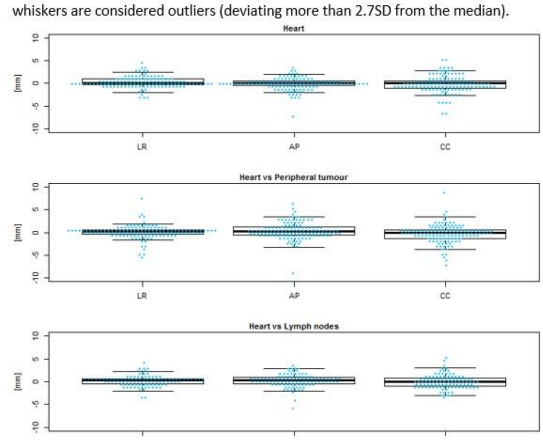
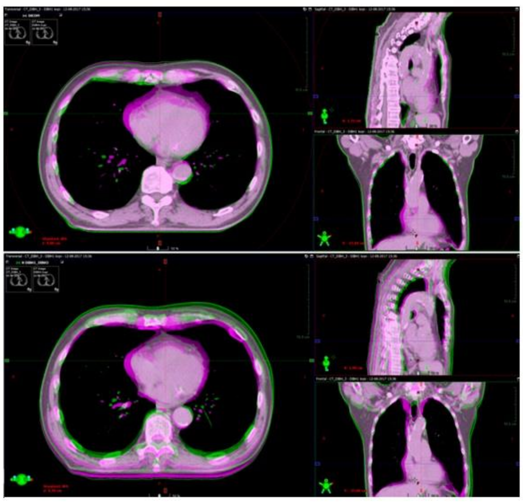


Figure 2 – green/magenta overlay of 1st (green) and 3rd (magenta) DIBH CT in patient #44. Top panel: registration between DIBH1 and DIBH3, based on DICOM origin: bones are well aligned, no major differences in lung volume or thorax surface, but clearly extended heart volume anteriorly. Bottom panel: CT scans are registered on the heart (3rd DIBH CT shifted 0.9 mm to the right, 7.4mm shift posteriorly and 3 mm cranially). There is still clear difference in heart circumference on both scans, while it fits well in cranio-caudal direction. DIBH lung volume increased by 54% compared to FB.



Conclusion
The position of the heart was reproducible between consecutive DIBHs. Deviations between heart and N were smaller than between heart and T.
Further investigations on the variations in the position and shape of the heart and its substructures are warranted, for both free breathing and DIBH, and in combination with the variation in the position of the lung tumour (due to the baseline shift and anatomical changes).

EP-1950 Phase gated lung SBRT verified by fluoroscopy
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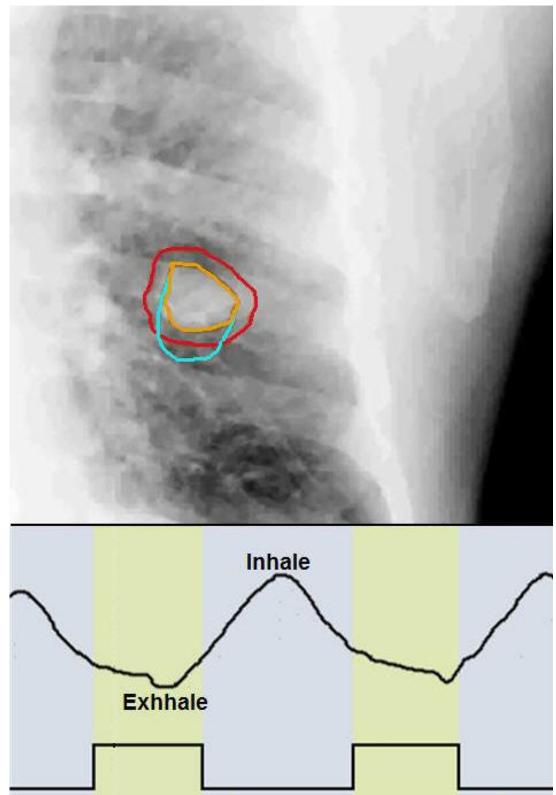
Purpose or Objective
Diaphragm motion may cause large motion of lung tumours. A resulting large internal target volume (ITV) may limit the possibility of stereotactic body radiotherapy (SBRT). By delivering radiotherapy phase gated during the mid-vent breathing phase the resulting ITV may be remarkably reduced thus enabling SBRT for otherwise unsuited patients. This retrospective study presents treatment management and reproducibility of free breathing mid-vent phase gated lung SBRT.
Material and Methods
During 2014-2018 30 patients have been treated for either primary lung cancer or metastatic disease with mid-vent phase gated lung SBRT. Treatment was planned on the average 4D-CT image created from the 30-70% breathing phases. The achieved reduction in ITV and resulting planning target volume (PTV) as compared with the full breathing cycle 4D-CT volumes were recorded for all patients. During treatment the patients breathed freely while their breathing amplitude was monitored with the Varian respiratory management system. Treatment was delivered mid-vent gated i.e. during the 30-70% phases of the breathing cycle (figure 1). Patient positioning was based on on-line cone beam computed tomography (CBCT) reconstructed with a 2 mm slice thickness and transaxial resolution of 1 x 1 mm. Following initial CBCT the match results was verified with on-line fluoroscopic images. A total of 198 fluoroscopic breathing cycles, acquired from 12 of the patients, were available for off-line analysis. From these images the tumours' cranio-caudal motion relative to that in the planning 4D-CTs was measured (figure 1). All individual cycles were controlled for the tumour being within the PTV during the gating interval as well as if the tumour's exhale maximum deviated from its position in the 4D-CT. Furthermore, it was analysed if the observed deviations from the exhale baseline correlated with variation in either the patient's cycle time or monitored breathing amplitude.
Figure 1: Fluoroscopic view (top) with ITV mid-vent (orange), ITV full cycle (blue) and PTV (red). Mid-vent gating interval (lower) indicated by yellow bars.



Results
The median ITV and PTV reductions were 40% (SD. 10%) and 30% (SD. 10%), respectively. The ITVs relative cranio-caudal motion between fluoroscopic images and planning 4D-CTs was on median 1.0 (SD. 0.2, p-value 0.82). Of the analysed fluoroscopic breathing cycles the tumours fitted into the ITV outline of the average 30-70% 4D-CT within ±1 mm and ±2 mm in 70% and 85% of the cycles, respectively. Thus a deviation larger than the CBCT resolution was observed in 15% of the cycles. In one patient the tumour moved outside the PTV during the gating interval. Deviations of the tumour's exhale maximum position did neither correlate with variations in breathing cycle length nor breathing amplitude.
Conclusion
Free-breathing mid-vent phase gated lung SBRT was clinically feasible and the exhale maximum was stable. Due to its better resolution fluoroscopic images may be used for correcting the on-line CBCT match.

EP-1951 Clinical feasibility of whole brain radiation therapy without a mask
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