

Supplementary Material

4D-CT scanning and mid-position reconstruction

All patients underwent 4D-CT imaging (Philips Brilliance Big Bore) with arms above the head. For 4D-CT reconstruction, phase binning with ten respiratory phases was used. To mitigate the effect of 4D-CT artefacts on midP reconstruction, all 4D and midP scans were visually inspected, and deemed suitable based on the target area, except for one central lung patient which was excluded from the study due to poor image quality. Based on the 4D-CT, an averaged 3D-CT image was generated for ITV planning. A midP image [13] was then reconstructed with in-house developed software. To this end, all phases of the 4D-CT were registered to the end-exhale phase using an enhanced optical flow algorithm [14], resulting in ten DVFs. A mean DVF was then calculated. Next, all ten phases registered to the end-exhale phase were warped to mid-position by summing the inverted mean DVF and the DVF corresponding to each phase specifically. Each voxel in the midP image was calculated as the median value of the corresponding voxels in the ten warped CT phases.

Treatment planning

All plans were optimized to satisfy the constraints given in Supp. Table S1. For dose calculation, a grid size of 3 mm was used and the uncertainty was set to 3% per control point, which yielded an effective uncertainty of less than 0.5% in the PTV. Monitor unit scaling was performed to achieve PTV D95% equal to 60 Gy for both ITV and midP treatment plans.

Target/OAR	Dosimetric parameter
PTV	D0.1cc < 145%
PTV	V100% > 95%
ITV/GTV	V100% > 100%
Lung-ITV/GTV	V20Gy < 10%
Lung-ITV/GTV	Dmean < 10%
Heart	V46Gy < 0.3cc
Bronchus	V41Gy < 0.5cc

Supplementary Table S1: Dosimetric criteria used for treatment planning

Direction	CC & AP		LR	
Error type	Σ [mm]	σ [mm]	Σ [mm]	σ [mm]
Delineation uncertainty	0.0	2.0	0.0	2.0
Residual inter-fraction	1.0	1.0	1.0	1.0
Intra-fraction	1.0	2.0	0.5	1.0
Total (without breathing amplitude)	1.41	3.0	1.1	2.4

Supplementary Table S2: Values for Σ and σ in the van Herk margin recipe. Delineation uncertainty is based on Peulen et al [17]. Residual inter-fraction motion includes systematic error in treatment planning system and geometric fidelity of the MR-image, and random error for not adapting to all slight anatomical changes. The intra-fraction error includes drift in a time window of 20-30 minutes based on Takao et al [18]

Case	PTV _{midP} [cc]	PTV _{ITV} [cc]	Location
1	60.3	69.3	Central
2	29.2	28.9	Central
3	155.1	159.4	Central
4	17.2	16.5	Central
5	3.1	3.3	Central
6	11.6	11.9	Central
7	6.2	7.4	Central
8	13.6	30.5	Central
9	21.1	48.7	Central
10	30.8	81.1	Central
11	4.3	6.1	Central
12	23.5	56.5	Central
13	16.9	34.8	Peripheral
14	105.0	162.7	Peripheral
15	29.3	104.4	Peripheral
16	86.9	105.7	Peripheral

Supplementary Table S3: PTVs for all tumours for both midP-based and ITV-based planning and there location. (PTV:planning target volume; midP:mid-position; ITV:internal target volume)