Table 2. *Motion-managed and PET/CT-guided radiotherapy components.* Listed with each component are approaches, their advantages and disadvantages, and comments related to their potential clinical implementation.

Approaches	***Advantages***	***Disadvantages***	***Comments***
		Motion measurement	
Abdominal displacement markers	Clinical feasibility	Insensitive to small abdominal displacements	Indicated for most patients. Use patient-specific block position, camera aperture and brightness to maximize detectable abdominal displacement
Lung volume spirometer	Stronger correlation to internal target motion	Patient coaching complexity	Indicated in patients with small abdominal displacements
Fiducial implants	Direct image of internal target motion	Invasive procedure and subsequent migration	Indicated in patients with accessible lesions when other respiratory signal surrogates not indicated
Image segmentation of diaphragm ROI	Non-invasive measure of respiratory motion	Challenges associated with deformable registration across phases	Ensure phase-sorted images not undersampled through sufficient projections or reliable undersampled image reconstruction algorithms
		Motion control	
Deep inspiration breath hold	Clinical feasibility	Lack of reproducibility and temporal inefficiency	Indicated in patients with sufficient lung function to allow for reliable breath hold under audiovisual coaching
Active Breathing Control	Reduction of motion envelope	Lung function requirement to permit forced breath hold	Determine patient-specific lung volume for breath hold (50-80 % of max)
Abdominal compression	Reduction of abdominal displacement	Upper lobe lesions subject to motion in non-diaphragmatic breathers	Indicated in diaphragmatic breathers with additional measurement of residual motion when possible to enact tolerance criteria
		PET/CT image acquisition	
Static PET/CT	Reproducibility	Motion-blurred image	Indicated for low amplitude motion lesions (e.g. upper lobe, chest wall attached)
Static prospectively gated PET/CT	Suppression of motion blurring without loss of SNR	Temporal inefficiency	Use in conjunction with ABC for patients with random breathing pattern that can achieve sufficient lung volume
Dynamic motion-tracked PET/CT	Better representation of target motion	Challenge to reproduce correlation at treatment	Use in conjuction with RF block, spirometer, fiducials, or image segmentation over all phases of breathing cycle for patients with periodic breathing
		PET/CT image processing	
Phase-averaged PET/CT	Robust low noise image	Reduced contrast and quantitative accuracy without motion information	Evaluate helical CT to determine whether to use phase-averaged PET or motion-compensated PET/CT
Maximum Intensity Projection PET/CT	Represents high confidence interval of motion envelope	PET image SNR reduced to equivalent counts for single phase	Weight intensity projection distribution across respiratory phases to improve SNR while maintaining motion envelope confidence interval
Quiescent period gated PET/CT	Variance reduction from motion over reproducible phase bin	Image quality dependent on fractional counts within quiescent window	Patient-specific gating window based on either relative displacement amplitude or absolute phase

Multiphase PET/CT	Motion compensated images with little information loss	Requires sufficient correlation between respiratory signal and target motion	Optimize number of phases and phase bin sizes as function of lesion size, location, motion amplitude
		Target definition	
Manual contour	Patient-specific target delineation	Inter-observer variability in target definition	Useful as higher order correction to target definition following automated techniques
Absolute/relative threshold	Clinical feasibility	Uncertainty in threshold due to noise or variation in backround uptake	Validate threshold-defined targets as prognostic factors of treatment outcome in abdominothoracic cancer patients
Confidence interval	Target motion margins weighted by spatiotemporal likelihood map	Limited to single target envelope by ignoring phase-specific information	Establish relevant confidence interval criteria based on MIP or motion-weighted intensity projection to build dose volume relationship for fixed normal tissue integral dose
Phase adaptive threshold	ROI specific to different phases of target motion	Complexity of threshold determination for all phases	Validate phase-adapted threshold-defined targets against known target parameters in motion phantoms
Phase adaptive stochastic segmentation	Robust to image noise and heterogeneities	Dependent on initialization conditions and susceptible to statistical variation	Validate in motion phantoms followed by comparison of prognostic value to phase-averaged targets
		Radiotherapy plan optimization	
Single plan from ROI	Clinical feasibility	Single plan may require frequent adaptation during treatment course	Indicated in patients with fewer normal tissue tolerance constraints that allow for sufficient target dose
Single plan from optimal margin target definition	Single plan feasibility with motion-compensated target definition	Reduced delivery degrees of freedom compared to phase-adapted plan	Indicated in patients whose single plan normal tissue constraints do not allow for sufficient target dose
Phase-adapted plan	Physical/biological advantages to differential delivery across phases	No consensus on weighting scheme for phase fluence maps	Indicated in patients whose single motion-compensated plan normal tissue constraints do not allow for sufficient target dose
		Radiotherapy plan quality assurance	
Single plan to static phantom	Clinical feasibility	Ignores impact of motion on clinical deliverability of treatment plan	Baseline measure of plan deliverability prior to motion uncertainties
Single plan to patient-specific motion phantom	Accounts for realistic motion trajectories	Plan deliverability limited by motion	Plans that fail QA due to motion should be replanned on individual phases
Phase-adapted plan to patient-specific motion phantom	Characterize deliverability of phase-correlated plan	Higher sensitivity to phantom setup and dosimeter measurement uncertainties	Ensure precise and accurate setup of phantom and sufficient spatiotemporal resolution of dosimeters
		Image-guided radiotherapy (IGRT) delivery	
IGRT	Clinical feasibility	Reliant on motion control or static lesion to maximize delivery efficacy	Daily imaging to verify target motion envelope within PTV

Respiratory-gated IGRT	Compromise between delivery reproducibility and treatment efficacy	Temporal inefficiency	Ensure gating window provides sufficient target coverage to phase gate-matched PTV through daily imaging and respiratory signal measurement
Respiratory-tracked IGRT	Advanced delivery optimized to complete target motion trajectory	Requires accurate and precise motion prediction algorithm to account for delivery system latency	Ensure correlation between imaged target trajectory and planned phase-correlated target trajectory
		Adaptive radiotherapy	
Planned adaptive treatment	Adapt to morphological and biological changes during RT	Adapted plan does not account for changes in image signal due to motion	Establish criteria for adapting plan that include uncertainties in imaging signal change due to motion
Planned phase-adaptive treatment	Adapt to motion-compensated morphological and biological changes during RT	Challenge of re-planning from mid Tx motion-compensated PET/CT or from on-board imager alone	Determine disease and site-specific criteria for adapting plan based on PET/CT or on-board imager