Purpose:
Current methods for deriving tumor motion in the pre-treatment setting, e.g. 4D-CT or planar x-ray fluoroscopy, fail to address breathing motion variability and result in imaging dose to the patient. “4D” treatment planning and delivery methods, most of which are under development, typically rely on a robust characterization of motion. Implementation of these beneficial 4D methods may be hindered by deficiencies in pre-treatment imaging. To characterize motion and associated variability over extended durations, we have developed a technique employing 2D dynamic MRI acquired in orthogonal planes intersecting the tumor.

Methods:
2D balanced steady-state free precession (bSSFP; TR=2.9 ms; TE=1.22 ms; flip angle=77-79°) MRI was acquired continuously over >4 minutes with interleaved sagittal and coronal planes in two healthy (lung and abdomen) volunteers at 1.5 T using a MAGNETOM Espree MRI (Siemens). In-plane resolution was 2 mm and the slice thickness was 5 mm. The imaging grid was 160×160 and 176×176 for the lung and abdominal volunteer, respectively. The resulting frame rate was 4 frames/sec. Synchronous with image acquisition, an external respiratory trace was collected at 50 Hz.

Results:
4D tracking of normal anatomy was successfully performed using custom software (Matlab, The Mathworks Inc.). Rectangular template matching was employed via normalized cross-correlation-based optimization. MRI frames were up-sampled (4×) to provide improved tracking resolution (0.5 mm). Image feature positions in 3D as a function of time were derived by interpolating 2D data from each plane onto a regular temporal grid according to the frame rate.

Conclusion:
In patients, this technique will be employed to derive the mean tumor trajectory and the breathing phase-dependent tumor position uncertainty over the imaging duration. The external respiratory trace provides important data, allowing for careful study of its viability as a surrogate. Future efforts will involve modifications to the bSSFP sequence for significant improvements in speed.

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