Analysis of lung motion and intrathoracic tumor mobility before and after radiotherapy: Therapy monitoring using dynamic MRI

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Purpose To monitor lung motion and intrathoracic tumor mobility before and after radiotherapy (RT) in patients with Non-Small-Cell Lung Carcinoma (NSCLC) using dynamic MRI (dMRI) in comparison with lung function parameters.

Methods and Materials Thirty-five patients (20 m/ 15 f; mean age 62 years – range 42 to 74 years) with stage I NSCLC were examined before and after RT using dMRI (trueFISP; TE/TR: 1.7/37.3 ms; flip angle: 65°; receiver bandwidth: 977 Hz/pixel; GRAPPA; acceleration factor: 2; field of view (FOV): 375x400; matrix 149x256; slice thickness: 10mm; voxel size: 2.5x1.6x10 mm^3; three images/sec). All patients were instructed to change from quiet tidal breathing to maximal inspiration followed by maximal expiration with as much effort as possible. This procedure was rehearsed several times to ensure reproducible conditions.

Tumors were divided into T1 and T2 tumors of the upper, middle and lower lung region (LR). Maximum craniocaudal (CC) lung dimensions and tumor mobility in three dimensions were monitored (Fig. 1). Tumor bearing and non-tumor bearing hemithoraces were measured separately. Vital capacity (VC) was measured using spirometry.

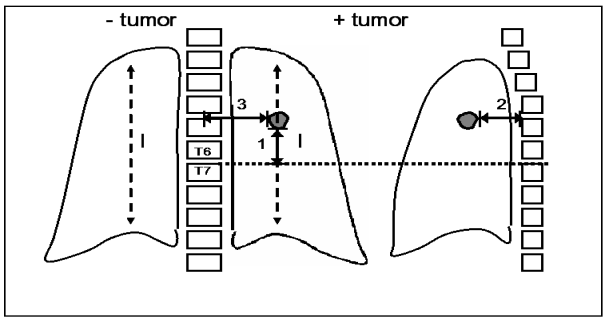

Figure 1 *Schematic display of the measurement of the lung motion and tumor mobility. Lung motion was measured from the apex to the diaphragmatic dome (I). Tumor mobility was measured in the craniocaudal direction from the T6/T7 disk space to the proximal external tumor edge (1). Tumor mobility was also measured in the anterior-posterior (2) and mediolateral direction (3).*

Results Continuous measurement of CC displacement of the diaphragm before and after RT is shown in Fig. 2. Measurement results of all included patients are shown in Fig. 3. Before RT maximum CC motion of the tumor bearing hemithorax was 5.2 ± 0.9 cm if the tumor was located in the lower LR (5.5 ± 0.8 cm middle, 6.0 ± 0.6 cm upper LR). After RT lung motion was significantly reduced in the lower LR (4.0 ± 1.3 cm, $p<0.05$). Before RT maximum CC tumor mobility was significantly higher in tumors of the lower LR 2.5 ± 0.6 cm vs 2.0 ± 0.3 cm (middle LR, $p<0.05$) vs 0.7 ± 0.2 cm (upper LR, $p<0.01$). After RT tumor mobility was significantly reduced in the lower LR (1.5 ± 0.7 cm, $p<0.05$) and in T2 tumor patients (2.2 ± 0.7 cm vs 1.2 ± 0.7 cm, $p<0.05$). Difference were insignificant for the anteroposterior and mediolateral direction in all cases. VC showed no significant changes.

Conclusion dMRI using parallel imaging technique is capable to detect changes in lung motion after RT, not suspected from spirometry. Changes of lung motion and tumor mobility are dependent on tumor localization and T-stage. The results might imply the possibility to stop the cascade of developing lung fibrosis and dyspnea early.

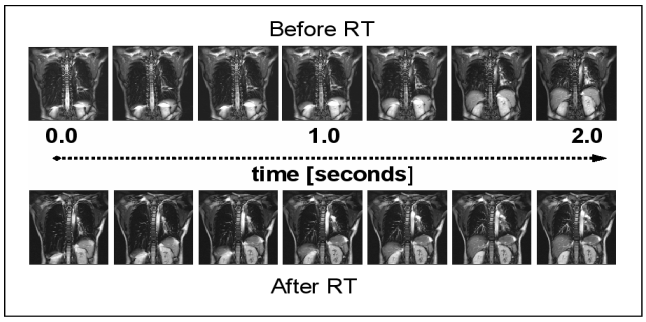

Figure 2 *MRI of tumor mobility from maximal ins- to expiration before and after radiotherapy (RT). In this patient there was a significant decrease of lung motion and tumor mobility of the left tumor bearing hemithorax after radiotherapy.*

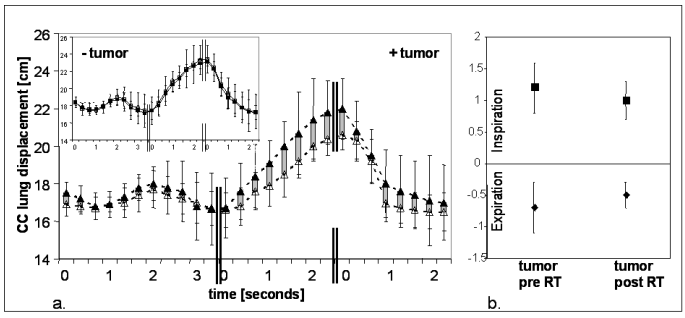

Figure 3 *All included patients:*
a. Complete breathing cycle from quiet tidal breathing followed by maximal ins- and expiration of the tumor bearing (+ tumor) and non-tumor bearing (- tumor) hemithorax before (filled symbols) and after RT (empty symbols).
b. Diagram of the differences (cm) in position of the tumor in deep expiration (square), and deep inspiration (quarter), and the quiet respiration acquisitions ("zero" value) before and after RT.