Lung Tumor Tracking with Simulated Navigator Echoes

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Target Audience: Researchers and clinicians working on the development of MR-guided radiation therapy.

Introduction: MR-guided linacs are being developed to combine the treatment of cancer with radiation therapy and the real-time target imaging. For patients with lung tumors, image guidance is especially critical for the accurate delivery of radiation due to the motion of the target. Navigator echoes offer a very fast imaging technique to monitor internal motion and are commonly employed in respiratory-gated sequences. Respiratory monitoring through navigator echoes typically uses the diaphragm edge as a surrogate for lung motion[1]. In efforts to adapt this MR technique for the treatment of cancer, Stam *et al* have demonstrated the ability to track kidney positions[2]. Lung tumors have a unique ability to be tracked directly due to the enhanced contrast of tumors compared to the surrounding healthy lung tissue.

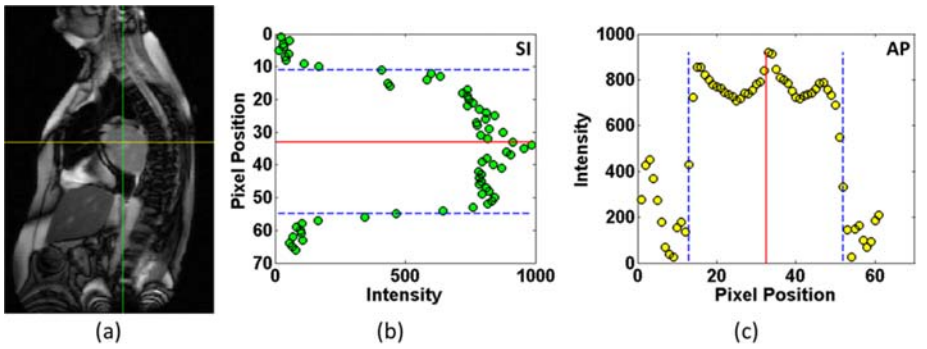

Figure 1: (a) Sagittal MRI from Patient 1 showing selected SI profile (green) and AP profile (yellow); (b) SI intensity profile with detected tumor edges (blue dashed lines) and calculated tumor center (red line); (c) AP intensity profile as in (b).

Materials and Methods: Five patients with lung tumors underwent free-breathing sagittal MR scans under an IRB-approved protocol for 8-12 minutes. Scan parameters were as follows: multi-slice 2D TruFISP, TE=1.29ms, TR=2.57ms, θ=60°, matrix=176x256, Res.=1.95x1.95x(9-16)mm, Tacq=2.5s. One-dimensional profiles of the images which passed through the center of the tumor were selected in the SI and AP directions (Fig. 1(a)). These profiles were analyzed as simulated navigator echo profiles: the tumor edges were detected by finding the pixels with the largest intensity slope, and tumor center was calculated as the mid-point between the edges as shown in Figures 1(b,c). The tumor position was tracked throughout the scan duration in each direction (see Figure 2). The navigator-tracked tumor positions were compared with tumor positions manually identified by a physician on the full images (200 acquisitions per scan) in the following ways: the linear correlation between the two positions was calculated and the difference between the two positions was calculated.

Results: Figure 3 shows the linear correlation coefficients between the manual positions and the navigator positions for all patients in each motion direction. The correlation was significant ($p<0.05$) in only one direction for each patient, corresponding to the direction of greater motion. The significant correlations ranged from strong ($R^2=0.86$, Patient 1) to weak ($R^2=0.19$, Patient 3). Figure 4 shows the error of the navigator position for all patients in both directions. The largest average difference between manual and navigator position was measured in Patient 1 in the AP direction (e1AP=1.53±1.1 pixels). The two patients with the lowest correlations, Patients 3 and 5, exhibit positional errors less than one pixel in the directions of greater motion (e3AP=-0.44±0.47 pixels, e5SI=-0.11±1.1 pixels).

Conclusion: We were able to track lung tumor motion using simulated 1-D navigator echo profiles. The correlation of navigator-identified tumor positions and manually-identified positions varied widely from patient to patient. The performance of this technique was likely dependent on tumor size, location, and range of tumor motion, all of which affect the accuracy of both the navigator position and the manually identified positions. The patients who had the lowest correlations also had the smallest motion amplitudes. In these cases the positional variation was likely dominated by noise, leading to low correlations with small positional errors. Navigator echoes have the potential to provide an efficient method for real-time tracking of the direct lung tumor motion, due to the contrast between the tumor and surrounding normal lung tissue.

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References: 1. Taylor AM, Jhooti P, Wiesmann F, *et al*. MR navigator-echo monitoring of temporal changes in diaphragm position: implications for MR coronary angiography. JMRI 1997;7:629–636.
2. Stam MK, Crijns SPM, Zonnenberg, BA, *et al*. Navigators for motion detection during real-time MRI-guided radiotherapy. PMB 2012; 57: 6797-805.

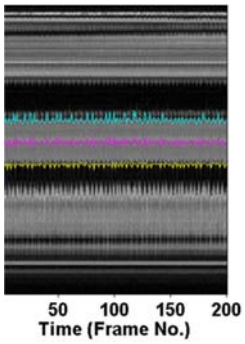

Figure 2: SI intensity profile versus time for Patient 1, with tumor top (cyan), bottom (yellow), and center position (pink).

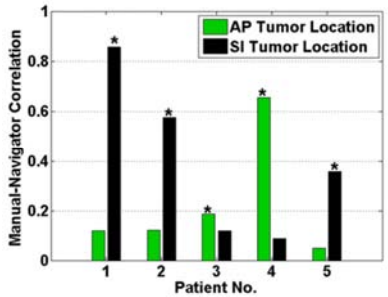

Figure 3: Correlation between manual and navigator tumor positions for SI (black) and AP (green) motion. (* indicates p<0.05)

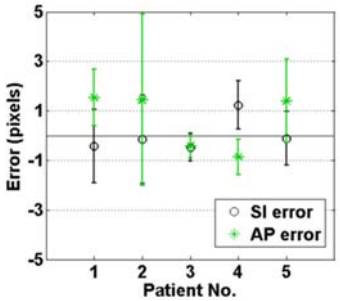

Figure 4: The tumor position error (± standard deviation) of the navigator compared to the manually identified position for the SI direction (black) and the AP direction (green).