A comparison of prostate tumor targeting strategies using magnetic resonance imaging-targeted, transrectal ultrasound-guided fusion biopsy

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Abstract

Purpose: Magnetic resonance imaging (MRI)-targeted, three-dimensional (3D) transrectal ultrasound (TRUS)-guided prostate biopsy aims to reduce the 21-47% false-negative rate of clinical two-dimensional (2D) TRUS-guided systematic biopsy, but continues to yield false-negative results. This may be improved via needle target optimization, accounting for guidance system errors and image registration errors. As an initial step toward the goal of optimized prostate biopsy targeting, we investigated how needle delivery error impacts tumor sampling probability for two targeting strategies.

Methods: We obtained MRI and 3D TRUS images from 49 patients. A radiologist and radiology resident assessed these MR images and contoured 81 suspicious regions, yielding tumor surfaces that were registered to 3D TRUS. The biopsy system's root-mean-squared needle delivery error (RMSE) and systematic error were modeled using an isotropic 3D Gaussian distribution. We investigated two different prostate tumor-targeting strategies using (a) the tumor's centroid and (b) a ring in the lateral-elevational plane. For each simulation, targets were spaced at equal arc lengths on a ring with radius equal to the systematic error magnitude. A total of 1000 biopsy simulations were conducted for each tumor, with RMSE and systematic error magnitudes ranging from 1 to 6 mm. The difference in median tumor sampling probability and probability of obtaining a 50% core involvement was determined for ring vs centroid targeting.

Results: Our simulation results indicate that ring targeting outperformed centroid targeting in situations where systematic error exceeds RMSE. In these instances, we

observed statistically significant differences showing 1-32% improvement in sampling probability due to ring targeting. Likewise, we observed statistically significant differences showing 1-39% improvement in 50% core involvement probability due to ring targeting.

Conclusions: Our results suggest that the optimal targeting scheme for prostate biopsy depends on the relative levels of systematic and random errors in the system. Where systematic error dominates, a ring-targeting scheme may yield improved probability of tumor sampling. The findings presented in this paper may be used to aid in target selection strategies for clinicians performing targeted prostate biopsies on any MRI targeted, 3D TRUS-guided biopsy system and could support earlier diagnosis of prostate cancer while it remains localized to the gland and curable.