Title: Model-based Navigation: An Ultrasound-guided Technique using Real-time Motion Compensation for Prostate Biopsies

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Structured Abstract:

Introduction: Prostate cancer has the second highest cancer incidence in men aside from skin cancer [1]. Three-dimensional (3D) transrectal ultrasound (TRUS) fused with a magnetic resonance image (MRI) is used to guide prostate biopsy as an alternative technique to conventional 2D TRUS biopsy. The TRUS-MRI fusion technique aims to provide intra-operative needle guidance to tissues suspicious of cancer identified using MRI. Currently, 3D TRUS-MR guided biopsy suffers from image and target misalignment caused by intra-operative motion, thus, we developed a real-time motion compensation algorithm to automatically align 2D and 3D TRUS images intra-operatively [2]. During clinical implementation, image misalignment still occurred when obtaining tissue samples near the boundary of the prostate. After observing excessive translation of the TRUS probe, our objective was to develop a model based navigation system in conjunction with our motion compensation algorithm to minimize probe translation. We hypothesize a model based navigation will minimize overall motion and reduce image misalignment relative to conventional practices.

Methods: A 3D model of the TRUS transducer, represented by a ring, was developed to display the transducer's orientation to the physician performing a prostate biopsy. The navigation procedure began by acquiring a 3D TRUS image of a patient undergoing a prostate biopsy, followed by manual segmentation of the prostate and a random distribution of biopsy targets. With the model ring displayed, the physician was instructed to keep the transducer's position towards the approximate centre of the segmented prostate when guiding the biopsy gun to the pre-determined targets. Although there was no tissue sampled, registration errors were assessed once reaching the final target positions. This procedure was evaluated on three patients undergoing a conventional 2D TRUS-guided prostate biopsy while using our real-time motion compensation in the background. Our ring navigation approach ($n = 18$) was compared to the conventional procedure ($n = 21$) using 2D and 3D TRUS image pairs with corresponding registration errors. A Mann Whitney U test (GraphPad Prism 7, La Jolla, CA) was performed to compare the distributions of registration errors.

Results: Ring navigation resulted in median [first quartile, third quartile] registration errors of 2.0 [1.3, 2.5] mm. This was a significant decrease in error ($p < 0.05$) compared to the conventional method, which had registration errors of 3.4 [1.5, 8.2] mm.

Discussion: Using our navigation approach, registration errors and variability were reduced when compared to the conventional 2D TRUS-guided procedure. This will allow for more accurate placement of biopsy needles during a 3D TRUS-MRI fusion-guided biopsy. Future work is directed at obtaining more patient samples and quantifying prostate deformation.

References: [1] Stewart et al, WHO, 2014; [2] Gillies et al, Med Phys 44(9), 2017