Title: Mechanically-assisted 3D Ultrasound System for Focal Liver Tumour Therapy

Trainee Name: Derek Gillies

Supervisor(s): Dr. Aaron Fenster

Structured Abstract:

Introduction: Liver cancer is the second and sixth most frequent cause of cancer mortality worldwide in men and women, respectively. Minimally invasive percutaneous techniques, such as microwave ablation, offer alternative therapy options with lower complication rates and shorter recovery times relative to conventional open surgery approaches. These techniques typically use x-ray computed tomography images for planning and two-dimensional (2D) ultrasound (US) for intraoperative guidance of applicator insertion(s) into the tumour(s). Unfortunately, these procedures have high local cancer recurrence rates due to insufficient local tumour ablation, which has been associated with variability in applicator targeting and placement accuracy from 2D US guidance. Thus, we have developed a novel intraoperative three-dimensional (3D) US imaging and guidance system with the goal of improving placement and verification of therapy applicators during focal liver tumour ablation therapies. The objective of this work was to perform the initial evaluations of the 3D US image reconstruction, first qualitative human volunteer scans, and image guidance software implementation.

Methods: A three-motor mechanical mover was designed to provide geometrically adjustable linear, tilt, and combined hybrid geometries for variable 3D US fields-of-view. This mover is held by a counterbalanced mechanically encoded tracking system mounted to a cart that features foot-released electromagnetic brakes for ease-of-use in the operating room. Verification of the three-motor mover was first performed using optical tracking with a mounted stylus to confirm mechanical motions of the scanner. Image reconstruction error was assessed by imaging a regularly spaced grid phantom with known dimensions and manually evaluating geometric differences in 3D Slicer (v4.8.1). Preliminary 3D US images were acquired of a healthy volunteer’s liver to assess clinical applicability and used to implement tumour segmentation, therapy applicator segmentation, and theoretical ablation volumes.

Results: Optical tracking using the stylus resulted in mean linear and angular motion differences of $0.09 \pm 0.11$ mm (0.20%) and $0.23 \pm 0.09^\circ$ (0.52%), respectively. Image reconstruction of the string phantom resulted in mean linear errors $<3\%$ for all dimensions and geometries. Human volunteer images were able to visualize the portal vein bifurcation, gallbladder, and kidney, which are clinically relevant anatomy.

Discussion: Our novel three-motor mover was able to reconstruct 3D US images accurately and allows for variable scan geometries to accommodate clinical anatomical variations. The mechanically assisted 3D US system was able to image clinically relevant anatomy and was used to implement preliminary software tools. Future work is focused on performing a simulated image-guided phantom procedure to assess ablation targeting accuracy.