Usability and accuracy of an electromagnetically tracked partial nephrectomy navigation system

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INTRODUCTION: Laparoscopic partial nephrectomy is increasing in popularity as the preferred method for managing small renal masses. The nephron-sparing technique preserves renal function and has comparable outcomes to radical nephrectomy. However, laparoscopic partial nephrectomy is challenging due to the lack of tactile feedback and risk of incomplete tumor resection and damage to surrounding calyces and vasculature. We propose an electromagnetically tracked navigation system that displays real-time three-dimensional anatomical models.

METHODS: The partial nephrectomy navigation system was configured using the SlicerIGT extension (www.slicerigt.org) of 3D Slicer (www.slicer.org). The experimental setup (Figure 1) consists of a laptop running the software, a TelemedMicrUS portable US machine with a linear transducer (Telemed Medical Systems, Lithuania), and an Ascension TrakSTAR electromagnetic position tracker (Northern Digital Inc., Waterloo, ON). Electromagnetic sensors are attached to the ultrasound probe and hooked needle. A reference sensor is placed inside the calyces of the kidney phantom, where a catheter would reside during surgery. The kidney phantom is placed in a laparoscopic box trainer and a sensor is attached to the laparoscopic scissors.

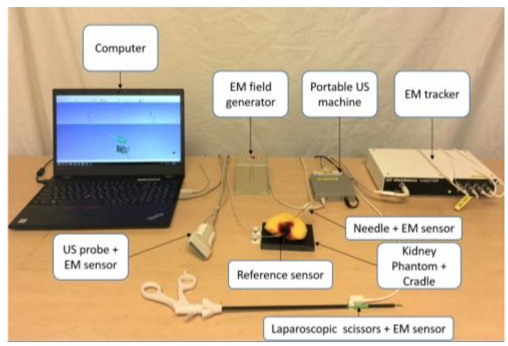

Figure 1. Experimental setup.

On the laptop screen, the three-dimensional view displays the laparoscopic scissors, tumor model, and a model of combined kidney calyces and vasculature. The tumor model is generated by placing points around the tumor boundary on live ultrasound images, as described by Ungi *et al* [1]. The model of combined kidney calyces and vasculature is segmented from live ultrasound reconstruction images generated using the Plus Remote module of SlicerIGT. The position of the laparoscopic scissors is displayed in relation to the anatomical models.

The navigation system was assessed for usability and accuracy. The usability of the system was assessed using a System Usability Survey administered to ten participants who were instructed to use the laparoscopic scissors to a trace the tumor border of a kidney phantom. Furthermore, the usability of the navigation display was assessed using a measurement of lag. The navigation screen and laparoscopic scissors were video-recorded. Frame-by-frame analysis was used to determine the time difference between the change in direction of the physical laparoscopic scissors and the model of the laparoscopic scissors. The accuracy of the system was measured using fiducial registration by placing the tip of the laparoscopic scissors on each corner of a box of known dimensions. The RMS error was recorded.

RESULTS: The mean calculated System Usability Survey was 82.8, with a standard deviation of 7.2. Using frame-by-frame analysis, it was found that the navigation view showed 5 frames per second. Average lag was 243 milliseconds with a standard deviation of 61 milliseconds. The RMS error was 2.84 mm.

CONCLUSION: An electromagnetically tracked partial nephrectomy navigation system was developed. The results of the study indicate that this navigation system is both usable and accurate. In future studies, this navigation system will be modified and validated for both clinical and educational use.

REFERENCES: [1] Ungi *et al.*, *IEEE Trans Biomed Eng*, 2016.