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Enhanced ultrasound with navigation leads to improved liver lesion identification and needle placement

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ABSTRACT

Background: The aim of this study was to evaluate whether enhanced three-dimensional ultrasound (US) could increase the accuracy and efficacy for liver tumor identification and needle placement.

Methods: In a prospective study, 30 surgeons of various training levels were evaluated for lesion identification success and accuracy of needle placement. All surgeons were evaluated for time (seconds) to identify the liver lesions in an artificial model and placement of needles after review of a 3-phase computed tomography scan of the liver, first using standard B-mode US and then using E-3DUS.

Results: Participants included 10 hepato-pancreatico-biliary surgeons, 5 surgical fellows, 10 postgraduate years 4 and 5 surgical residents, and 5 postgraduate year-3 residents. Liver lesions were correctly identified in 73% of the cases using B-mode US alone and 100% in E-3DUS. The mean time to identification using B-mode was 51.9 s (standard deviation ±37.1), which was significantly longer than with E-3DUS (time, 17.9 s, standard deviation ±10.7; $P = 0.002$). There was significant improvement in time-to-lesion identification using E-3DUS across all training levels ($P \leq 0.002$). There was also a significant reduction in time for accurate needle placement across all training levels (mean reduction of 60%, with enhanced accuracy [$P = 0.001$])

Conclusions: E-3DUS significantly enhances lesion identification regardless of size and enhances needle accuracy for all surgeons. This adjunctive system should be considered for both training and for all complex liver tumor ablations.

1. Introduction

Existing guidelines for the number of ultrasounds (US) required before clinical competency are based not on scientific study but on consensus opinion. Certain number requirements have been suggested to become competent in hepato-pancreatico-biliary ultrasound (HPB-US), but these numbers have not been validated and do not include clinical competencies. HPB-US requires two specific types of clinical competencies: Anatomy identification and/or diagnosis and therapeutic targeting. Currently, the HPB-US skill set is not a requirement for general surgical training and has only recently been discussed as a requirement for HPB certification. Intraoperative US for anatomic identification and diagnosis is

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critical for any patient undergoing an HPB resection. This critical demand has only increased with the advent of laparoscopic (minimal tactile feel) and robotic (no tactile feel) instruments, which require surgeons to guide transection planes and to ensure adequate surgical margins without the information gleaned via the minimal interface of the hand, scalpel, and tissue. Similarly, HPB-US targeting, especially for ablative procedures, is critical and is one of the dominant factors in ablation recurrences and/or failures; thus, we see the wide range in incomplete ablations regardless of the technology used (radiofrequency, microwave, or cryoablation). New nonthermal injury–based ablative techniques, in particular irreversible electroporation, put a greater demand on US accuracy and technical proficiency because the precision for needle spacing has to be within 5 mm to obtain both a safe and effective irreversible electroporation. As a result, there remains an increasing demand to optimally train and maintain HPB surgeons' US skill set to ensure the safety, quality, and effectiveness of both resections and ablations are maintained when compared with the historical open techniques.

Recent advances have occurred with preoperative three-dimensional (3D) virtual planning of complex liver resections [1,2]. This preoperative planning has led to an environment of evaluating various surgical resection planes before the operation so that surgical margins can be optimized for oncologic margins, while preserving a maximal amount of liver tissue [3] and avoiding postoperative liver dysfunction. Recent developments have now allowed for these 3D images to then be merged onto a real-time image-guidance system for real-time anatomic tracking. These image-guidance systems are well established and are now part of the standard-of-care in orthopedic, neuro-spine, and ear, nose, and throat surgery. It has been well established that these types of 3D surgical navigation systems have shown an increase in surgical confidence through accurate reproductions of planned interventions in the operating room. This type of support, which connects the preoperative planning phase with intraoperative instrument guidance based on 3D image data, continues to evolve. Similar advances around electromagnetic tracking have allowed for precise targeting down to 5-mm lesions [4–6]. Current limitations include the cost of these types of devices and the need to determine in which specific clinical applications they should be used.

The aim of this study was to evaluate whether enhanced three-dimensional ultrasound (E-3DUS) could increase the accuracy and efficacy for liver tumor identification and needle placement.

2. Materials and methods

In a prospective study at a single institution, 30 surgeons across various training levels were evaluated regarding their accuracy of needle placement and time to localization for liver lesions using both standard B-mode US and E-3DUS. All surgeons were evaluated for the time in seconds to identify four liver lesions and the time to place needles appropriately after review of 3-phase computed tomography (CT) scan of the liver using standard B-mode US and then using E-3DUS. All surgeons and/or surgical trainees were chosen at random based on their interest while attending an ablation training course. They were offered to participate during preparation time of this course and randomly selected based on their surgical skill education. Each participant was asked to perform the tasks two to three times, and their times were averaged for a final time.

The CAS-One guidance system for open liver surgery (CAScination, Bern, Switzerland) [7] was used for these experiments. Three-dimensional models of the silicon liver phantom and its vascular anatomy were segmented prior from computed tomography images (MeVis Distant Services, Bremen, Germany) and uploaded to the navigation system (Fig. 1A and B). Registration of the virtual liver model to the real organ was performed using the inherent locally rigid landmark-based registration capabilities of the guidance system, using a tracked US probe (BK Medical, Peabody, MA). Thereafter, real-time 3D-US was achieved via integrated functionality that automatically overlays US images onto the phantom model. A standard single-dimension US view was displayed with additional functional screens including the 3D view via a split-screen view (Fig. 2).

3. Experimental setup

The liver phantom was placed in the wide basin and filled with water approximately 1 cm below the liver surface. Liver registration was then performed with registering vital inflow and outflow structures, which serve as real-time registration

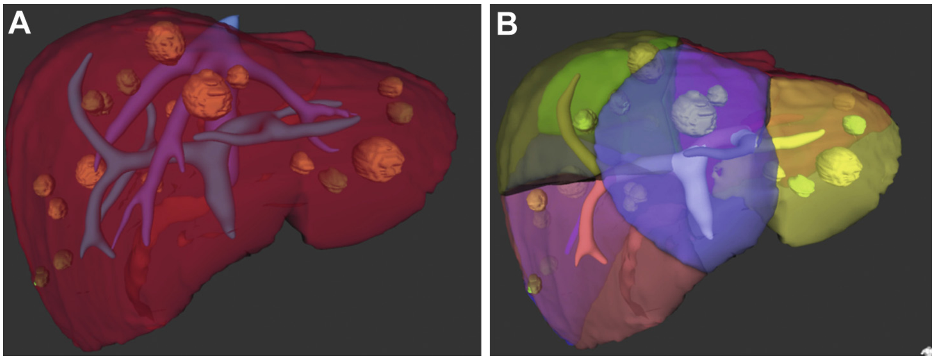

Fig. 1 – (A) Three-dimensional liver and representative tumor models from liver phantom used for this study. (B) Three-dimensional liver model with liver segmentation. (Color version of the figure is available online.)