Augmented reality guidance in laparoscopic hepatectomy with deformable semi-automatic computed tomography alignment (with video)

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Running head: Laparoscopic hepatectomy with augmented reality

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Abstract. Laparoscopic liver resection (LLR) has many known advantages but its use remains limited. A major reason is the difficulty to use laparoscopic ultrasonography to localize endophytic tumours. The state-of-the-art augmented reality (AR) guidance for monocular laparoscopic hepatectomy requires the surgeon to *manually* overlay a *rigid* preoperative model onto a laparoscopy image. This may be fairly inaccurate because the liver deforms significantly. We propose a new technique to improve AR guidance. This technique overlays a *deformable* preoperative model semi-automatically onto a laparoscopy image using a new AR software named *Hepataug* developed in our group composed by surgeons and scientists. *Hepataug* runs as follow: first, a preoperative 3D model of the liver and its internal anatomy is reconstructed from the CT; second, this model is aligned to a laparoscopy image and AR delivered to the surgeon. Because the liver offers very few anatomical landmarks, finding a method to compute the alignment was the core scientific challenge. *Hepataug*'s first breakthrough is to complement the anatomical landmarks by natural visual cues such as the silhouette. *Hepataug*'s second breakthrough is to deform the preoperative 3D model to compensate for the changes between the CT and the laparoscopy. This allows us to locate tumors easily and resect safely. To show how *Hepataug* runs, we present the proof-of-concept case of a laparoscopic segmentectomy 6 for two metachronous colorectal liver metastases. *Hepataug* was efficient in guidance where laparoscopic ultrasonography was not able to reveal the location of the tumors due to imaging artifacts. In this case, *Hepataug* showed that the resection needed to be extended. Postoperative histopathology confirmed that margins were lower than 1 mm on the initial piece and greater than 1 cm on the secondary piece. In conclusion, we have proposed *Hepataug*, the first AR software able to localize subsurface tumors accurately in monocular laparoscopy thanks to a new mechanism of semi-automatic deformable alignment. *Hepataug* yields reproducible results, is easy to use and can be largely deployed in the future in any existing operating room.

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