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

**Titre : Réalité augmentée en chirurgie hépatique laparoscopique avec recalage semi-automatique déformable du volume tomodensitométrique (avec vidéo)**

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**Running head:** Laparoscopic hepatectomy with augmented reality

**Key words:** laparoscopy, liver, resection, augmented reality, deformable 3D model, overlay

TEXT:

Laparoscopic liver resection has many known advantages but its use remains limited in clinical practice. A major reason for this limitation is the difficulty to use laparoscopic ultrasonography to localize intrahepatic tumours. Today, augmented reality (AR) guidance for monocular laparoscopic hepatectomy requires the surgeon to *manually* overlay a *rigid* preoperative model onto a laparoscopy image (1,2). This strategy is sometimes inaccurate because the liver deforms significantly (3). We propose a new algorithm to improve AR guidance. This algorithm overlays a *deformable* preoperative model semi-automatically onto a laparoscopy image using a new AR software named *Hepataug*. This software, developed in our group composed by surgeons and scientists runs in several steps. 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 external landmarks, finding a method to compute the alignment was the core scientific challenge. *Hepataug* allows to complement the anatomical landmarks by natural visual cues such as the silhouette. Then, the software can deform the preoperative 3D model to compensate for the changes between the CT and the laparoscopy. This allows surgeons to locate tumors intraoperatively and resect those tumors in a safe manner. This video shows a 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 precise location of the tumors due to imaging artifacts. In this patient, the software indicated to the operating surgeon that the resection needed to be extended. Postoperative histopathology confirmed that margins were lower than 1 mm on the initial specimen but was greater than 1 cm on

the secondary specimen. In conclusion, this video showed the first AR software able to localize intrahepatic tumors accurately in monocular laparoscopy using a new algorithm of semi-automatic deformable alignment. *Hepataug* is easy to use and could be deployed in the future in any existing operating room. This tool represents a promising new step in AR with encouraging initial clinical results but it still needs good quality comparative assessment.

**References:**

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The authors declare that they have no conflicts of interest concerning this article. The software we used was developed by our research group within the computer science department of Université Clermont Auvergne. It is a non-profit software used solely for research purposes within our group.

