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Utility of 3D Reconstruction of 2D Liver Computed Tomography/ Magnetic Resonance Images as a Surgical Planning Tool for Residents in Liver Resection Surgery

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OBJECTIVE: A fundamental aspect of surgical planning in liver resections is the identification of key vessel tributaries to preserve healthy liver tissue while fully resecting the tumor(s). Current surgical planning relies primarily on the surgeon's ability to mentally reconstruct 2D computed tomography/magnetic resonance (CT/MR) images into 3D and plan resection margins. This creates significant cognitive load, especially for trainees, as it relies on image interpretation, anatomical and surgical knowledge, experience, and spatial sense. The purpose of this study is to determine if 3D reconstruction of preoperative CT/MR images will assist resident-level trainees in making appropriate operative plans for liver resection surgery.

DESIGN: Ten preoperative patient CT/MR images were selected. Images were case-matched, 5 to 2D planning and 5 to 3D planning. Images from the 3D group were segmented to create interactive digital models that the resident can manipulate to view the tumor(s) in relation to landmark hepatic structures. Residents were asked to evaluate the images and devise a surgical resection plan for each image. The resident alternated between 2D and 3D planning, in a randomly generated order. The primary outcome was the accuracy of resident's plan compared to expert opinion. Time to devise each surgical plan was the secondary outcome. Residents completed a prestudy and poststudy questionnaire regarding their experience with liver surgery and the 3D planning software.

SETTING AND PARTICIPANTS: Senior level surgical residents from the Queen's University General Surgery residency program were recruited to participate.

RESULTS: A total of 14 residents participated in the study. The median correct response rate was 2 of 5 (40%; range: 0-4) for the 2D group, and 3 of 5 (60%; range: 1-5) for the 3D group ($p < 0.01$). The average time to complete each plan was 156 ± 107 seconds for the 2D group, and 84 ± 73 seconds for the 3D group ($p < 0.01$). A total 13 of 14 residents found the 3D model easier to use than the 2D. Most residents noticed a difference between the 2 modalities and found that the 3D model improved their confidence with the surgical plan proposed.

CONCLUSIONS: The results of this study show that 3D reconstruction for liver surgery planning increases accuracy of resident surgical planning and decreases amount of time required. 3D reconstruction would be a useful model for improving trainee understanding of liver anatomy and surgical resection, and would serve as an adjunct to current 2D planning methods. This has the potential to be developed into a module for teaching liver surgery in a competency-based medical curriculum. (J Surg Ed ▮:▮▮▮-▮▮▮. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: liver surgery, computer-assisted surgery, medical education, surgical education

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COMPETENCIES: Practice-Based Learning and Improvement, Medical Knowledge

INTRODUCTION

The 5-year survival for primary and secondary liver cancer without resection is approximately 3%. Surgical resection with negative margins increases 5-year survival rates from 20% to 30%.[1,2] The challenge lies in removing enough tissue to achieve negative margins, while sparing healthy liver tissue to reduce the risk of postresection liver failure. A fundamental aspect of surgical planning is the identification of vascular tributaries that are key in preserving healthy liver tissue and their relation to the tumor(s).[3,4]

Current surgical planning primarily relies on the surgeon's ability to interpret and mentally reconstruct 2D computed tomography/magnetic resonance (CT/MR) images into 3D while planning resection margins. This is mentally strenuous and increases cognitive load, especially in trainees, as it relies on CT/MR interpretation, anatomical and surgical knowledge, experience, and spatial sense.[5,6] Prior research has shown the benefit of 3D reconstruction with hepatobiliary specialized surgeons in planning complex liver resections with unconventional resection planes,[7] but no studies exist evaluating the use of 3D reconstruction as a surgical planning tool for trainees. The objective of this study is to determine if 3D reconstruction of preoperative CT/MR images will assist trainees in selecting appropriate surgical plans for liver resection surgery.

MATERIAL AND METHODS

Study Design

This was a prospective cohort study (2016). The study was approved by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board. Voluntary enrollment and signed consent was obtained from each participant.

Study Participants and Setting

Senior level general surgery residents in postgraduate year (PGY) 3 to 5 were recruited from the Queen's University General Surgery residency program. Junior level trainees (PGY 1 and 2) were excluded from the study as exposure and knowledge expectation at that level does not include liver resection planning. The participants performed the study on a standard personal computer without access to the internet or textbooks. An investigator was present to facilitate the study and answer technical questions about the use of the 3D visualization software, but questions related to surgical planning were not answered during the study.

Study Protocol

Liver resection cases completed at our institution from 2011 to 2016 were reviewed. Preoperative patient CT/MR images were chosen on the basis of quality images that provided adequate visualization for surgical planning. Inclusion criteria for liver resection cases were single stage operative interventions with preoperative imaging that accurately reflected the intraoperative findings and the final surgery performed was in keeping with the preoperative plan. Each preoperative image was independently reviewed by 2 hepatobiliary surgeons to provide expert opinion on the optimal surgical plan, and cases with differing opinions were excluded. Cases with 2 stage resections, radiofrequency ablation, or preoperative portal vein embolization were also excluded. A total of 10 cases were selected and patient data were anonymized.

Five cases were allocated to the 2D method and 5 cases were allocated to the 3D method. Both groups were case-matched so that similar types of resections and level of difficulty were assigned to each planning method. Each group had one of the following: left lateral segmentectomy, right posterior segmentectomy, left trisegmentectomy, right hepatectomy, and wedge resection of segment 8. The 2D group consisted of raw CT/MR images without the radiologist report. The 3D group consisted of digital reconstructions that can be manipulated 360° to view the tumor(s) in relation to the hepatic structures from any viewpoint (Fig. 1). These were created using an open source segmentation module in 3D Slicer (www.slicer.org).

Residents were given a sample 3D case to orient them to the technology and allow them to learn how to manipulate the model. They were then asked to evaluate the images from the 10 cases, and write down the optimal surgical approach for each. This was defined as the type of liver resection they would perform to obtain negative margins while still maintaining adequate hepatic function (i.e., left lateral segmentectomy). Residents had to devise the plans de novo, they were not aware that the groups were case-matched, or that there were only 5 different types of resections. Each resident alternated between 2D and 3D cases in a different predetermined randomized order (https://www.random.org/lists/). Their surgical plan and time (seconds) to devise each plan was recorded. Residents did not know that their times were being recorded. Residents completed a prestudy and poststudy questionnaire regarding their level of training, prior experience with liver surgery, and their experience with the 3D planning software (Appendix Table A).

Data Analysis

Residents received a score of 1 for a correct response and 0 for an incorrect response. A correct response was based on expert opinion, and can be defined as the optimal surgery to obtain clear margins while maintaining hepatic function. This was tallied for a score out of 5 per resident for each group. The