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TECHNICAL REPORT

Interpreting three-dimensional structures from two-dimensional images: a web-based interactive 3D teaching model of surgical liver anatomy

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Abstract

Background: Given the increasing number of indications for liver surgery and the growing complexity of operations, many trainees in surgical, imaging and related subspecialties require a good working knowledge of the complex intrahepatic anatomy. Computed tomography (CT), the most commonly used liver imaging modality, enhances our understanding of liver anatomy, but comprises a two-dimensional (2D) representation of a complex 3D organ. It is challenging for trainees to acquire the necessary skills for converting these 2D images into 3D mental reconstructions because learning opportunities are limited and internal hepatic anatomy is complicated, asymmetrical and variable. We have created a website that uses interactive 3D models of the liver to assist trainees in understanding the complex spatial anatomy of the liver and to help them create a 3D mental interpretation of this anatomy when viewing CT scans.

Methods: Computed tomography scans were imported into DICOM imaging software (OsiriX™) to obtain 3D surface renderings of the liver and its internal structures. Using these 3D renderings as a reference, 3D models of the liver surface and the intrahepatic structures, portal veins, hepatic veins, hepatic arteries and the biliary system were created using 3D modelling software (Cinema 4D™).

Results: Using current best practices for creating multimedia tools, a unique, freely available, online learning resource has been developed, entitled *Visual Interactive Resource for Teaching, Understanding And Learning Liver Anatomy (VIRTUAL Liver)* (http://pie.med.utoronto.ca/VLiver). This website uses interactive 3D models to provide trainees with a constructive resource for learning common liver anatomy and liver segmentation, and facilitates the development of the skills required to mentally reconstruct a 3D version of this anatomy from 2D CT scans.

Discussion: Although the intended audience for *VIRTUAL Liver* consists of residents in various medical and surgical specialties, the website will also be useful for other health care professionals (i.e. radiologists, nurses, hepatologists, radiation oncologists, family doctors) and educators because it provides a comprehensive resource for teaching liver anatomy.

Keywords

3D liver model, web-based learning, hepatic anatomy, surgical anatomy

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Introduction

Young surgical trainees experience a steep learning curve in the process of acquiring even a rudimentary understanding of hepatic anatomy, as formal learning opportunities are limited and only basic liver anatomy is taught to medical students.[1] Hepatic surgical procedures require the surgeon to be sufficiently comfortable with anatomy to be able to rely on his or her own three-dimensional (3D) mental reconstruction of the 2D images provided by computed tomography (CT) scans. Interpreting CT

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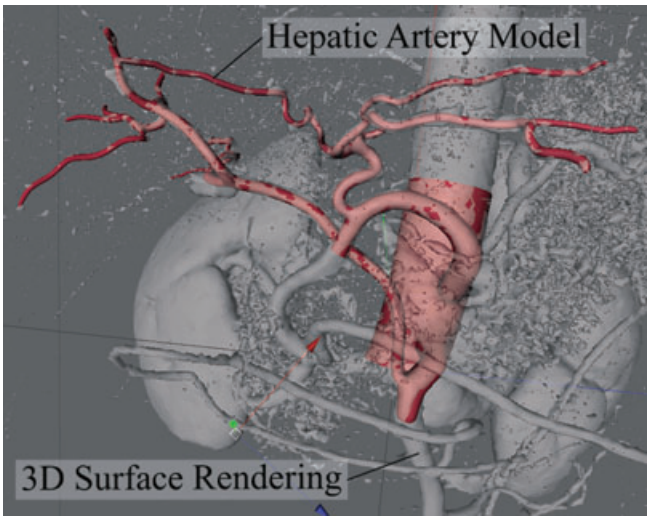

Figure 1 3D surface renderings developed in OsiriX™ are imported into Cinema4D™ and used as a template for building spatially accurate models of liver structures, such as the hepatic artery shown here

scans is difficult and students find it a frustrating task that hinders their ability to optimize their educational experiences on hepatobiliary surgical rotations.[2,3]

It is difficult to demonstrate the superiority of online education resources compared with traditional methods of teaching,[4] However, there is considerable evidence that web-based learning is a preferred method for students.[5–7] This modality allows users to control content, learning pace and learning sequence,[8] and can also be accessed by large numbers of students, on demand.[9] Because learning increases with repeated exposure that is distributed over time,[10] the utility of a teaching tool will increase if it can be accessed as needed in the clinical setting. Provided that online tutorials are well designed, from both an instructional and user-centred perspective,[11–13] they are effective teaching tools and have been shown to improve subsequent face-to-face teaching sessions.[14] Such a tool would have particular value for surgical residents engaged in interpreting CT scans during clinical sessions with surgeons.

We describe the creation of a website referred to as the *Visual Interactive Resource for Teaching, Understanding And Learning Liver Anatomy (VIRTUAL Liver)*, which uses interactive 3D models to aid understanding of complex spatial internal hepatic anatomy and to assist trainees in creating a 3D mental interpretation of this anatomy from CT scans.

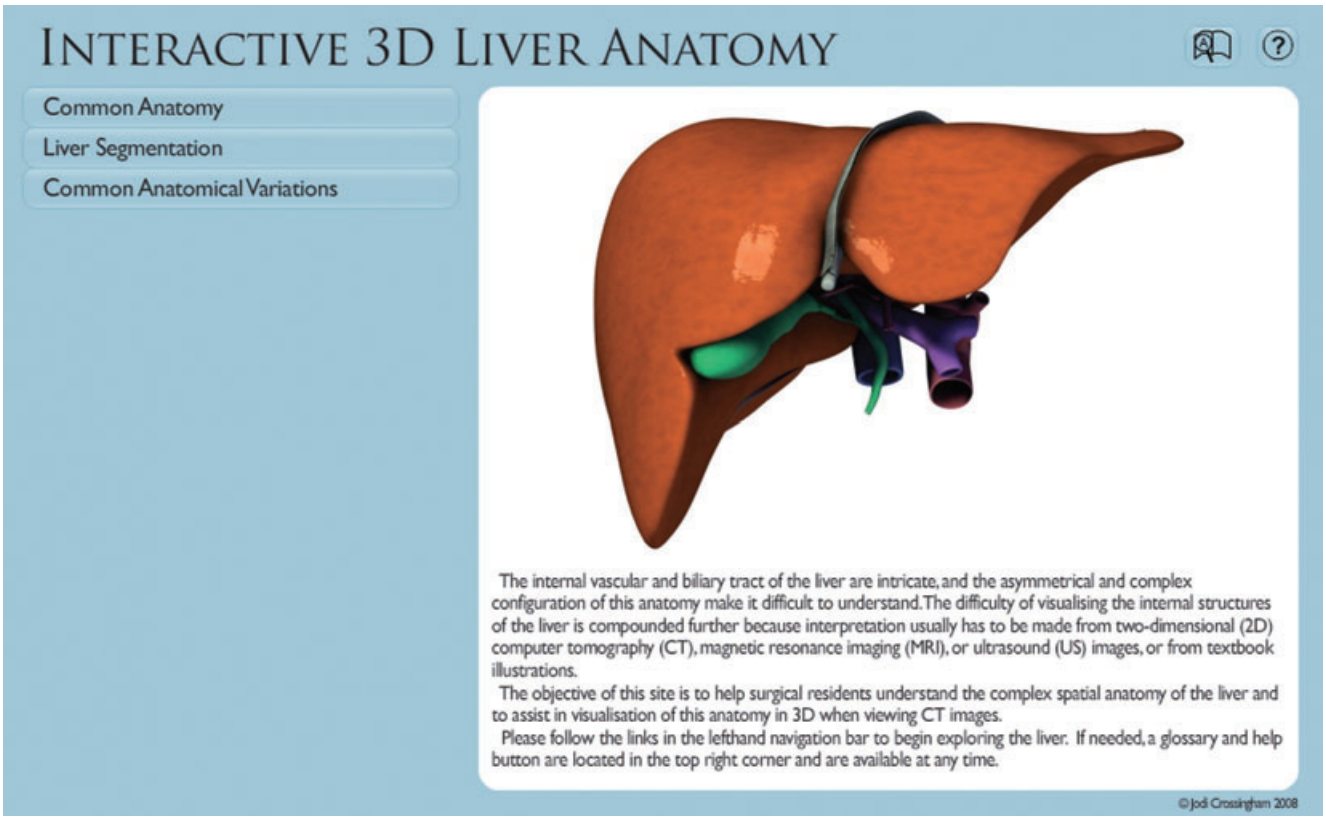

Figure 2 The *VIRTUAL Liver* website homepage (http://pie.med.utoronto.ca/VLiver/), showing the navigational toolbar located on the left and help tools located in the top right-hand corner