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Personal Computer Software Evaluation in Interactive Generation of Pig Liver Three-Dimensional Anatomical Images

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ABSTRACT

The efficiency of software for a personal computer in the interactive generation of three-dimensional (3D) images from computer tomography was studied in six pig livers after hepatic resection and catheterization of the hepatic and portal veins. After perfusion the livers were submitted to computed tomography angiography, volumetric measurement by water displacement, and production of an acrylic model of the veins by the injection and corrosion method, by which the lengths of the hepatic and portal veins were measured. From the angiogram, the software generated a 3D image that allowed measurement of the vein lengths. The identified branches of the hepatic and portal veins were correlated with the hepatic sectors and segments, respectively. The virtual measures from the 3D images were compared with the real measures. There were no significant differences between the topography and the vessel length. The mean difference between the volumes calculated from software and those measured by water displacement corresponded to 1.2%, and between the vessel lengths, 0.2%. In conclusion, the software for personal computer (named LIVER3D) is efficient, allowing interactive inspection of 3D images. All virtual measurements of liver vessel length and partial/total liver volume were similar to the actual ones.

ANALYSIS OF THE LIVER vascular system and volume measurements obtained by computed tomography (CT) are considered necessary to plan a hepatectomy and select the proper size of the liver graft from a living donor.[1] Helicoidal CT with graphics workstations is a technological advance that allows high-speed and high-resolution helical imaging to render and analyze three-dimensional (3D) angiograms. However, in developing countries, this technology is restricted; data are evaluated by simple procedures, largely performed using bidimensional images. Searching for a low-cost alternative of visualization and analysis of 3D CT images, we realized that there are many efficient volume-rendering techniques for personal computers (PC) using regular graphics processing units (GPUs) whose capabilities are similar to those of graphics workstations.[2] This paper sought to develop and experimentally test a software program (LIVER3D) for interactive inspection of 3D images on a PC platform. This program measures liver-vessel lengths and liver volumes acquired by helicoidal CT.

METHODS

Six of landrace pig livers from donors weighing around 22.5 kg, were catheterized ex vivo to perfuse the portal vein and vena cava with 1 L of SF 0.9% containing heparin. An ionic contrast medium was injected for a CT angiogram, consisting of transverse slices obtained by a defined image acquisition protocol at 120 kV peak kilovoltage, 150 mA tube current, pitch 1.5, slice thickness 3mm, 512 × 512 pixels (0.625 mm in plane spacing) and 16-bits/pixel grey-scale. The hepatic and the portal vein diameters were measured in the tomography angiogram. The pig liver volume was determined by water displacement. Thereafter the vena cava and portal vein were injected with methylmethacrylate. The liver parenchyma was corroded with chloride acid (35%) to generate an acrylic model of the pig liver veins. A line superimposed over the acrylic model measured vessel length.

3D images were produced in a PC Pentium 4, with 2 Ghz, 512 Mb, graphics board ATI 9800, using OpenGL API and C++

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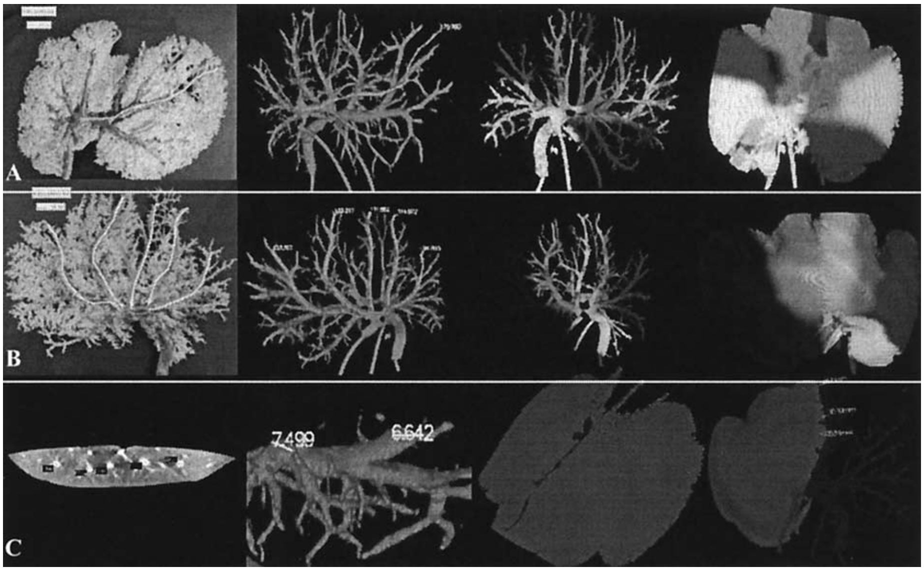

Fig 1. Images from the angiogram, from the acrylic model photography and from the software LIVER3D. **A** Pig liver segments in acrylic model and 3D images. **B** Pig liver sectors in acrylic model and 3D images. **C** Bidimensional angiogram, zoom of the vessels, VHM identification, and hepatectomy planning.

language. We used two transfer functions defined according to the image acquisition protocol described before. Basically, our interest lay in visualizing the liver parenchyma and vessels and suppressing background artifacts. The protocol included the image windows defined by the radiologist with Merge eFilm workstation software. The acquired images, as well as the defined transfer functions, were received in a DICOM medical image file format. By using the defined transfer function and the Hounsfield density values, we designed our transfer functions, including color and opacity attributes.

In LIVER3D, the volume of the scanned liver was determined by computing the amount of pixels on the slices and multiplying it by the voxel volume as read from the DICOM file. A virtual line superimposed over the virtual vessels measured the vessel length.

We compared the topography and vessel lengths obtained with the acrylic model and the ones obtained with LIVER3D. In the same way, we compared the liver volume determined by the software and by water displacement.

RESULTS

There were no significant differences between the topography, volume, or vessel lengths. The percent difference ($\Delta\%$) was analyzed by a *t* test: volume: $\Delta\% = 1.2\%$. Vessel length: portal vein $\Delta\% = 0.31\%$; left hepatic vein $\Delta\% = 0.24\%$, left middle hepatic vein $\Delta\% = 0.001\%$; middle hepatic vein $\Delta\% = 0.26\%$; right middle hepatic $\Delta\% = 0.18\%$; and right hepatic vein $\Delta\% = 0.21\%$. With reference to the vein diameter, the percent difference ($\Delta\%$) was left hepatic vein $= 1.17\%$; left middle hepatic vein $= 0.25\%$; middle hepatic vein $= 0.66\%$; right middle hepatic vein $= 3.36\%$; and right hepatic vein $= 2.6\%$.

DISCUSSION

All established goals were achieved by this computer program, including visualisation of the 3D anatomical images as well as the interaction and the measurements. All developed tools for cutting, classification, and measurement allowed as to exclude parts of the image, to measure the partial volume, and to plan the hepatectomy (Fig 1). The accuracy of volumetry observed in our data was dependent on slice number, acquisition time, object size and format, contrast dilution, slice thickness, and respiratory movement. Determination of the limits of window level and Hounsfield coefficient allowed the delimation of vessels and parenchyma, during liniarization and transfer functions. Brown et al[3] measured the volume of pig kidney ex vivo with a difference of 1.3%, which was similar to our results using pig liver. The measurement of vessel length with a virtual line superimposed over the vessels accompanying the curvature is a new and accurate method for comparison with a real model.

Today's use of 3D anatomic images to study and teach liver anatomy and hepatectomy planning reduces training time.[4] However, the 3D images are not intended to substitute for but to reduce the use of human cadavers or experimental animals.[5,6]

In conclusion, the program (LIVER3D) for a personal computer is an efficient method to generate 3D images from computed tomography, allowing interaction with these images as well as measurement not only of the liver volume but also of the vein length and diameter. The 3 Measurements were similar to those obtained from the actual organ and the acrylic model.

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