Original Investigation

Comparative Evaluation of Three Software Packages for Liver and Spleen Segmentation and Volumetry

Puskar Pattanayak, MD, Evrim B. Turkbey, MD, Ronald M. Summers, MD, PhD, FSAR

Rationale and Objectives: This study aims to compare the speed and accuracy of three different software packages in segmenting the liver and the spleen.

Materials and Methods: The three software packages are Advantage Workstation Solutions (AWS), Claron Technology (Claron) Liver Segmentor, and Vitrea Core Fx (Vitrea). The dataset consisted of abdominal computed tomography scans of 30 patients obtained from the portal venous phase. All but two of the patients had a cancer diagnosis. The livers of 14 patients and the spleens of 24 patients were reported as normal; the remaining livers and spleens contained one or more abnormalities. The initial segmentation times and volumes were recorded in Claron and Vitrea as these created automatic segmentations. The total segmentation times and volumes following corrections were recorded. The livers and spleens were segmented separately by two radiologists who used all three packages. Accuracy was assessed by comparing volumes measured using fully manual segmentation on the AWS.

Results: Claron could not segment the spleen in four subjects for the first reader and in two subjects for the second reader. The final mean segmentation times for the liver for both readers were 6.5 and 5.5 minutes for AWS, 4.4 and 3.6 minutes for Claron, and 5.1 and 4.2 minutes for Vitrea. The final mean segmentation times for the spleen were 2.7 and 2.1 minutes for AWS, 2.1 and 1.4 minutes for Claron, and 1.8 and 1.2 minutes for Vitrea. No statistically significant difference was found between the organ volumes measured by the two readers when using Vitrea. The mean differences between the initial and final segmentation volumes ranged from –1.2% to 0.4% for the liver and from –4.0% to 9.8% for the spleen. The mean differences between the automated liver segmentation volumes and the AWS volumes were 2.5%–2.9% for Claron and 4.9%–6.6% for Vitrea. The mean differences between the automated splenic segmentation volumes and the AWS volumes were 5.0%–6.2% for Claron and 10.6%–12.0% for Vitrea.

Conclusions: Both automated packages (Claron and Vitrea) measured liver and spleen volumes that were accurate and quick before manual correction. Volumes for the liver were more accurate than those for the spleen, perhaps due to the much smaller splenic volumes compared to those of the liver. For both liver and spleen, manual corrections were time consuming and for most subjects did not significantly change the volume measurement.

Key Words: Image processing; observer study; quantitative imaging; software evaluation.

INTRODUCTION

A quick and accurate assessment of liver and spleen volumes is important in various clinical and research settings. Volume measurements may be required in evaluating suspected or known organomegaly, following disease progression, and assessment before organ transplantation or resection. Response to different therapies may also be assessed, such as an increase in splenic volume post chemotherapy (1).

The liver and the spleen have complex and highly variable shapes in most patients. For example, in a particular patient, there are complex invaginations of the liver contour in the region of the porta hepatis, and frequently considerable variation in shape from the top to the bottom of both the liver and the spleen. There is also considerable variability in liver and spleen shapes from one patient to another. These complexities and variabilities make manual segmentation time consuming and automated segmentation more difficult. However, the state-of-the-art in automated liver and spleen segmentation has improved substantially over the past decade. For example, a recent study has shown non-inferiority of an

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From the Clinical Image Processing Service, National Institutes of Health Clinical Center, Bethesda, Maryland (P.P., E.B.T., R.M.S.); Imaging Biomarkers and Computer-Aided Diagnosis Laboratory, Radiology and Imaging Sciences, National Institutes of Health Clinical Center, 10 Center Dr., Building 10, Rm. 1C224D MSC 1182, Bethesda, MD 20892-1182 (R.M.S.). Received October 4, 2016; revised February 1, 2017; accepted February 1, 2017. Note: Present address of PP and EBT: Johns Hopkins University School of Medicine, Baltimore, MD, USA. This research was supported by the Intramural Research Program of the National Institutes of Health Clinical Center, project 1Z01 CL040004. Disclaimer: The content of this publication does not necessarily reflect the views or policies of the U.S. Department of Health and Human Services or the National Institutes of Health, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. government. Potential Conflicts: A former employee of our department is currently an employee at Claron. RMS receives patent royalties from iCAD Medical and license royalties from Imbio and Zebra Medical. RMS's lab receives research support from Ping An and is negotiating software licenses with Imbio, Zebra Medical and Carestream. **Address correspondence to:** R.M.S. e-mail: rms@nih.gov

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automated liver segmentation compared to manual segmentation with improved reproducibility (2).

The use of automatic segmentations and then application of volumetric thresholds to identify splenomegaly (3) or definition of volumetric nomograms to identify hepatomegaly (4) have been shown to be accurate. These types of applications may improve detection of organomegaly compared to visual inspection or craniocaudal height measurement.

Our department receives several requests a day from clinical teams to measure liver and spleen volumes. A number of different commercial software packages are available for this purpose. The decision of which package to use is often based on personal preference or a subjective impression of efficiency. To our knowledge, no studies have compared different commercial segmentation software packages to assess their speed and efficiency in segmenting the liver and the spleen.

The goals of the present study were to determine the accuracy and the time taken to fully automatically measure liver and spleen volumes from computed tomography (CT) images, and to determine the magnitude of any added benefit in terms of improved volume measurement of manual correction following the automated segmentation. We used three packages that were available in our department and that could measure both organs.

MATERIALS AND METHODS

Under the terms of the software license, Claron reviewed a draft of the manuscript and provided comments. The authors had full control over the data and content of the manuscript.

Case Selection

The present study was approved by our institutional review board. The requirement for informed consent was waived. CT scans of 30 patients who were scanned on four different days at our institution's radiology department were selected for analysis. Thirty cases that included a portal venous phase abdominal scan and contained both organs were analyzed. The portal venous contrast phase was used in the volume measurements. The 5-mm slices were used for analysis. The average age of the patients was 55.8 ± 12.4 years (mean ± standard deviation). There were 18 men and 12 women.

All but two of the patients had a cancer diagnosis (four had lung cancer [one of whom also had colorectal cancer], four had renal cancer, four had mesothelioma, four had neuroendocrine cancer, four had prostate cancer, and eight had other types of cancer). The remaining two patients had lymphangioleiomyomatosis.

The liver was reported as normal on 14 scans; eight showed one or more cysts or hypodensities that were too small to characterize (likely cysts or hemangiomas); three showed fatty infiltration or diffuse steatosis; one showed cirrhosis; one showed punctate calcifications; two showed minimal biliary dilatation; one had a large infiltrating mass at the root of the mesentery extending into the porta hepatis; one had multiple hyperenhancing and hypoenhancing lesions measuring up to 1.3 cm, possibly metastatic; and one had pneumobilia. On three scans, right pleural disease (nodules or effusions) abutted the right hemidiaphragm. Because of multiple findings on some scans, numbers do not add to 30.

The spleen was reported as normal on 24 scans; three showed hypodensities that were cysts or indeterminate; one showed old granulomatous disease; one showed perisplenic postoperative changes; one showed an infiltrating low-density mass adjacent to the splenic hilum; and one showed splenomegaly. Because of multiple findings on some scans, numbers do not add to 30.

Image Acquisition

The patients underwent scanning on a Somatom Force scanner (Siemens Medical Solutions, Erlangen, Germany) with a voltage of 120 kVp and a quality reference standard of 120 mAs. The actual milliampere second varied according to patient characteristics. The patients underwent scanning following intravenous administration of iodinated contrast (Isovue 300; Bracco Diagnostics, Milan, Italy). The amount of contrast was determined by body weight up to a maximum of 130 mL.

Software Packages

The software packages that were assessed were

1. Advantage Workstation Solutions (AWS) Version 3 (GE Healthcare, Wauwatosa, WI)
2. Claron Liver Segmentor (Claron Technology Inc, Toronto, ON, Canada)
3. Vitrea Core Fx version 9998.1 (Vital Images, Minnetonka, MN)

All three packages enabled exporting of the analysis.

The cases were individually analyzed by two radiologists (P.P., reader 1; E.B.T., reader 2). Reader 1 is a radiologist with 3 years' post-residency experience. Reader 2 is a radiologist with 8 years' post-residency experience. Each radiologist was unaware of the other's time and volume measurements.

The Advantage Workstation Solutions package will be referred to as AWS. There is no fully automated segmentation with AWS. AWS requires an initial manual segmentation on several slices and then completes the segmentations on the remaining slices. The top and bottom slices of the organ may be manually segmented, and the software will then automatically segment the slices in between. These automatically segmented slices are increasingly more accurate as the number of slices that the reader segments manually is increased. Typically, between five and seven slices were manually segmented. Corrections were made at the time of the segmentation. The scans have to be loaded from PACS (picture archiving and communication system) onto the local database. Once the scan is opened, the axial slices and the multiplanar reformats are shown. The contours are drawn by manually placing the cursor at the edge of the organ and then manually tracing around the border of the organ on that slice. Figure 1a