Original Investigation

The Best Single Measurement for Assessing Splenomegaly in Patients with Cirrhotic Liver Morphology

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Rationale and Objectives: There is little agreement within the radiology literature as to the best single measurement for assessing splenomegaly. In this study, we evaluate the correlation of multiple unidirectional measurements of the spleen with splenic volume in patients with cirrhotic liver morphology on computed tomography (CT).

Materials and Methods: Splenic volume was retrospectively calculated from CT examinations of 179 adult patients, 47 of whom were approved as renal donors, and 132 of whom were referred for various other indications, and were found to have cirrhotic liver morphology on CT. Seven unidimensional measurements (long-axis, cranial-caudal, width, and four measures of thickness) of each spleen were evaluated to identify which most closely correlated with the calculated volume.

Results: The splenic width had the best correlation with splenic volume for mild-to-moderate splenomegaly, and the splenic cranial-caudal measurement had the best correlation with splenic volume for massive splenomegaly. Receiver operating characteristic analysis demonstrates that a splenic width measurement of approximately 10.5 cm has a sensitivity of 89% and a specificity of 78% for mild-to-moderate splenomegaly, and a cranial-caudal measurement of 14.6 cm has a sensitivity of 92% and a specificity of 91% for massive splenomegaly.

Conclusions: A splenic width threshold of 10.5 cm is the most sensitive (89%) and specific (78%) single measurement for mild-to-moderate splenomegaly in patients with cirrhotic liver morphology, whereas a cranial-caudal height threshold of 14.6 cm is the most sensitive (92%) and specific (91%) single measurement for massive splenomegaly.

Key Words: Spleen; splenomegaly; cirrhosis; portal hypertension; measurement.

INTRODUCTION

Although nonspecific, splenomegaly is an important finding in a variety of disease processes, including portal hypertension, hematologic disorders, and chronic inflammatory conditions (1–9). In patients who have cirrhosis or who are at risk of cirrhosis, identification of splenomegaly is of particular value, as splenomegaly is the most sensitive imaging finding of portal hypertension, and correlation between splenomegaly and the subsequent development of cirrhosis, as well as between splenomegaly and the severity of esophageal varices, has been established (2,10–12). However, determining splenomegaly on computed tomography (CT) imaging has long vexed the radiology community, and there is no established consensus for when or how to diagnose it. The gold standard for determining splenomegaly requires calculating the splenic volume, although this is rarely performed, as it is both technically challenging and time-consuming (13–16). Rather, radiologists commonly rely on unidimensional proxy measurements, including cranial-caudal (CC) and long-axis (LA) measurements, as seen in Figure 1 (12). Despite the common use of these measurements, no single unidimensional measurement has been established in the literature with both a high sensitivity and a high specificity for all cases of splenomegaly, owing largely to the complex and varied shape and orientation of the spleen. For example, the commonly accepted LA and CC measurements of the spleen, ranging from 10 to 13 cm, have been demonstrated to have a low sensitivity (33%–68%) and specificity (68%–76%) for sub-massive splenomegaly, resulting in both underdiagnosis and misdiagnosis (13).

Studies to date have tacitly assumed that the same unidirectional measurement for splenomegaly can be applied to any spleen, regardless of the suspected etiology of splenomegaly. For example, it is assumed that the same unidimensional measurement is equally valid for identification of splenomegaly in a patient with lymphoma as in a patient with cirrhosis. Although this may be the case, we do not assume it to be so. For this reason, we have studied spleen size specifically in patients

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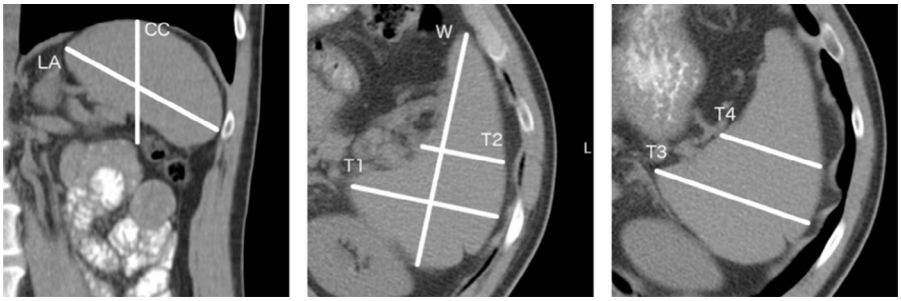

Figure 1. Unidirectional measurements.

with cirrhotic liver morphology, who are presumed to have splenomegaly secondary to portal hypertension. It is important to recognize that although CT is not sensitive for cases of mild cirrhosis, it is approximately 100% specific for cirrhosis, which allows us to use the imaging appearance of the liver to predict the presence of portal hypertension, which is reported to be present in 90% of patients with cirrhosis (2). In this study, we present a unidimensional measurement for splenomegaly with a high degree of sensitivity and specificity for patients with cirrhotic liver morphology on cross-sectional imaging.

MATERIALS AND METHODS

Study Patients

This retrospective study follows the Health Insurance Portability and Accountability Act compliance standard and was approved by our institutional review board. No informed consent was necessary at our institution for this type of study.

Included in the study were CT scans of 179 adult patients performed between January 2008 and December 2015. Of these patients, 47 were approved for renal donation (17 males [mean age 42; range 28–71] and 30 females [mean age 47; range 24–68]), and functioned as controls, whereas 132 (71 males [mean age 57; range 32–85] and 61 females [mean age 60; range 21–86]) were referred for various other indications, and were found to have cirrhotic liver morphology on CT. The patient cases were collected based on search parameters defined within the Radiology Information Systems (RIS—Cerner Millennium, Cerner Corporation). For those cases with cirrhotic liver morphology, the first 132 patients with the keywords "cirrhotic liver morphology" included in the CT report were selected. In addition, all cases reported to have cirrhotic liver morphology by the initial reading radiologist were reviewed independently by two diagnostic radiology residents (ZN and AR), who were both required to agree with the finding for the study to be included. For the control cases, patients who underwent our institutional renal donor CT protocol were reviewed for medical clearance for renal donation, and selected if clearance was granted. All cases were reviewed to avoid the inclusion of cases with misrepresentative keywords in the report. Patients with a previous splenectomy, significant accessory splenic tissue, or CT artifact were excluded.

All renal donor studies were acquired with a multidetector row helical scanner (Brilliance64, Phillips Healthcare) at 2-mm section thickness. Noncontrast and post-intravenous contrast images were acquired; however, only the noncontrast images were used for segmentation. Studies with cirrhotic liver morphology were acquired with one of three multdetector row helical scanners (LightSpeed VCT, GE Healthcare; Ingenuity TF PET/CT, Phillips Healthcare; or Brilliance64, Phillips Healthcare) at 2- to 5-mm section thickness without intravenous contrast.

In the population with cirrhotic liver morphology, seven unidirectional measurements of each spleen were obtained by a trained medical student (TM), which were subsequently reviewed by a diagnostic radiology resident (ZN) for accuracy. In addition, a subset of the spleens were measured by a second medical student (SK) to evaluate interobserver agreement (28 patients). As has been previously described in the literature, CC, LA, width (W), and four thickness (T1–T4) measurements were recorded for each spleen (17). The CC dimension was measured as the maximum CC dimension (or height) of the spleen on coronal reformatted images, whereas LA was measured as the maximum dimension of the spleen on coronal reformatted images, without respect to the CC axis. Width was measured as the maximum dimension of the spleen on axial images. T1 was measured as the maximum splenic thickness on the slice where W was determined, whereas T2 was the thickness of the midpoint of the W on that same slice. T3 was measured as the maximum thickness on any slice, and T4 was the thickness at the midpoint where T3 was determined (Fig 1).

Segmentation

All spleens were segmented using the semiautomatic segmentation function of the application itk-SNAP by a medical student (TM), with manual correction performed, as necessary (18). Figure 2 depicts the process of segmentation. In addition, 21 cases were segmented by a second medical student (SK) to allow for interobserver agreement analysis. A Pearson correlation coefficient was calculated and Bland-Altman plots were generated. All cases were reviewed by a diagnostic radiology resident (ZN) to ensure accurate segmentation.

Definition of Splenomegaly and Volumetric Thresholds

There is no consensus definition of splenomegaly within the medical literature. Prior studies that have calculated splenic