Abstract. The aim of this study was to apply a random marking volumetric technique in MR images for estimation of spleen volume. The MR imaging was performed in phantoms and 16 patients with indications unrelated to splenic disease. Images were transferred to a workstation to perform volumetric measurements using the random marking technique and the conventional technique of manual planimetry. Two observers independently measured splenic volume in order to evaluate reproducibility of both volumetric techniques. Phantom experiments revealed that the accuracy of the random marking technique and manual planimetry was approximately the same. In vivo splenic volume measurements derived from both volumetric techniques were highly correlated (r = 0.99, p < 0.0001). For both observers intraobserver variation was found to be lower with the random marking technique than with manual planimetry. Interobserver coefficient of variation using the manual planimetry was 4.6% and was reduced to 2.9% by adopting the random marking technique. The random marking technique was almost two times faster than the manual planimetry. The combination of the random marking technique with MR imaging might provide accurate, reproducible, quick splenic volume estimations.

Key words: Volume measurement – Spleen – MRI

Introduction

The increase of splenic size, known as splenomegaly, is a manifestation strongly related with a variety of diseases [1, 2, 3]. Evaluation of splenomegaly using palpation is difficult and may lead to inaccurate diagnosis [4]. Accurate measurements of splenic volume is an important parameter in diagnosing splenomegaly and in improving therapeutic management of patients. Splenic volume measurements have already been reported using magnetic resonance (MR) data. Most of the volumetric studies have been performed using the conventional technique of manual planimetry based on the user’s ability in precisely tracing the organ boundaries in all MR sections [5, 6, 7]. The volume index of the spleen has also been used to predict organ size [8]; however, splenic volume estimations based on simple linear measurements in MR data may provide a number related to the size of the organ of interest and not an accurate volumetric measurement [8]. To our knowledge, the application of the random marking technique in a series of MR slices for the estimation of spleen volume has not been investigated. This technique is independent on the operator’s outlining dexterity. It has been applied in several studies using tomographic sections [9, 10, 11].

The purpose of the present study was to investigate whether the combination of MR imaging and the random marking technique can provide efficient splenic volume estimations.

Materials and methods

Patient study

Sixteen adult patients (10 men and 6 women) without a known history of splenic disease underwent abdominal MR examinations using a 1.5-T unit (Magnetom Vision Plus, Siemens, Erlangen, Germany). Standard quadrature radio-frequency body coil was used for both excitation and signal detection. Splenic shape and position appeared normal in all patient examinations. The axial T1-weighted gradient-echo images from which splenic volume was calculated were obtained from a breathhold 2D fast low-angle shot (FLASH) technique (TR/TE/flip angle: 168 ms, 4.1 ms, 90°). High-performance gradients (23 mT/m) and a relatively long receiver bandwidth (260 Hz/pixel) were used to increase the number of slices in the selected TR and minimize chemical shift artifacts. The slice thickness was 8 mm, with an inter-
slice gap of 2 mm. A rectangular field of view covering an area of 25 × 50 cm² was used. The image reconstruction matrix was 128 × 256 pixels, compromising for a square pixel matrix. The mean whole-body specific absorption rate value for the aforementioned imaging sequence parameters never exceeded the value of 3 W/kg. Splenic volume measurements were performed using the random marking technique and manual planimetry. The aforementioned volumetric techniques are available in the Analyze software (Mayo Foundation, Rochester, Minn.) running on a SUN Sparc 5 computer workstation (Sun Microsystems, Mountain View, Calif.).

**Random marking technique**

The current volumetric technique randomly marks voxels in a 3D array of known size. The voxels appear as colored points in all sections imaging the object of interest. The user can select the marked voxels which lie inside the object being measured in each section. The ratio of the marked voxels on the object to the total number of marked voxels within the 3D array provides an estimation of the object’s volume; therefore, if a sufficient number of voxels (P_t) are randomly marked within the total volume (V_t) and the number of voxels falling inside the object of interest is P_{obj}, then the object’s volume (V_{obj}) is referred to as a fraction (V_{obj}) of V_t:

$$V_{obj} = V_t \times P_{obj}$$

(1)

According to the binomial distribution [12], the standard error (SE) of the foregoing volume estimation is given by the following equation:

$$SE = \left[ V_{obj} \left( 1 - V_{obj} / P_t \right) \right]^{1/2}$$

(2)

The relative standard error (RSE) is equal to:

$$RSE = \frac{SE}{V_{obj}} \times 100\%$$

(3)

To reduce the SE of the foregoing volume estimations, the object of interest must comprise as large a portion of the total volume as possible. The MR slices not imaging the spleen at the beginning and at the end of the examination were ignored. This means that voxels were not marked in the above slices. For each patient examination, a reference image was interactively selected from any of the several middle images in which the spleen appeared to have the larger size. A subregion fully encompassing the spleen in the reference image was manually traced. The same subregion was automatically transferred in all MR slices imaging spleen (Fig. 1); therefore, a subvolume encompassing the spleen was defined.

Splenic volume was measured by applying the random marking technique in the foregoing slice data sets (Fig. 2). The operator interactively selected the voxels hitting the spleen in each slice. The total number of voxels within the spleen boundaries was automatically calculated by the computer software.

![Fig. 1. Four MR slices derived by the procedure of defining a sub-volume around the spleen](image)

![Fig. 2. Voxels illustrated as white dots are randomly marked on an MR slice](image)

The total number of voxels (P_t) that should be marked was correlated with the quantities V_{obj} and SE as shown in Eq. (2). An RSE of 5% is considered as sufficient for volume estimations using the random marking technique [9]. The fraction (V_{obj}) of spleen volume to the total volume was expected to be more than 25% of V_t. Considering that V_{obj} was equal to 0.25, the optimal number of marked voxels (P_{obj}) which can yield an RSE of 5% was 1200 using Eqs. (2) and (3).