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● *Original Contribution*

AUTOMATIC REGISTRATION BETWEEN REAL-TIME ULTRASONOGRAPHY AND PRE-PROCEDURAL MAGNETIC RESONANCE IMAGES: A PROSPECTIVE COMPARISON BETWEEN TWO REGISTRATION METHODS BY LIVER SURFACE AND VESSEL AND BY LIVER SURFACE ONLY

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Abstract—The aim of this study was to compare the accuracy of and the time required for image fusion between real-time ultrasonography (US) and pre-procedural magnetic resonance (MR) images using automatic registration by a liver surface only method and automatic registration by a liver surface and vessel method. This study consisted of 20 patients referred for planning US to assess the feasibility of percutaneous radiofrequency ablation or biopsy for focal hepatic lesions. The first 10 consecutive patients were evaluated by an experienced radiologist using the automatic registration by liver surface and vessel method, whereas the remaining 10 patients were evaluated using the automatic registration by liver surface only method. For all 20 patients, image fusion was automatically executed after following the protocols and fused real-time US and MR images moved synchronously. The accuracy of each method was evaluated by measuring the registration error, and the time required for image fusion was assessed by evaluating the recorded data using in-house software. The results obtained using the two automatic registration methods were compared using the Mann–Whitney *U*-test. Image fusion was successful in all 20 patients, and the time required for image fusion was significantly shorter with the automatic registration by liver surface only method than with the automatic registration by liver surface and vessel method (median: 43.0 s, range: 29–74 s vs. median: 83.0 s, range: 46–101 s; $p = 0.002$). The registration error did not significantly differ between the two methods (median: 4.0 mm, range: 2.1–9.9 mm vs. median: 3.7 mm, range: 1.8–5.2 mm; $p = 0.496$). The automatic registration by liver surface only method offers faster image fusion between real-time US and pre-procedural MR images than does the automatic registration by liver surface and vessel method. However, the degree of accuracy was similar for the two methods. (E-mail: leeminwoo0@gmail.com)

Key Words: **Fusion imaging, Registration error, Registration time, Radiofrequency ablation, Biopsy, Ultrasound, Magnetic resonance imaging.**

INTRODUCTION

Ultrasonography (US) is the most commonly used guiding modality for percutaneous biopsy or local ablation therapy of focal hepatic lesions. However, sometimes it is difficult to localize small hepatic lesions with US when the lesions have poor sonographic conspicuity (Kim et al. 2012; Lee et al. 2010). This difficulty is more frequently encountered in patients with advanced liver cirrhosis, because the operators can be confused

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Conflict of interest disclosure: Authors from Samsung (Y.T.O., J.Y.J., J.W.C., J.R., K.J.L., J.K., W.C.B.) and Samsung Medison (D.K.S., S.J.C., D.K., B.K.S.) participated in the development of automatic registration methods. They provided technical advice during the clinical trial but had no direct or indirect conflicts of interest. The authors from Samsung Medical Center (A.Y.K., M.W.L, D.I.C., H.K.L.) had full control of data acquisition and interpretation.

by cirrhosis-related pseudo-lesions around a small target lesion (Lee et al. 2011).

To overcome these problems, many US vendors have provided fusion imaging techniques for US-guided procedures (Clevert et al. 2012; Ewertsen et al. 2011; Lee et al. 2013; Liu et al. 2012; Mauri et al. 2015; Minami et al. 2008). Fusion imaging simultaneously displays the real-time US image and the corresponding pre-acquired computed tomography (CT) or magnetic resonance (MR) image, thus providing multimodality comparison capability (Lee 2014). However, most fusion imaging techniques developed by different vendors should be operated in the manual mode. Hence, the registration time required for image fusion varies, depending on the level of experience of the operator, the patient population and the US machine. The process of image fusion can be cumbersome and time consuming, especially when performed by less experienced operators. For these reasons, automatic image fusion between real-time US and pre-acquired CT images has been introduced to enhance the performance of fusion imaging techniques (Nam et al. 2012; Wein et al. 2008). However, clinical data using automatic image fusion between real-time US and pre-acquired CT images are rare in the literature. Moreover, there are few data on automatic image fusion between real-time US and pre-acquired MR images. Given that MR images are generally preferred over CT images as the reference data set because of higher contrast between liver and target lesions, and similar patient respiration status between US and MR images (Kunishi et al. 2012; Lee et al. 2012), many operators and patients would benefit from automatic image fusion between real-time US and pre-acquired MR images.

In this study, we developed two types of automatic image fusion between real-time US and pre-acquired MR images, in which the 3-D US volume of the right lobe of the liver was used. The purpose of this prospective study was to compare the performance of the two automatic image fusions between real-time US and pre-acquired MR images.

METHODS

Patients and enrollment criteria

The study protocol was approved by the institutional review board of Samsung Medical Center, and all patients gave written informed consent before being enrolled. From June 2014 to December 2014, a total of 20 patients were prospectively enrolled in our study. The diagnosis of hepatocellular carcinoma was based on the typical imaging features (arterial enhancement followed by portal or delayed washout), according to the American Association for the Study of Liver Disease guidelines (Bruix et al. 2011). The inclusion criteria were as follows: (i) patients referred for planning US to assess the feasibility of radiofrequency ablation (RFA) or biopsy for focal hepatic lesions, (ii) patients with focal hepatic nodules 1–3 cm in diameter, (iii) contrast-enhanced MR imaging performed with gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid. Exclusion criteria were as follows: (i) patients with target lesion expected to be located in blind spots (*i.e.*, right liver dome) on US, (ii) age <20 y or >80 y, (iii) patients in whom the target lesion was a locally recurrent tumor, (iv) patients who declined to participate in our study.

Operator

An expert radiologist (M.W.L) with 10 y of experience in abdominal intervention (>1000 cases of fusion imaging-guided biopsy or RFA of focal hepatic lesions) participated in this study. The radiologist performed more than 30 training sessions on the two newly developed automatic image fusions before enrolling patients in our study.

Ultrasound system

A RS80A US system (Samsung Medison, Seoul, Korea), capable of fusion imaging (S-Fusion, Samsung Medison, Seoul, Korea) was coupled with a magnetic field generator. Two electromagnetic position sensors were connected to a position sensing unit (3-D guidance driveBAY tracker, Ascension Technology) and were attached on a convex array CA1–7A transducer using a bracket (Fig. 1).

Automatic registration by liver surface and vessel

Before image fusion, Digital Imaging Communications in Medicine (DICOM) data of up to six sequences of MR images were uploaded to the US machine. Among them, a 20-min hepatobiliary phase was used as a fused imaging sequence because the target lesion, as well as landmark hepatic vessels, was relatively well visualized on this image. After image fusion, the hepatobiliary phase image can be switched to the other sequences of MR images automatically by selecting other sequences if needed.

Automatic registration by liver surface and vessel consists of an orientation lock, marking of the inferior vena cava (IVC) on MR images, and sweeping of the liver with an US transducer. For the orientation lock, a convex array CA1–7A transducer is placed on top of the solar plexus (junction between the body of the sternum and the xiphoid process) in the sagittal plane to give the patient's orientation information to the system. The system already knows the orientation of the patient encoded in the MR DICOM images beforehand, so it internally aligns the orientation of the MR images and the patient (US images) automatically through orientation lock.