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Focal liver lesions detection: Comparison of respiratory-triggering, triggering and tracking navigator and tracking-only navigator in diffusion-weighted imaging

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ABSTRACT

Purpose: To compare low *b* value (10 s/mm^2) spin-echo echo-planar (SE-EP) diffusion-weighted imaging (DWI) acquired with respiratory-triggering (RT), triggering and tracking navigator (TT), tracking only navigator (TRON) techniques for image quality and focal liver lesions (FLL) detection in non-cirrhotic patients.

Material and methods: This bi-centric study was approved by the institutional review boards; informed consent was obtained. Eighty-three patients were prospectively included and SE-EP-DWI with RT, TT and TRON techniques were performed. DWI sequences were randomized and independently analyzed by two readers. The qualitative evaluation was based on a 3-point score for axial artifacts (motion, ghost, susceptibility artifacts and distortion) and stair-step artifacts. Sensitivity of FLL detection was calculated for all lesions together and after lesion size stratification (≤10 mm, >10–20 mm and >20 mm). The standard of reference consisted of a retrospective reading of the conventional MRI, the three DWI sequences and by follow-up (12 months): a total of 409 FLL were detected.

Data between sequences was compared with non-parametric tests. Cohen's kappa coefficient was used for inter-observer agreement.

Results: Image quality was comparable for RT and TT. TRON showed statistically significantly more axial artifacts for the two readers ($p < 0.05$). Stair-step artifacts were not statistically significantly different between DWI sequences.

Overall sensitivities for RT, TT, TRON were 85%, 86%, 82% and 86%, 89% 83%, respectively, for readers 1 and 2. The inter-observer agreement was very good.

Conclusion: Image quality was better for RT and TT compared to TRON. Overall sensitivities for FLL detection were comparable between techniques and readers.

1. Introduction

The detection and characterization of focal liver lesions (FLL), especially malignant primary and secondary tumors, are mandatory for treatment planification and patient prognostic assessment [1,2]. In this setting, magnetic resonance imaging (MRI) is the imaging tool of choice since it has shown higher sensitivity and specificity compared to multidetector CT and PET-CT, especially for the detection of liver metastases of gastro-intestinal tract tumors [3,4].

Diffusion-weighted imaging (DWI) is a MRI acquisition technique sensitive to the Brownian motion of water molecules. In the detection and characterisation of FLL, DWI has shown added value to conventional MRI sequences [4–8]. When spin-echo echo-planar (SE-EP) DWI is performed in the liver with low *b* values, i.e., equal or inferior to 50 s/mm^2, the signal of flowing spins is suppressed and therefore, the signal of liver vasculature is suppressed. This phenomena known as black-blood (BB) effect, may improve lesion conspicuity when compared to conventional T2-weighted images [9–14]. Thereby, in the setting of FLL detection, black-blood SE-

Abbreviations: BH, breath-hold; DWI, diffusion-weighted imaging; FLL, focal liver lesion; MRI, magnetic resonance imaging; RT, respiratory-triggering; SE-EP, spin-echo echo-planar; TRON, tracking only navigator; TT, trigerring and tracking.

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EP-DWI may replace the T2-weighted sequence as suggested by Hussain et al. [10]. SE-EP-DWI sequences, with low *b* value, used in several published studies have been acquired either with respiratory triggered (RT) [10,11,14] or breath-hold (BH) techniques [9,12,13].

The RT approach synchronizes the image acquisition with the patient's breathing cycle and acquires the imaging data during the end expiratory phase to avoid motion artifacts [15]. The BH technique has the advantage of being faster, however it has poorer signal-to-noise ratio, greater sensitivity to distortions and more ghosting artifacts compared to RT [15,16].

Technical advances have been recently implemented to improve image quality and to reduce acquisition time. The navigator based triggering is a respiratory-triggered prospective acquisition technique in which the position of the diaphragm is measured by the navigator-echo and triggered on the expiratory phase [14,17]. This approach has been compared to BH and free-breathing (FB) techniques for image quality and FLL detection [17,18]. The triggering and tracking (TT) technique is a navigator based triggering technique with an additional real time correction of the selection gradients in order to realign the slice position according to the diaphragm position at the end expiratory phase.

Tracking only navigator (TRON) is a modified navigator-echo technique that allows real-time slice tracking and position correction during the entire respiratory cycle, without using any gating window. Few reports have been published evaluating the TRON, limited by a low number of subjects and assessing only image quality [19–21].

The aim of the present study was therefore to compare the image quality of SE-EP-DWI sequences acquired with a *b* value of 10 s/mm^2 and performed with RT, TT and TRON techniques and to assess the sensitivity of these three SE-EP-DWI sequences in the detection of FLL.

2. Material and methods

This bi-centric study was approved by the institutional review boards of each institution. Written informed consent was obtained from all participants.

2.1. Study population

During a 15-month period between March 2010 and June 2011, a total of 103 consecutive liver MRI investigations were prospectively conducted in the two institutions. The inclusion criteria for enrolment were the suspicion or presence of a FLL based on other imaging modalities (US, CT, PET/CT) and/or on the basis of laboratory findings (tumor markers, hepatic enzymes). Exclusion criteria were cirrhosis and general contraindication to MRI.

Twenty patients were later excluded: seven patients because of an incomplete examination (at least one diffusion sequence and/or one conventional sequence was lacking) and thirteen patients because of cirrhosis.

Finally 83 patients were included in this study, 47 men and 36 women (mean age: 60.6 years, age range: 27–83 years).

2.2. MRI protocol

In the two institutions, MRI examinations were performed using a 1.5-T Unit (Achieva; Philips Medical System, Best, The Netherlands) equipped with a 16-channel phased-array surface coil and with parallel imaging capabilities (sensitivity encoding). All patients were placed in the magnet in a supine position.

The conventional MRI protocol consisted of unenhanced and contrast-enhanced MRI-sequences after intravenous administration of gadolinium chelates (0.1 ml/kg) (Gadobutrol 1 mmol/ml, Gadovist©, Bayer Healthcare, Leverkusen, Germany). The acquisition sequences included axial and coronal respiratory triggered T2-weighted turbo spin echo, axial T2-weighted turbo spin echo with spectral fat suppression, axial T1-weighted gradient-echo in and out of phase and axial three-dimensional T1-weighted gradient-echo with spectral fat suppression sequences (before and after administration of intravenous contrast agent).

The three SE-EP-DWI sequences were acquired in the axial plane with a spectral fat-suppressed SE-EP sequence, *b* value of 10 s/mm^2 in three orthogonal diffusion-sensitized directions and with four repetitions using the following parameters: TE 56 ms, EPI factor 63, half Fourier factor 0.60, Sense factor 2, anterior–posterior phase encoding direction, 30 slices with no interslice gap, voxel size 1.9 mm × 2.4 mm × 5 mm, and a field of view of 290 mm × 305 mm. SE-EP-DWI sequences were consecutively acquired just before administration of intravenous contrast agent following the same order for each patient: (1) RT sequence used an air-filled sensor placed on the hypocondrial region and fixed with an elastic belt. Data were acquired at the end- expiratory phase; (2) TT sequence using the navigator-echo to detect and to trigger the acquisition at the end expiratory phase and additionally tracking for the actual diaphragm position. For RT and TT data were acquired during 1200 ms. During these 1200 ms, 8 slices were consecutively acquired meaning that 4 packages were required to acquire the 30 slices. The mean acquisition time for RT and TT (considering a 4 s respiratory cycle duration) was estimated to 3 min 12 s; (3) TRON technique was used to track and correct for liver displacement, using a navigator-echo to measure the displacement of the diaphragm, between the liver and the lung and to update the gradients in order to align the slice position to the actual anatomical position (Tracking). Data were acquired during the entire respiratory cycle. A fixed TR of 4200 ms was used. The acquisition time was 50 s. All the acquired axial images were then reformatted in the coronal plane.

2.3. Image analysis

The three SE-EP-DWI sequences were randomized using a table of randomization (randomizer.org) and then transferred for analysis to an independent diagnostic workstation (Viewforum, Philips Medical System, Best, The Netherlands). The randomized SE-EP-DWI sequences were analyzed by two independents readers: a senior radiologist, reader 1, and a radiologist in training, reader 2, with respectively, 13 years and 1 year of experience in liver MRI interpretation. Both readers were blind to the type of SE-EP-DWI sequence under evaluation. They were unaware of any information regarding patient history, clinical examination, laboratory and other imaging findings and the final diagnosis.

One month before the beginning of the independent reading sessions, a learning consensus session took place. This session was performed using images from patients that were not included in the study and served to define axial artifacts (motion, ghost, susceptibility artifacts and distortions) and stair-step artifacts (i.e., stair-step-like deformation of organ contours, such as those of the liver and gallbladder, due to a mismatch between two sequential image acquisition) (Figs. 1 and 2). A 3-point score, grading axial and stair-step artifacts, was also defined: (1) good, when no artifacts at all were observed; (2) moderate, when minimal artifacts were present with little perturbations on interpretation; (3) poor, when serious artifacts with difficulties on interpretation were present.

2.4. Image quality analysis

Image quality was assessed in the axial plane for the presence of motion, ghosts, susceptibility artifacts and distortions; and in the