High spatiotemporal resolution liver perfusion imaging in focal liver lesions

Yong Chen[1], Chaitra Badve[1], Shivani Pahwa[1], Mark Griswold[1,2], Nicole Seiberlich[1,2], and Vikas Gulani[1,2]

[1]Department of Radiology, Case Western Reserve University, Cleveland, OH, United States, [2]Department of Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States

Target Audience This work targets those interested in high resolution liver dynamic contrast-enhanced (DCE) MRI and perfusion quantification.

Purpose Liver perfusion imaging has been shown to be useful in a variety of pathological conditions, including early detection of hepatocellular carcinoma (HCC) and predicting therapeutic response in metastatic lesions[1,2]. However, accurate quantification of perfusion parameters in liver is extremely challenging due to the anatomy (large organ) and physiological motion. A non-Cartesian parallel imaging based technique for high resolution 3D liver perfusion imaging was recently introduced, which allows free breathing acquisitions, retrospective image registration, and subsequent quantitative perfusion modeling of the data with no view sharing[3]. The objectives of this study are 1) to evaluate the quantitative mapping in patients with focal liver lesions and demonstrate initial clinical experience, and 2) to evaluate the image quality of the underlying free breathing images in comparison to conventional Cartesian acquisitions.

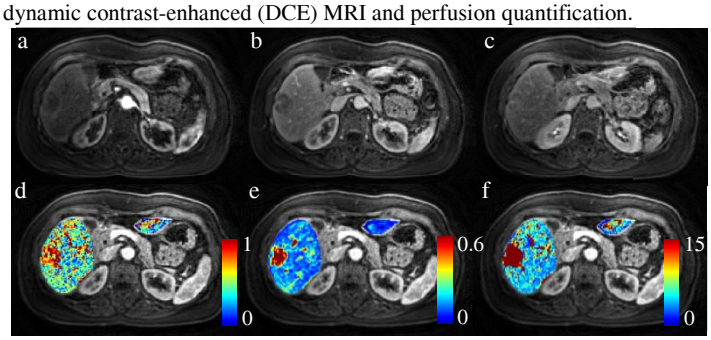

Fig. 1. (a-c) Representative post-contrast free-breathing images acquired at arterial phase, portal phase and equilibrium phase of a subject with metastatic breast adenocarcinoma. Corresponding liver perfusion maps of (d) arterial fraction, (e) distribution volume, and (f) mean transit time.

Methods MRI experiments were performed on a Siemens 3T Skyra scanner using 30 coil elements. Ten asymptomatic subjects (M:F, 7:3; mean age, 20.9 years) and thus far seven patients who underwent liver examination as part of clinical care at our institution were recruited for this study (M:F, 4:3; mean age 69.7 years; 4 with metastatic adenocarcinoma and 7 total lesions, one with HCC, one with recurrent HCC post RF ablation, and one with a solitary sclerosing hemangioma). All the lesion pathologies were conclusively established with image-guided biopsies.

3D free breathing liver perfusion imaging was performed using through-time spiral GRAPPA acceleration[3]. Briefly, a stack-of-spirals trajectory was undersampled in-plane with a reduction factor of 6, and reconstructed using 3D through-time non-Cartesian GRAPPA[4]. High resolution 3D images ($1.9\times1.9\times3.0$ mm^3) were acquired with a true temporal resolution of 1.6~1.9 seconds, while the subjects were breathing freely. A total of 100 to 120 volumes were acquired continuously in approximately 3.5 min. After the 5th volume was acquired, 0.1 mmol/kg Gadobenate (Multihance, Bracco Diagnostics, Princeton, NJ) was injected at 3 mL/s followed by 20 mL of saline flush. A dual-input single-compartment model was used to retrieve liver perfusion parameters from DCE-MRI data[5], which were co-registered using an algorithm designed to reduce the effects of dynamic contrast changes on registration[3].

For the image quality comparison, conventional Cartesian T_1-weighted fat-suppressed images were acquired from five of the ten healthy volunteers immediately after the fast spiral acquisition. For each subject, two separate scans, one with breath-hold (BH-VIBE) and the other with free breathing (FB-VIBE), were acquired in about 14~18 sec at the same spatial resolution as the spiral acquisitions (FB-SPIRAL). Two radiologists, who were blinded to the type of images, were asked to rate the images on a scale of 1-5 (5=excellent image quality, 4=good, 3=acceptable, 2=poor, and 1=unacceptable) for motion artifact, image blurring, liver edge sharpness, clarity of vessels, and overall image quality.

Table 1. Liver perfusion parameters.

		Arterial fraction (%)	Distribution volume (%)	Mean transit time (sec)
Normal (n=10)		25.0 ± 4.3	29.4 ± 8.3	8.8 ± 6.1
Met AdenoCA (n=7)	Lesion	90.8 ± 10.8*†	46.1 ± 12.1*†	51.9 ± 23.4*†
	Surrounding tissue	38.1 ± 12.3	23.6 ± 10.4	8.0 ± 5.1
HCC (n=1)	Lesion	45.3	32.2	9.5
	Surrounding tissue	17.6	13.9	7.2
HCC Recurrence (n=1)	Lesion	83.8	48.1	17.9
	Surrounding tissue	50.3	33.8	20.9
Hemangioma (n=1)	Lesion	99.4	21.0	27.6
	Surrounding tissue	39.4	30.5	6.4

Note. --- Data are means ± standard deviations.
* P<0.05 as compared with the normal group; † P<0.05 as compared with surrounding tissue.
n: number of volunteers in the normal group and number of lesions in the patient groups.

Results and Discussion Fig. 1(a-c) shows representative post-contrast images of a subject with a metastatic lesion spanning segments 5 and 6. Perfusion modeling for this patient is presented in Fig. 1(d-f) and the lesion showed arterial fraction (AF), distribution volume (DV), and mean transit time (MTT) of 67.5%; 40.4%; and 99.8 s, respectively, all clearly different from surrounding parenchyma in the parametric maps. A summary of all the perfusion parameters obtained from the ten normal volunteers and seven patients is shown in Table 1. The mean AF, DV and MTT measured from all the lesions of the four patients with metastatic adenocarcinoma are statistically different as compared to those from surrounding liver ($P < 0.05$) and also compared to the normal volunteers ($P < 0.05$). Early experience with HCC and hemangioma is also shown, but more patients are needed for statistical analysis.

The summary of image quality analysis for the free-breathing spiral images and two types of conventional Cartesian images is presented in Table 2. Both BH-VIBE and FB-SPIRAL had significantly higher scores as compared to FB-VIBE in all categories ($P < 0.01$). BH-VIBE had significantly less image blurring than FB-SPIRAL ($P = 0.025$), but no statistical difference was found in other categories. All FB-SPIRAL images were rated as having acceptable or better overall image quality by both readers.

Conclusion The high spatiotemporal resolution 3D liver imaging technique allows voxel-wise quantification of liver perfusion parameters in healthy as well as patient volunteers. Image quality shows slight degradation in comparison to long breath-held Cartesian imaging, with worsening in image blurring, but as expected, is significantly better in exams where the subject does not provide a breath-hold. Significant difference in perfusion parameters was observed between metastatic adenocarcinoma lesions and adjacent liver, which illustrates the possibility of quantitative lesion characterization using this technique.

Table 2. Mean image quality scores of the post-contrast spiral and Cartesian T_1-weighted images from five normal subjects.

	Motion artifacts	Image blurring	Liver edge sharpness	Clarity of vessels	Overall quality
BH-VIBE	4.8 ± 0.3	3.9 ± 0.2	4.1 ± 0.7	4.1 ± 1.0	4.2 ± 0.4
FB-SPIRAL	4.4 ± 0.4	3.0 ± 0.4*	3.8 ± 0.6	3.9 ± 0.5	3.5 ± 0.5
FB-VIBE	1.4 ± 0.5*†	1.4 ± 0.5*†	1.4 ± 0.6*†	1.5 ± 0.7*†	1.4 ± 0.5*†

Note. --- Data are means ± standard deviations.
* Tukey-adjusted P < 0.05 as compared with BH-VIBE
† Tukey-adjusted P < 0.05 as compared with FB-SPIRAL

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