Automated Fast Liver MR Scan: A Preliminary Evaluation

Chao Ma[1]; Jing Li[1]; Yukun Chen[1]; Aiguo Jin[1]; Qingsong Yang[1]; Berthold Kiefer[2]; Bernd Kuehn[2]; Caixia Fu[3]; Jianping Lu[1]

[1] Department of Radiology, Changhai Hospital of Shanghai, Shanghai, China
[2] Siemens Healthineers, Erlangen, Germany
[3] Siemens Shenzhen Magnetic Resonance Ltd., Shenzhen, China

Introduction

Magnetic resonance imaging (MRI) has become increasingly important in the diagnosis and evaluation of various abdominal diseases in clinical practice, thanks to its advantages of no ionizing radiation and multiple soft-tissue contrasts (T1w, T2w, DWI, etc.). However, compared with computed tomography (CT), MRI still has disadvantages, such as long scanning times and high operational complexity. The abdomen exam workflow, which requires respiratory motion control and strict timing of contrast agent injection, is especially time-consuming and complex. This is a challenge for weak patients who cannot cooperate very well, and for technicians working in a busy setting. A fast and easy abdomen scan workflow is urgently needed to improve both patient comfort and daily throughput. Such a workflow would reduce the cost per exam and allow more patient exams per MRI scanner. With the continuous development of hardware and software technologies, the new generation of MRI systems has been equipped with various accelerated acquisition techniques and one-stop automated scan workflows. With the *syngo* MR D11A software platform, Siemens Healthcare released a technology called Dot (day optimizing throughput) engines, which helps improve the automation of the MRI exam workflow. The technology

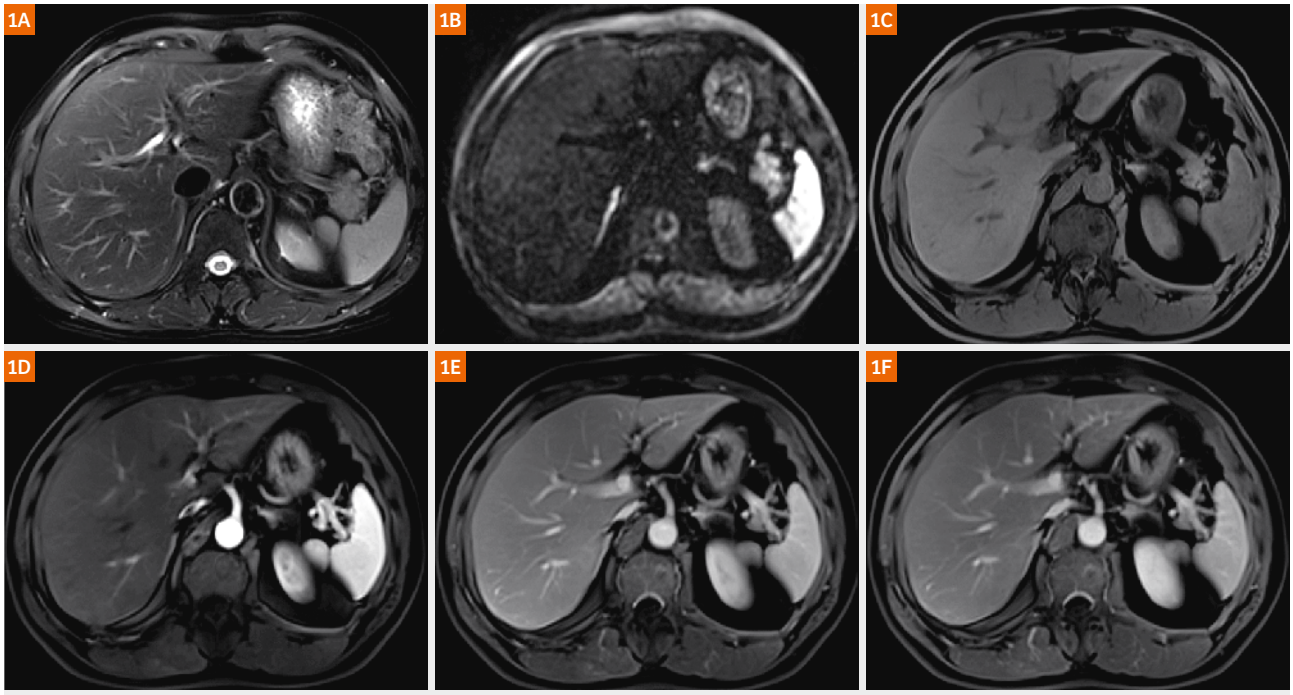


Figure 1: Images of a healthy 53-year-old man: **(1A)** T2-weighted BLADE; **(1B)** DWI, b = 1000 s/mm^2; **(1C)** pre-contrast T1w; **(1D)** arterial phase T1w; **(1E)** venous phase T1w; **(1F)** delayed phase T1w. The images show that the automated fast protocol achieves satisfactory image quality and anatomic structure visualization.

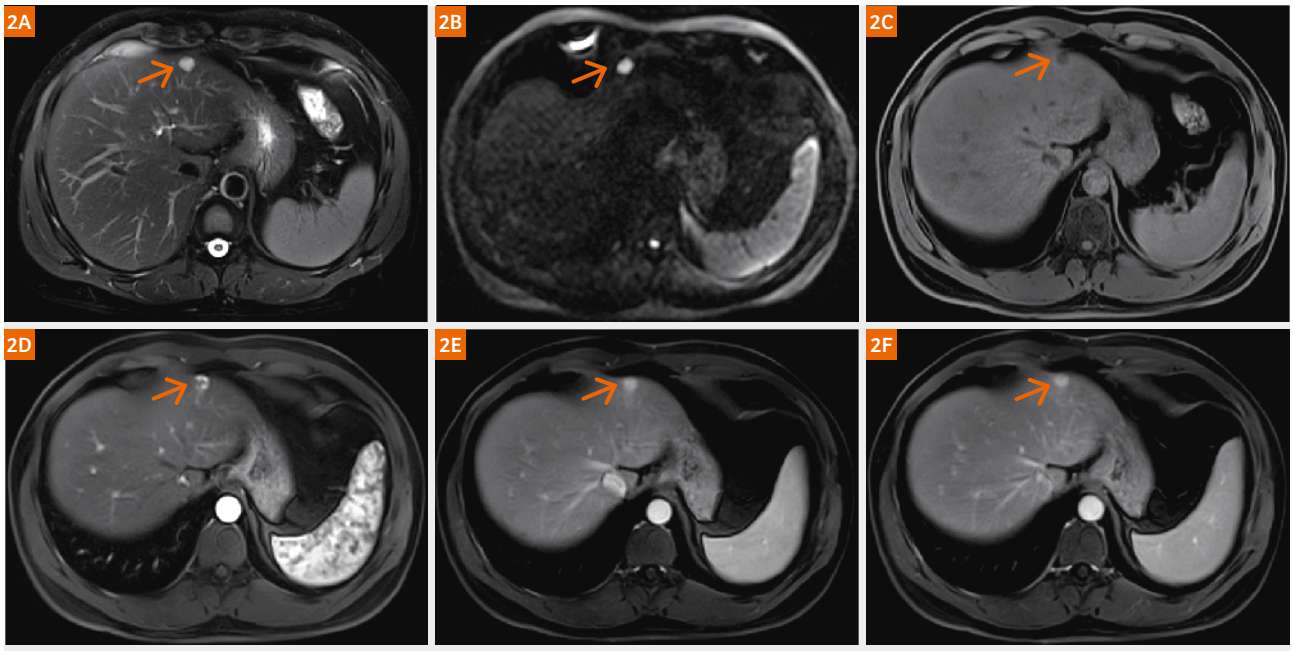


Figure 2: MRI images of a hemangioma: The lesion appears as a hyperintense mass on both the T2-weighted image **(2A)** and DWI b = 1000 s/mm² **(2B)**, and is hypointense on the pre-contrast T1-weighted image **(2C)**. The post-contrast-enhanced T1w images **(2D-F)** show the progressive centripetal contrast enhancement in the hemangioma.

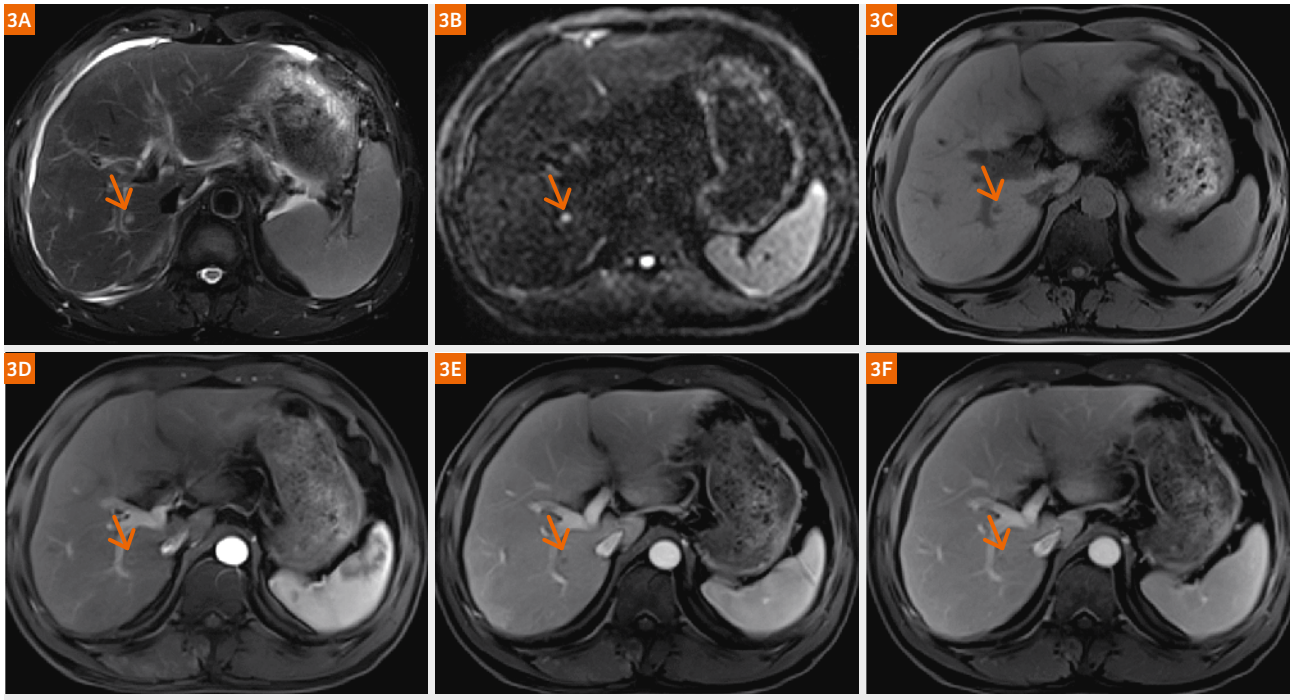


Figure 3: Liver metastasis (primary: colon cancer) in a 46-year-old man: **(3A)** T2-weighted BLADE; **(3B)** DWI, b = 1000 s/mm²; **(3C)** pre-contrast T1-weighted; **(3D-F)** contrast-enhanced T1-weighted. The lesion is isointense to hyperintense in T2-weighted images, is hyperintense in DWI, and has low intensity in T1-weighted images. Annular enhancement is visible in the arterial phase of the enhanced T1-weighted images relative to the surrounding liver parenchyma.

has been successfully applied to workflows for examining areas such as the abdomen, heart, head, knee joint, among others. However, the default workflow provided by the manufacturer contains redundant protocols and has long scanning times. Thus, our goal was to develop a fast and automated liver MR workflow with reproducible exam times for short time slots that can optimize patient throughput.

At ISMRM 2017, we proposed a fast MRI workflow[1] with only ~12 minutes total measurement time for a liver exam [1]. In this workflow, we used an abbreviated protocol set configured with auto-positioning, auto-FOV, auto-voice-command, and auto-care-bolus functions (provided by the Abdomen Dot Engine package) to shorten the exam time, automate the process, and improve throughput while still producing sufficient diagnostic information. This paper outlines our experiences and provides some example cases.

Method

Our workflow includes the following:

1. **Localizer** in one breath-hold of 18 s, with auto-coverage scout for the liver. The scout data is used to process the auto-alignment of the following protocols.

2. **Coronal T2w HASTE** in one breath-hold of 20 s

3. **Axial T2w BLADE** with respiratory triggering

FOV = 400 x 400 mm^2, scan matrix = 320 x 320, TE = 79 ms, TR = respiratory period, slice thickness = 6 mm, number of slices = 28, Grappa iPAT factor = 2, scan duration of 2 to 4 mins

4. **T1w VIBE with 2 echoes and Dixon reconstruction** in one breath-hold of 15 s, acting as:

a) pre-contrast in-phase and opposed-phase T1-weighted scan and

b) pre-contrast T1-weighted scan

FOV = 325 x 400 mm^2, scan matrix = 195 x 320, CAIPIRINHA iPAT factor = 3, TE= 1.26/2.43 ms, TR =3.97 ms, flip angle = 12°

[1] WIP, the product is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.

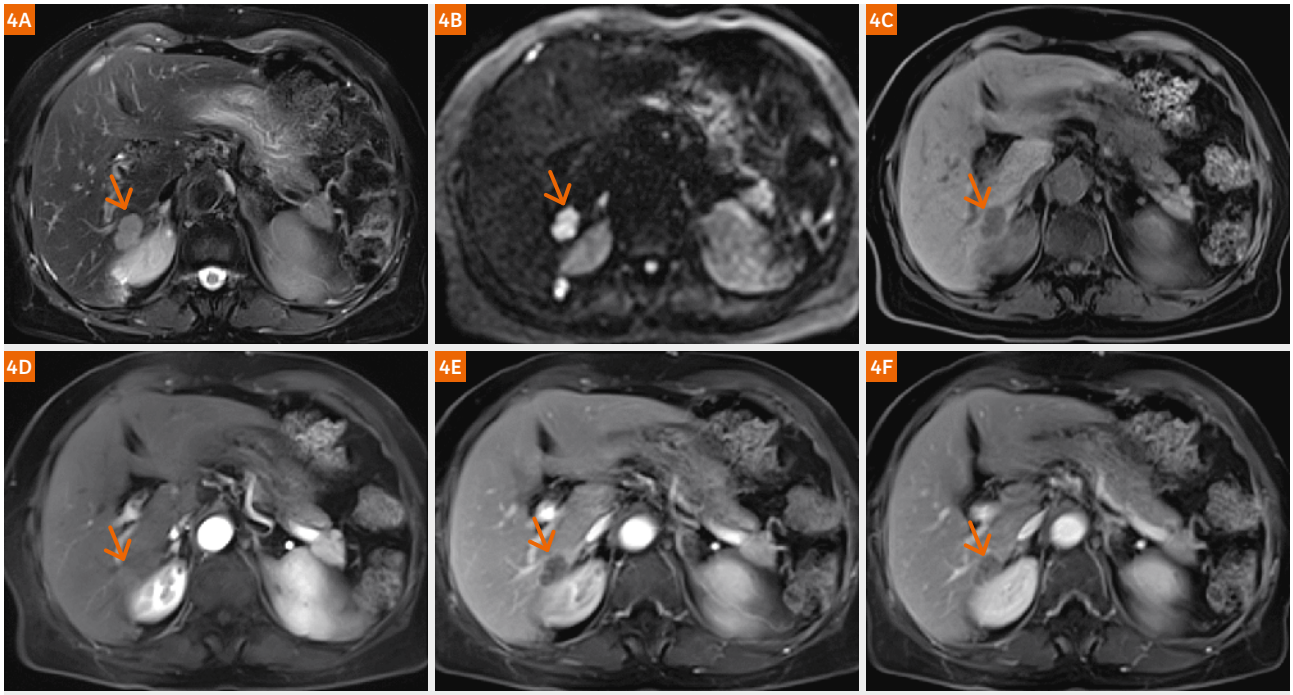


Figure 4: Liver metastasis (primary: colon cancer) in a 69-year-old man: **(4A)** T2-weighted BLADE; **(4B)** DWI, b = 1000 s/mm^2; **(4C)** pre-contrast T1w; **(4D-F)** contrast-enhanced T1w. The lesion is isointense to hyperintense in T2-weighted images, is hyperintense in DWI, and has low intensity in T1-weighted images. Annular enhancement is visible in the venous and delayed phase of enhanced MR imaging relative to the surrounding liver parenchyma.

5. **EPI DWI sequence** with 3-scan trace mode and a single high b-value of 1000 s/mm² in two breath-holds (18 s each). FOV = 400 x 400 mm², scan matrix = 256 x 256 with interpolation, TE = 61 ms, TR = 3100 ms, slice thickness = 6 mm, number of slices = 30, GRAPPA iPAT factor = 2

6. **Auto bolus detection** with 2D FLASH sequence and high temporal resolution of ~0.8 s with automatic ROI placement for the aorta, provided by the Abdomen Dot Engine

7. **Post-contrast T1w VIBE** for arterial, venous, and delayed phase measurements in one breath-hold of 14 s each, using similar parameters as the pre-contrast T1w VIBE scan, except that CAIPIRINHA iPAT factor = 4 was selected and fat saturation was used instead of Dixon.

The total acquisition time of this workflow is between 5.7 and 7 minutes. The total examination time including time for adjustment, shimming, breath-hold commands, etc. for each patient varies from 11 to 13 minutes, depending on the patient's breathing period.

So far, the proposed workflow has been used successfully with 109 liver patients on our 3T MAGNETOM Skyra. The image quality from each sequence is good to excellent.

The average measurement time is about 12 minutes and 36 seconds. The example cases shown in Figures 1-6 demonstrate the high lesion delineation capability of this fast workflow for various liver diseases.

Discussion

We used respiratory-triggered BLADE for T2-weighted acquisition to improve the measurement success rate, since this sequence is more motion-robust than conventional TSE. For DWI, we only acquired a b-value of 1000 s/mm² and ignored ADC maps in the liver examination. This is because our experience shows that ADC maps do not provide any additional information for diagnosing liver diseases in clinical practice. We used the Dixon technique to acquire opposed-phase, in-phase, and pre-contrast T1w images in one sequence, which removes the need for a separate pre-contrast T1w acquisition. Additionally, we applied CAIPIRINHA to increase the PAT acceleration factor for the VIBE sequence to achieve high spatial resolution and significantly shorter scan times. The Abdomen Dot Engine – with its auto-positioning, auto-FOV, auto-voice-command, and auto-care-bolus functions – allowed us to automate the exam workflow and improve scan reproducibility. It also reduced the technician's workload, which is especially important in

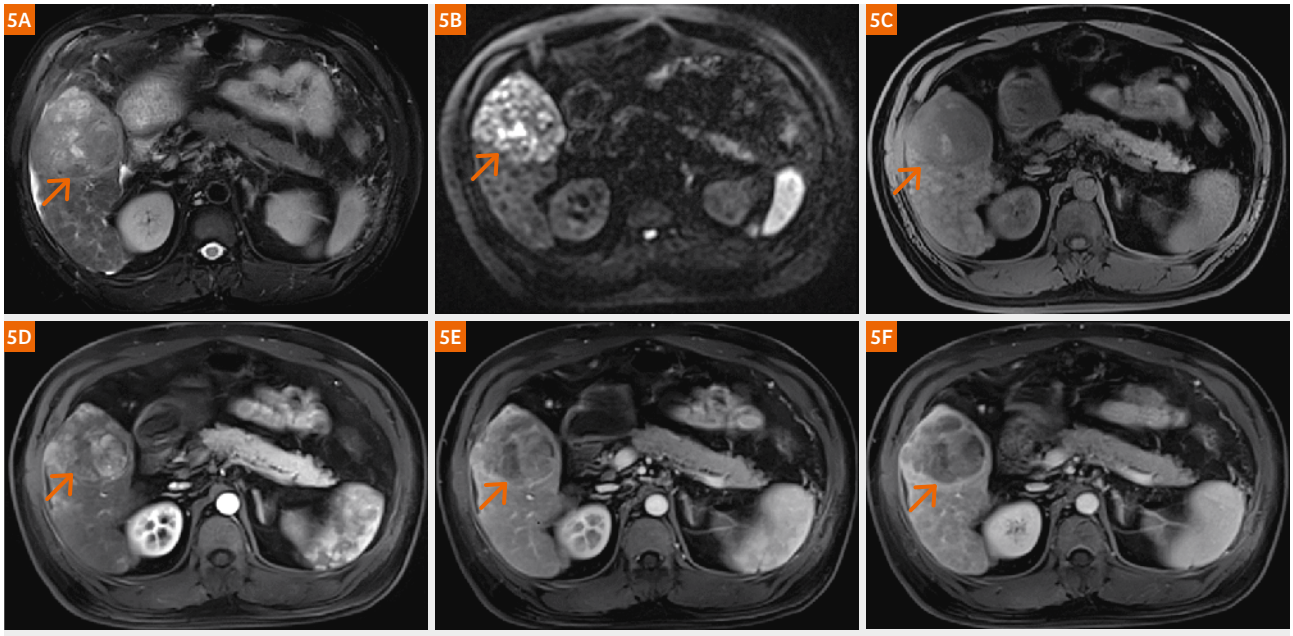


Figure 5: Large HCC in a 43-year-old man with cirrhosis resulting from hepatitis B: The axial T2-weighted MR image **(5A)** and DWI with b = 1000 s/mm² **(5B)** show a heterogeneous mass (arrow) with high signal intensity in the right lobe bordering the liver capsule. The axial T1w image **(5C)** shows the mass as hypointense (arrow). The axial T1w image **(5D)** obtained in the arterial phase shows heterogeneous hypervascular enhancement of the mass (arrow). The axial T1w images obtained in the venous and delayed phases **(5E, F)** show washout (arrow). A thin circumferential hypointense rim is visible around the periphery of the tumor, a finding which is indicative of a capsule, with typical late enhancement after administration of a gadolinium-based contrast medium.

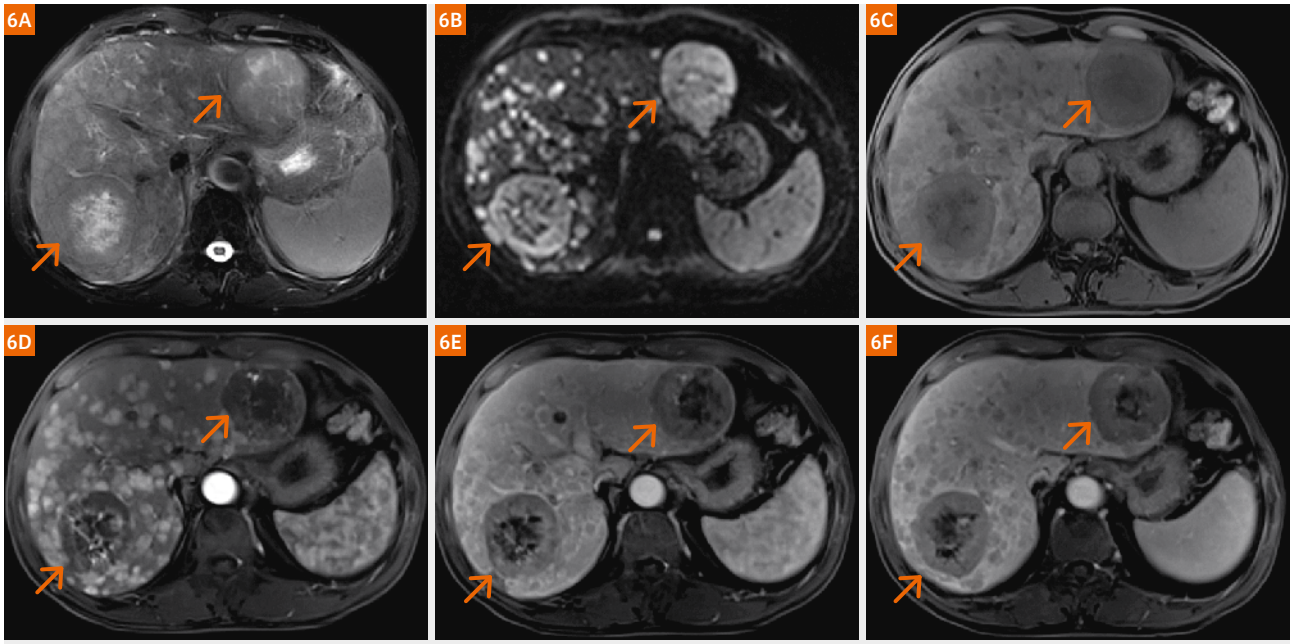


Figure 6: Multiple HCCs in a patient with known hepatitis B and an elevated α-fetoprotein level: Axial T2w image and DW image **(6A, B)** show a cirrhotic liver with multiple slightly high-intensity nodules (arrow). Axial T1w image **(6C)** shows these nodules as hypointense (arrow). Axial arterial phase T1w image **(6D)** shows numerous nodules with variable enhancement throughout the cirrhotic liver (arrow). On venous and delayed phase images **(6E, F)**, most of these nodules show washout (arrow).

our hospital. Normally, our technicians are also responsible for laying out and printing every patient's images via eFilm. With the automated scan workflow, they can complete scanning and printing tasks simultaneously and with minimal effort.

Conclusion

Our automated fast liver MRI workflow is feasible on 3T MRI systems. Combining it with the Dot technology speeds up the scanning process, allows for reproducible patient slot times, and reduces technician workload. The workflow makes it easy to implement and standardize liver examinations, and has good prospects for clinical application.

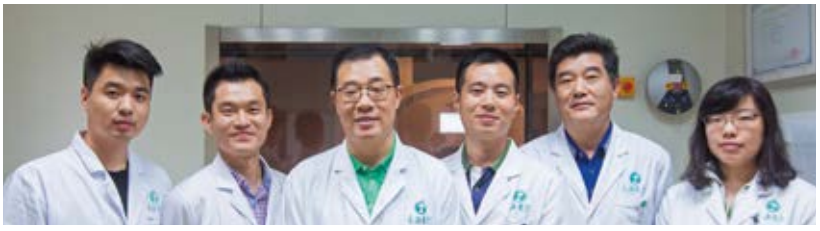
Reference

1 Yang Q, Chen Y, Fu C, Kuehn B, Kiefer B, Wang Y, et al. A clinically-validated, fast and semi-automated MR workflow for liver evaluation. Presented at: Ad Hoc Electronic Poster Session 4446-4464, ISMRM 25th Annual Meeting & Exhibition, Honolulu, HI, USA; 2007, April 22-27.

Contact

Professor Jianping Lu, M.D.
Director Radiology Department
Changhai Hospital of Shanghai, the Second Military Medical University

10 Building, 168 Changhai Road,
Shanghai, 200433
P. R. China
Phone: +86 21 31162146
Fax: +86 21 81873226
cjr.lujianping@vip.163.com



From left to right:
Yukun Chen, Qingsong Yang, Jianping Lu, Chao Ma, Aiguo Jin, Jing Li