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A DL-based, isotropic dynamic liver protocol to address difficult cases

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In liver MR imaging, where hyper-vascular tumors such as hepatocellular carcinoma (HCC) are common, the diagnosis of vascularity through multi-arterial phase, dynamic contrast enhanced (DCE) MR imaging is crucial. At Fukuoka University, we routinely perform between 8 to 10 MR liver examinations each week that utilize a dynamic protocol where an accurate evaluation of both the DCE and hepatobiliary phases (HBP) help address difficult cases.

Multi-arterial phase imaging has been used for liver DCE for some time. In previous MR software versions, DISCO was employed to improve temporal resolution. DISCO efficiently enhances temporal resolution through view sharing. However, DISCO shares *k*-space data during the phases, leading to contamination between the phases. During the acquisition of the arterial phase with DISCO, complete breath-holding is required. We have experienced cases where, if breathing becomes irregular during the scan, motion artifacts affect all phases. Additionally, contrast enhancement also suffers from phase contamination, resulting in a diminished appearance of the contrast effect. In some cases, even though the early arterial phase is artery-dominant, we have observed hepatic veins being depicted.

To suppress poor breath-holding and contrast contamination, it was necessary to optimize the imaging parameters. We examined high temporal resolution multi-phase LAVA to prevent inter-phase contamination. Since each phase in multi-phase LAVA is independent, it prevents contamination during the phases. To improve the temporal resolution of LAVA, it is essential to optimize the HyperSense parameters. While a higher acceleration factor can improve temporal resolution, it inversely lowers SNR. In previous systems, this issue could not be resolved, which prevented us from adopting this method.

However, with the latest MR 30 for SIGNA™ software on our Discovery™ MR750w 3.0T, the availability of AIR™ Recon DL 3D has allowed us to overcome these challenges. While SNR deficiency was a concern with the imaging parameters of the previous version, AIR Recon DL 3D compensates for the lack of SNR, enabling high temporal resolution scanning without compromising image quality. At Fukuoka University Hospital, we set the imaging parameters to 7 seconds per phase for multi-phase LAVA. This allows us to achieve a 7 second, three-phase multi-arterial phase. Since each phase in this multi-phase LAVA is independent, it is no longer affected by contamination due to poor breath-holding. Even in cases of poor breath-holding, it is rare for motion artifacts to affect all phases, and cases where arterial phase diagnosis becomes impossible have decreased.

When we investigated the success rate of breath-holding, multi-phase LAVA showed a 97% success rate compared to 85% with the conventional method (DISCO). Additionally, the contamination by contrast enhancement effect has been eliminated, leading to improved contrast in each phase. This allows for a more accurate understanding of hemodynamics in the early arterial phase and has improved the detection of small lesions. Furthermore, it was difficult to accurately detect lesions with

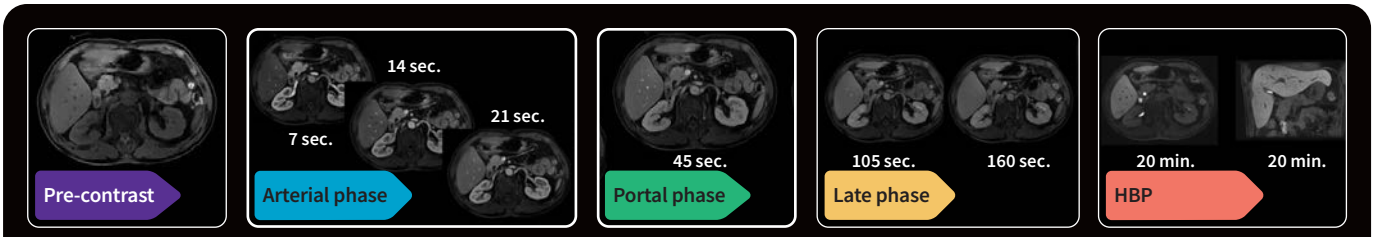

Figure 1. The dynamic liver protocol at Fukuoka University Hospital (Japan) utilizes AIR Recon DL to overcome SNR deficiency in the dynamic and hepatobiliary phases. In the dynamic phase, AIR Recon DL improves temporal resolution through high-speed imaging to achieve multi-arterial phase imaging without view sharing. In the hepatobiliary phase, AIR Recon DL allows for high spatial resolution, iso-voxel imaging during breath-hold. HyperSense is also utilized in multi-phase LAVA acquisitions.

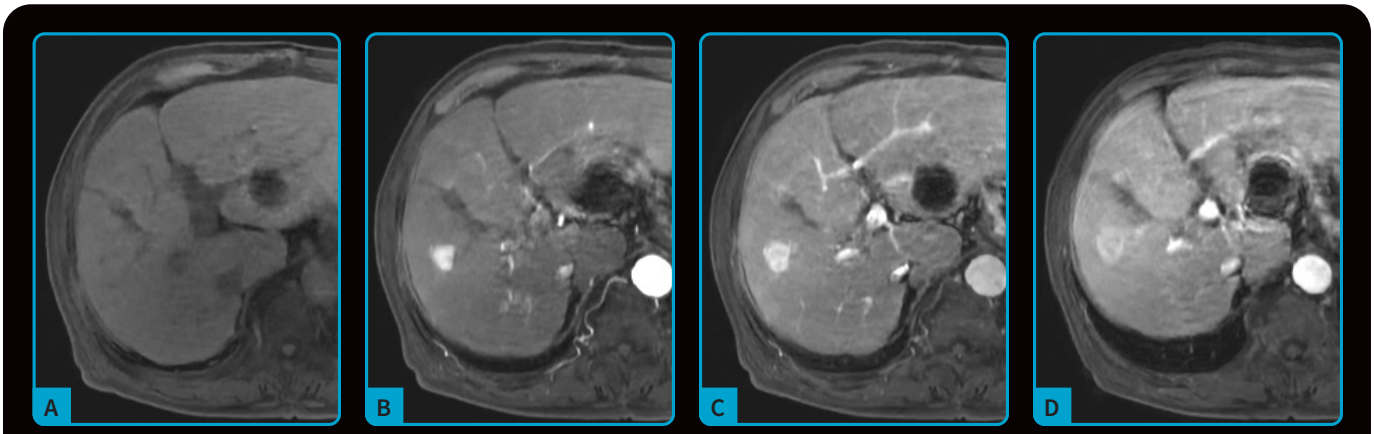

Figure 2. Case 1. A 72-year-old male with primary HCC. (A) Pre-contrast LAVA followed by (B-D) arterial phases. The lesion showed contrast uptake as early as the first phase of the multi-arterial acquisition. Although the patient was unable to hold his breath during (D) the third arterial phase, the exam was successful due to several factors: sufficient SNR provided by AIR Recon DL, rapid acquisition enabled by HyperSense and the absence of phase contamination thanks to the independent nature of each phase in the LAVA sequence during multi-arterial acquisitions.

corona enhancement or early wash-out using the view share method. However, with multi-arterial phase LAVA, the contrast has improved, allowing for confident diagnosis of these lesions.

In contrast-enhanced imaging, it is necessary to acquire the HBP where the contrast media is taken up by hepatocytes. Previously, HBP was imaged at high resolution with Navigator at 2 mm/1 mm slices. However, with this slice thickness, sufficient resolution could not be achieved during reformatting. Therefore, it was necessary to supplement with breath-hold LAVA in different planes (e.g., coronal) in addition to the axial plane.

To obtain detailed information in HBP, imaging with higher spatial and slice resolution is necessary. We implemented iso-voxel imaging with 1.5 mm using AIR Recon DL 3D. The loss of SNR that comes with increased spatial resolution is compensated by AIR Recon DL 3D. Additionally, improving slice resolution increases the number of slices within the slab, leading to extended scan times. However, we were able to set scan parameters that allow the scan to be completed within a breath-hold duration by utilizing HyperSense.

With iso-voxel LAVA at 1.5 mm, we can now obtain an excellent resolution hepatobiliary phase. Imaging with thin slices significantly reduces partial volume effects, greatly contributing to improved diagnostic capability. It provides more detailed information compared to a directly acquired 4 mm LAVA slice. Additionally, when comparing reformatted coronal images from iso-voxel LAVA to direct coronal LAVA, the former shows better contrast and more clearly depicts lesion areas. Direct coronal LAVA requires separate breath-holding, which can sometimes lead to misalignment between axial and coronal positions depending on the breathing state. However, with iso-voxel LAVA, the positions between axial and reformatted coronal images align perfectly, maintaining positional accuracy. Additionally, the elimination of separate coronal imaging and reduced number of breath-holds likely enhance patient comfort.

Case 1

Patient history

A 73-year-old male with primary HCC was referred to MR.

Imaging Results

Sufficient SNR is maintained even with short imaging times and high resolution is achieved with AIR Recon DL 3D. Additionally, the seamless integration of high-speed imaging sequences such as HyperSense is a significant advantage.

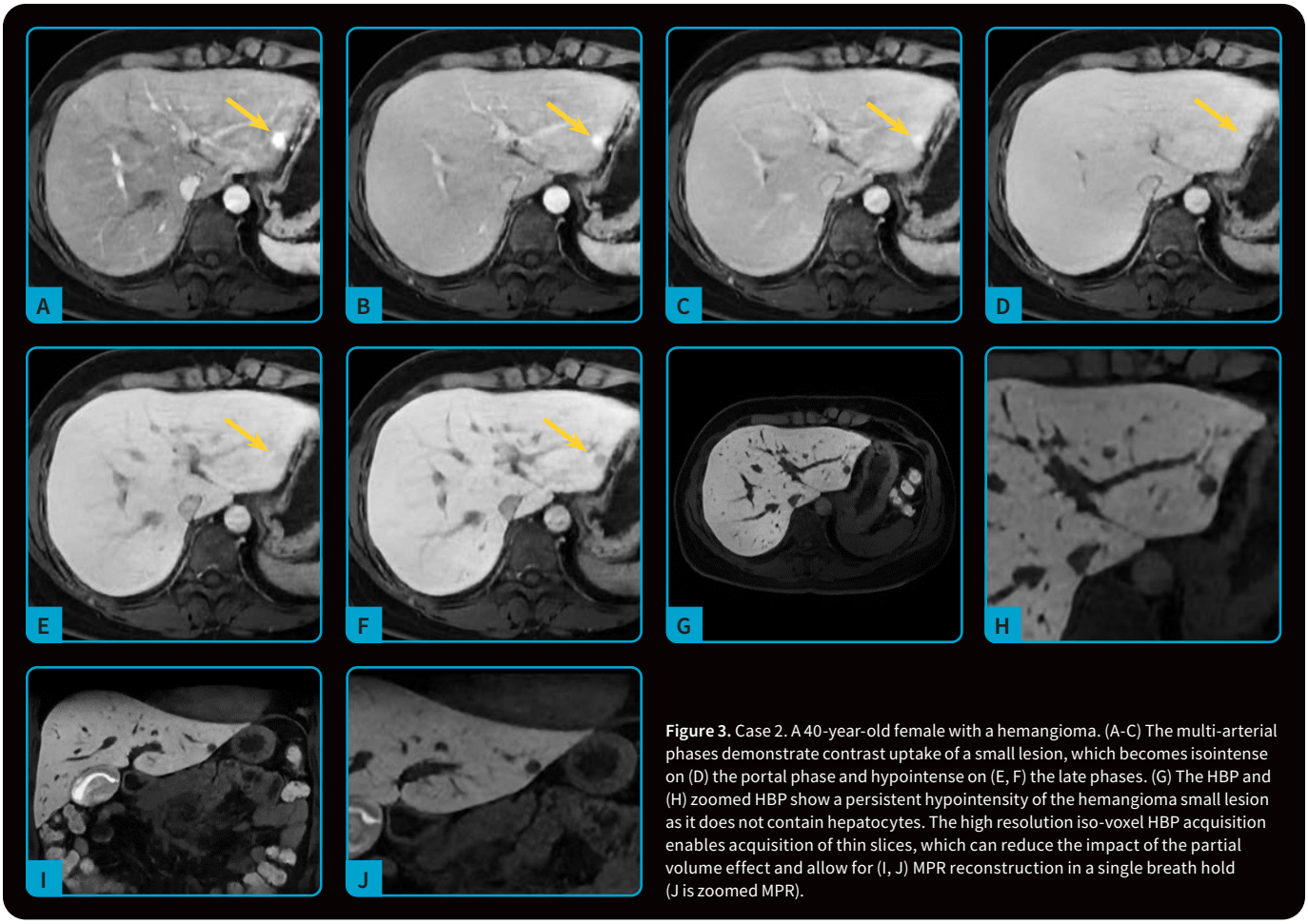

Figure 3. Case 2. A 40-year-old female with a hemangioma. (A-C) The multi-arterial phases demonstrate contrast uptake of a small lesion, which becomes isointense on (D) the portal phase and hypointense on (E, F) the late phases. (G) The HBP and (H) zoomed HBP show a persistent hypointensity of the hemangioma small lesion as it does not contain hepatocytes. The high resolution iso-voxel HBP acquisition enables acquisition of thin slices, which can reduce the impact of the partial volume effect and allow for (I, J) MPR reconstruction in a single breath hold (J is zoomed MPR).

Discovery MR750w 3.0T, MR 30.1 software	LAVA
TR/TE (msec):	3.52/1.3
FOV (cm):	40
Slice thickness (mm):	1.5
Frequency:	270
Phase:	270
NEX:	0.85
Scan time (sec.):	17
Option:	AIR Recon DL, HyperSense

Case 2

Patient history

A 40-year-old female with a hemangioma.

Imaging results

To detect small lesions, imaging with enhanced spatial resolution and slice resolution is necessary. We have implemented iso-voxel imaging at 1.5 mm using AIR Recon DL 3D. AIR Recon DL 3D compensates for the loss of SNR associated with increased spatial resolution. This allows for high-detail images during breath-hold, leading to excellent detection of small lesions. Additionally, using thinner slices has improved contrast.

Improving slice resolution increases the number of slices within the slab, resulting in longer imaging times. However, with HyperSense we can now set scan parameters that fit within the available breath-hold time.

Discussion

With MR 30.1 software and AIR Recon DL 3D, the images produced are of high reliability, even for physicians from other specialties. Diagnostic accuracy is maintained even for clinicians who might not be aware of noise or artifacts.

In HBP, iso-voxel LAVA has enhanced spatial resolution, contributing to the accurate detection of lesions. Short temporal resolution in multi-arterial phase DCE is crucial for diagnosis. Multi-phase LAVA, where each phase is independent, is recommended. A temporal resolution of around 5 to 7 seconds is generally sufficient for diagnosis. If the arterial phase is acquired for more than 20 seconds, it becomes possible to capture corona enhancement. To differentiate between conditions such as focal noduler hyperplasia and small cell cancer, it may be necessary to further increase the temporal resolution.