Radial k-space sampling for 3D fat-suppressed contrast-enhanced imaging of the liver during free breathing

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Purpose:
T1-weighted fat-saturated three-dimensional volumetric interpolated examination (VIBE) is the conventional sequence used for dynamic post-contrast liver MR examinations and is essential for liver lesion detection and characterization (1, 2). VIBE is routinely acquired as a breath-hold acquisition. Respiratory motion in patients who cannot comply can render images non-diagnostic. Radial k-space sampling can result in a substantial reduction in respiratory motion-related artifacts and has shown potential for improving image quality for 2D T2-weighted TSE imaging as well as DWI of the liver (3, 4). We sought to examine whether this method could enable high quality dynamic VIBE imaging despite free-breathing, which to our knowledge has not been extensively evaluated for clinical liver imaging at 3T. Therefore, the purpose of our study was to compare the image quality of three VIBE approaches: conventional breathhold VIBE (BH VIBE), free breathing radially sampled k-space (FB radial VIBE) and free breathing conventional VIBE with multiple averages (FB VIBE).

Materials and Methods:
In this prospective HIPAA compliant IRB approved study, 11 consecutive outpatients (7 male, 4 female; mean age 52 years) who were referred for clinically indicated liver MRI were imaged at 3T (Verio, Siemens Medical System, Erlangen, Germany). Patients were referred for following indications: viral hepatitis and/or cirrhosis (n=6), metastasis work-up (n =2), abnormal liver function test (n=2), and liver lesion characterization (n=1). Routine liver MRI included transverse 3D BH VIBE pre- and post-contrast acquisition in arterial, portal, and equilibrium phases of enhancement. Subsequently, FB radial VIBE, BH VIBE, and FB VIBE with four averages were acquired in random order with matching sequence parameters as follows: slice thickness 3 mm, flip angle 12^{o}, voxel size 1.6 x 1.6 x 3 mm, TR/TE 3.56-3.62 ms/1.51-1.55 ms, 80 slices, BW 590-610 Hz/pix, parallel imaging factor 2 (for conventional VIBE). For radial VIBE 400 radial views were acquired in 4 rotations (100 views/rotation) with 'stack-of-stars' scheme: i.e. normal sampling in the z-direction and radial sampling in the xy-plane. Acquisition time for BH VIBE was 14 seconds, for radial VIBE and FB VIBE with 4 averages, the acquisition time was 56 seconds each.

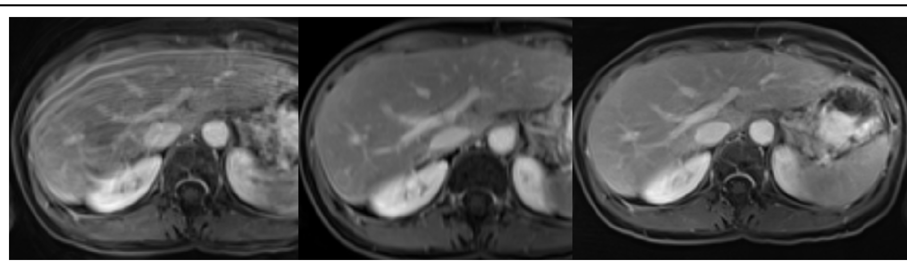
All image data sets were evaluated independently by two experienced radiologists with 3 and 5 years of abdominal MRI experience who were blinded to patient and sequence information. For each data set, each reader independently scored following parameters of image quality using a scale of 1 – 5, with the highest score indicating the most desirable exam: overall image quality, respiratory artifact, pulsation artifact, liver edge sharpness, and hepatic vessel clarity. Streak artifact was also scored (1-3: 1-degrades image quality; 3 – no artifact). The three acquisition techniques were compared for each imaging parameter. Wilcoxon paired test was used to test for statistical significance differences in image quality score as assessed by each reader.

Results:
All patients tolerated the MR examination and performed adequate breath-holds. For both readers although there was differences in absolute score for each category, there was no statistically significant difference between FB radial VIBE and BH VIBE regarding over all image quality, respiratory artifact, liver edge clarity, and sharpness of hepatic vessels (p >0.1). Radial VIBE demonstrated significantly lower pulsation artifact (p<0.01) and significantly higher degradation of image quality due to streak artifact (p <0.01) compared to BH VIBE. Both the FB radial VIBE and BH VIBE had significantly higher image quality for all parameters graded when compared to FB VIBE with multiple averages (P<0.05).

Reader 1 (N = 11)	BH VIBE	Radial VIBE	FB VIBE	P values
Overall Image quality	4.4 ± 0.7	4.5 ± 0.5	2.5 ± 0.5	BH vs. Radial p=0.73
Resp. artifact	4.8 ± 0.6	5.0 ± 0	2.5 ± 0.5	BH vs. Radial p=0.33
Pulsation artifact	4.0 ± 0.6	4.9 ± 0.3	2.3 ± 0.4	BH vs. Radial p <0.001
Liver edge sharpness	4.9 ± 0.3	4.8 ± 0.4	3.0 ± 0.9	BH vs. Radial p=0.55
Hepatic vessel clarity	4.5 ± 0.7	4.4 ± 0.5	2.4 ± 1.3	BH vs. Radial p=0.49

Reader 2 (N = 11)	BH VIBE	Radial VIBE	FB VIBE	P values
Overall Image quality	3.9 ± 1.0	3.7 ± 0.6	1.7 ± 0.9	BH vs. Radial p= 0.63
Resp. artifact	4.3 ± 0.9	4.2 ± 0.7	1.9 ± 0.9	BH vs. Radial p= 0.62;
Pulsation artifact	3.7 ± 1.2	5.0 ± 0	1.9 ± 0.9	BH vs. Radial p = 0.002
Liver edge sharpness	4.3 ± 0.9	4.0 ± 0.6	2.9 ± 0.9	BH vs. Radial p=0.59
Hepatic vessel clarity	3.7 ± 0.9	3.6 ± 0.5	2.0 ± 0.9	BH vs. Radial p=0.77;

Conclusion:
In our patient population, subjects frequently struggle to breath-hold for more than 10 seconds, resulting in decreased image quality. Here we have shown the utility of a 3D radial VIBE technique for post-contrast liver MRI performed during free breathing which is comparable in image quality to BH VIBE and significantly better than conventional VIBE performed with multiple averages during free breathing. Lesion detection and diagnostic quality remain to be assessed.



FB VIBE BH VIBE Radial VIBE

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