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CAIPIRINHA-VIBE and GRAPPA-VIBE for Liver MR Imaging at 1.5T: a Comparative in vivo Patient Study

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Abstract

Objective—Three-dimensional T1-weighted gradient recall echo (3D T1W GRE) volumetric interpolated breath-hold examination (VIBE) using generalized autocalibrating partially parallel acquisitions (GRAPPA), is one of the key sequences in liver magnetic resonance imaging (MRI) and is used for precontrast, dynamic postcontrast, and delayed postcontrast imaging. The purpose of this study is to compare image quality and liver lesion detection on a shorter duration T1-weighted VIBE sequence using the controlled aliasing in parallel imaging results in higher acceleration (CAIPIRINHA) technique with the conventional T1W GRAPPA-VIBE sequence during a single liver MRI session on a 1.5T Siemens scanner.

Methods—20 consecutive patients (9F and 11M, age range: 36–85y) were included in this prospective study. All patients underwent a complete liver MRI on a 1.5T magnet (Aera, Siemens Erlangen, Germany) that consisted of a T1W (in/out-of-phase), T2W, DWI, and pre- and post-contrast multiphasic images (late arterial, 50s, 120s, and 300s) with GRAPPA-VIBE. CAIPI-VIBE images were acquired for precontrast and at 300s (5min) postcontrast phases (6.9s/phase) in addition to GRAPPA-VIBE (21s/phase). The shorter time for the CAIPI-VIBE was selected to allow post-processing of image acquisition in the setting of multi late arterial phase (single breath hold) post contrast images. Five radiologists independently analyzed image quality with predefined scores for liver edge sharpness (LES), artifacts, fat saturation deficiency (FSD), visualization of the portal veins (PV) and hepatic veins (HV), and liver lesion detection (LLD, size 0.5mm to 3.8cm). Score 0 was suboptimal (inadequate), 1 was acceptable for diagnosis and 2 was optimal (excellent). Kappa statistics were used to assess agreement among readers. Generalized

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linear mixed model with generalized estimation equation (GEE) method was used to estimate and compare the LLD failure rates.

Results—No statistically significant difference was seen in the degree of reader variability between CAIPI-VIBE and GRAPPA-VIBE for all evaluated categories using multi-rater Kappa statistics. For the pre- and 5 minute postcontrast phase sequences, greater than 95% of images were considered to be of acceptable quality in all image quality categories for both sequences. 41 lesions were evaluated in 17 patients with total 204 observations (n=204) by 5 readers. For 5 min post-contrast images, the lesion detection rate (LLD) of CAIPI-VIBE (80%) was lower than GRAPPA-VIBE (84%) ($p=0.03$) for small lesions (0.5 to 1.7 cm). There was no significant difference in lesion detection on pre-contrast images.

Conclusions—At 1.5T, the CAIPI-VIBE may be helpful in reducing scan time, and demonstrates similar image quality compared to traditional GRAPPA-VIBE. CAIPI-VIBE has shorter breath-hold time requirement and thus can be an acceptable alternative for the precontrast and 5-minute postcontrast GRAPPA-VIBE in patients with breath-hold difficulties.

Keywords

CAIPIRINHA; Liver MRI; CAIPI-VIBE; GRAPPA-VIBE

Introduction

Magnetic resonance imaging (MRI) is widely used for characterization of focal liver lesions in normal and diffuse liver disease. Breath-hold precontrast, dynamic postcontrast, and delayed postcontrast sequences are key sequences in liver MRI.^{1–3} Image quality may be markedly degraded by respiratory motion artifact caused by poor patient breath-hold compliance.^{4–7} Currently, various parallel imaging techniques are used to reduce the scan time so that the breath-hold required for these sequences can be reasonably achieved by most patients.⁸ However, 7–10% of patients undergoing hepatic MRI are unable to hold their breath for as short as 15 seconds.^{4–7} Inability to breath hold results in increased patient scan time due to the necessity of obtaining repeat images and decreased throughput.⁷

Controlled aliasing in parallel imaging results in higher acceleration (CAIPIRINHA) is a recently developed parallel imaging technique by Siemens Medical Systems (Siemens, Erlangen, Germany) that can further reduce MRI acquisition time of T1W GRE VIBE sequences.^{8,9} CAIPIRINHA allows the use of higher acceleration factors (>2) with modified data acquisition pattern and the image reconstruction to more optimally exploit the sensitivity variations of the receiver coil array in two phase encoding dimensions.^{1,6–8,10} Technical details of the CAIPIRINHA sequence has been explained elsewhere.^{1,6–8,10–14} This improves the current clinically feasible acceleration factor of 2 used by the conventional standard GRAPPA parallel imaging technique at 1.5T during T1W GRE VIBE acquisition in routine liver MRI on Siemens scanners.^{6,15} Two recent reports have shown that CAIPIRINHA reduces breath-hold times and optimizes contrast at the same time, for T1W GRE VIBE sequence in liver MR imaging.^{7,8} The purpose of this study was to compare the image quality including liver lesion detection using CAIPI-VIBE versus

standard GRAPPA-VIBE sequences in precontrast and 5 minutes delayed postcontrast phases during a single routine liver MRI session.

Materials and Methods

This study was performed as an ABR (American Board of Radiology) board-required practice quality improvement (PQI) project to optimize our institution's routine clinical abdominal MRIs and, therefore, was exempt from Institutional Review Board approval. The project was approved by the institutional PQI team.

Subjects

The patient population consisted of 20 consecutive oncologic patients (11 men and 9 women; age range: 36–85 years) that were scheduled for MRI of the abdomen on a Siemens 1.5T scanner (Aera, Siemens Medical Systems).

MRI technique

Imaging parameters are shown in Table 1. All patients underwent a complete liver MRI on a 1.5T magnet (Aera, Siemens) with coronal T2W single shot turbo spin echo, T1W (in and out-of-phase dual echo GRE), T2W turbo spin echo with fat saturation, DWI with echo planar imaging, precontrast, dynamic multiphasic postcontrast and 5 minute delayed post-contrast images with GRAPPA-VIBE. To allow direct comparison between new CAIPI-VIBE and our standard of care GRAPPA-VIBE within same patient with unique physiology at reasonably same time, additional CAIPI-VIBE images were acquired within 6.9s per phase for precontrast and 5 minute postcontrast phases compared to 21s and 15s per phase respectively for GRAPPA-VIBE. The CAIPI-VIBE sequence can be implemented with a much higher acceleration factor compared to the regular VIBE with GRAPPA (5 vs. 2) without noticeable parallel imaging artifacts. For our study, the detailed parameters of the different sequences were designed with the help of a Siemens senior scientist and an advanced application specialist. Considering the different implementations of the CAIPI-VIBE and GRAPPA-VIBE sequences, we allowed some small differences (as little variation as possible) in scan parameters, with the main consideration being to limit the total acquisition time of each GRAPPA-VIBE sequence within a breath hold of approximately 15–20 seconds and the time of each CAIPI-VIBE within a breath hold of approximately 6–8 seconds.

Image analysis

Qualitative image analysis of precontrast and 5 minute delayed CAIPI-VIBE and GRAPPA-VIBE sequences were performed independently by 5 abdominal imaging radiologists with between 5 and 20 years of MRI experience. Each independent reader was blinded to the imaging parameters. Image quality criteria and corresponding scores are shown in Table 2. For each sequence, the radiologists evaluated and scored the liver edge sharpness (LES), artifacts, fat saturation deficiency (FSD), visualization of the portal veins (PV) and hepatic veins (HV), and liver lesion detection (LLD, size <0.5cm to 3.8cm). These were scored using the following categories: score 0 was suboptimal (inadequate), 1 was acceptable for diagnosis, and 2 was optimal (excellent) for any given particular category. The LES was

scored as sharply delineated (score = 2), slightly sharp (not affecting image interpretation; score = 1), and not sharp or blurred (affecting image interpretation; score = 0) (Figures 1). Artifacts were scored as, absent (score = 2), slight (acceptable for image interpretation; score = 1), severe (affecting image interpretation; score = 0) (Figures 2). The FSD was scored as, no deficiency (score = 2), impaired fat saturation in <10% of images or slices in a sequence (score = 1), and impaired fat saturation in >10% of the images or slices (score = 0). For portal vein delineation, visualization of all, the main, right and left portal veins was scored as 2. Incomplete delineation of any of the main, right or left portal veins, was scored as 1. Lack of vein visualization was scored as 0. Similarly, delineation of all 3 hepatics veins (HV) was scored as 2. Incomplete/partial delineation of the HVs was scored as 1 (Figures 3). Lack of HV visualization was scored as 0.

Regarding LLD, up to 5 lesions were evaluated and scored per patient for both CAIPI and GRAPPA VIBE sequences (pre- and 5 min post contrast). The standard of reference for lesion detection in a particular patient was a full review of all MR sequences acquired in that patient. These 5 lesions and their order were predetermined by a senior radiologist and noted by a junior radiologist. To make sure that the same 5 lesions are reviewed by each blinded reader, the junior radiologist was present with each unbiased blinded reader during the review process and documented all the findings. The LLD was scored as, lesion confidently seen (score = 2), possible lesion seen (score = 1) and failure to detect lesion (score = 0).

Statistical analysis

Multi-rater Kappa statistics (Fleiss, 1971) were used to assess the agreement among the five readers on CAIPI-VIBE and GRAPPA-VIBE sequence using 3-scale scores. Scores of acceptable (score = 1) and optimal (score = 2) were combined for other analyses. The frequencies and percentages were calculated for all scores (i.e. scores for all categories on precontrast and 5-minute postcontrast images). Comparison was performed between CAIPI-VIBE and GRAPPA-VIBE using combined acceptable/optimal scores for each category. A generalized linear mixed model with GEE method (Liang and Zeger, 1986) was used to compare probability of lesion detection failure for CAIPI-VIBE versus GRAPPA-VIBE sequences, thus accounting for correlations between readers' scores for the same lesion. Statistical analysis was carried out using SAS version 9 (SAS Institute, Cary, NC). All tests were two-sided, and p-values of <0.05 were considered statistically significant.

Results

The precontrast VIBE was acquired within 6.9s of breath hold using CAIPI, and it took 21s of breath hold for the same sequence acquisition using GRAPPA parallel imaging technique. The scan time reduction for precontrast CAIPI-VIBE was 67%. Acquisition time for the 5 minute postcontrast VIBE sequence was 6.9s using CAIPI, compared to 15s using GRAPPA, with a corresponding scan time reduction of 54% for CAIPI-VIBE.

CAIPI- vs. GRAPPA-VIBE Image Quality

On the precontrast images, though there was a trend that GRAPPA-VIBE (multi-rater kappa values = 0.006 to 0.48) showed better reader agreement than CAIPI-VIBE (multi-rater

kappa values = -0.05 to 0.32) in all categories evaluated except for visualization of portal veins, this difference was not statistically significant. On the 5-minute postcontrast images, GRAPPA-VIBE (multi-rater kappa = -0.16 to 0.09) showed better inter-observer agreement than CAIPI-VIBE (multi-rater kappa = -0.03 to 0.11) for artifacts, LES and PVs, whereas CAIPI-VIBE (multi-rater kappa = 0.22 – 0.24) showed better reader agreement than GRAPPA-VIBE (multi-rater kappa = 0.15 to 0.23) when assessing FSD and HVs. However, there was no statistically significant difference in the inter-observer agreement for the degree of score variability between CAIPI-VIBE and GRAPPA-VIBE.

The readings by five independent readers of the different image quality parameters in 20 consecutive patients yielded a total of 100 observations for each image quality variable (except LLD). Because the number of suboptimal images was too small for all image quality categories, formal generalized linear mixed modeling was infeasible, therefore, the frequencies and percentages were provided for all the scores at both time points (precontrast and 5 minute delayed postcontrast) and across all categories. The optimal (score =2) and acceptable (score =1) scores were combined and compared to suboptimal (score =0) scores for each category for all the readers combined. For both pre-contrast and 5 minute post-contrast phases, the percentage of images with acceptable or optimal quality were higher than 95% for both CAIPI-VIBE and GRAPPA-VIBE. (Tables 3 and 4)

CAIPI- vs. GRAPPA-VIBE Lesion Detection

Of the 20 patients reviewed, 17 patients had liver lesions based on the review of all imaging sequences for each study. A total of 41 liver lesions were evaluated among all patients. One of the readers failed to comment about 1 lesion, resulting in a total of 204 observations (i.e. $41 \text{ lesions} \times 5 \text{ readers} - 1$). The lesions varied in size from less than $<0.5\text{cm}$ to 3.8cm , and ranged from benign to malignant in etiology. The 5 min postcontrast CAIPI-VIBE (80%) was significantly worse than 5 min postcontrast GRAPPA-VIBE (85%) for LLD (odds ratio = 1.37 for LLD failure, 95% CI: 1.07 – 1.74 , $p=0.03$). However, no statistically significant difference (odds ratio = 2.01 for LLD failure, 95% CI: 0.78 – 5.19 , $p=0.12$) in LLD rate was observed between precontrast CAIPI-VIBE (91%) versus precontrast GRAPPA-VIBE (95%); (see Table 5, Figures 1 & 2). The sizes of non-detected liver lesions (LLD failure) matched on both CAIPI-VIBE and GRAPPA-VIBE. The sizes of non-detected liver lesions (LLD failure) were 5 – 17mm on precontrast CAIPI-VIBE and, on 5min postcontrast CAIPI-VIBE as well as GRAPPA-VIBE images. The sizes of non-detected liver lesions (LLD failure) on precontrast GRAPPA-VIBE were 13 – 17mm . Overall, there was no size based difference in LLD failure between CAIPI-VIBE and GRAPPA-VIBE images.

Discussion

Our results demonstrate that images from precontrast CAIPI-VIBE and 5 minutes postcontrast CAIPI-VIBE show mostly non-significant differences in the various categories evaluated for liver imaging and, in over 95% of the cases, the performance of two sequences was congruent and comparable. The review of the images by 5 abdominal imaging radiologists showed no significant difference in the interobserver agreement between CAIPI-VIBE and GRAPPA-VIBE. Since there was an average reduction in acquisition time

of 54–67% for comparable image quality on CAIPI-VIBE (6.9s) when compared to GRAPPA-VIBE (15 and 21s), CAIPI-VIBE may be especially useful for liver MRI of patients who cannot hold breath longer enough for the duration of acquisition using conventional GRAPPA-VIBE, but may be able to hold their breath enough for the shorter duration of CAIPI-VIBE (Figures 2).^{4–6} Our results are consistent with those by Park et al.⁸ who showed a reduction in the number of non-diagnostic arterial phase studies in patients receiving Gd-EOB-DTPA on a 3T magnet, when acquiring arterial phase T1W images using CAIPIRINHA VIBE technique. In their study, the overall acquisition time of arterial phase using CAIPI-VIBE was reduced to 13 seconds (up to a 35% reduction in acquisition time compared from 20 seconds acquisition of GRAPPA-VIBE in their study).

For the detection of liver lesions, we found that the CAIPI-VIBE images had a slightly lower score than GRAPPA-VIBE (Figures 1 & 2). However, the sizes of non-detected liver lesions (LLD failure) matched on both CAIPI-VIBE and GRAPPA-VIBE images, and there was no size based difference in LLD failure between CAIPI-VIBE and GRAPPA-VIBE images in our study. Differences in performance between our study and that of Park et al.⁸ may be due to the higher field strength (3T) used, which would affect signal to noise ratio in addition to acquisition time.

The recent study by Wright et al.⁷ revealed better subjective image quality of 3–5 minutes postcontrast CAIPI-VIBE (with an acceleration factor of 4) among their radiologists compared to GRAPPA-VIBE (with acceleration factor of 2) on 3T liver MRI. In their study, they did not evaluate the liver lesion detection. In a study similar to ours but done on 3T magnet (in contrast to our study on 1.5T), Riffel et al.⁶ reported a comparison of CAIPI-VIBE (with an acceleration factor 4) and GRAPPA-VIBE (with different acceleration factors of 2, 3, 4) in liver evaluation in volunteers and patients. They found overall better image quality, liver edge sharpness, vessel clarity, and less parallel imaging artifacts on CAIPI-VIBE compared to GRAPPA-VIBE. However, Riffel et al.⁶ also did not evaluate the liver lesions in their study. Though the signal-to-noise ratio (SNR) on CAIPI-VIBE (with acceleration factor 4) was slightly worse than the GRAPPA-VIBE with an acceleration factor of 2, but it had better SNR compared to GRAPPA-VIBE with higher acceleration factors of 3 and 4. Yu et al.¹ reported better hepatic vessel clarity and liver lesion conspicuity on CAIPI-VIBE (with an acceleration factor 4) compared to standard GRAPPA-VIBE (with acceleration factor of 2) on 20 minute delayed postcontrast images of Gadoteric acid enhanced 3T liver MRI. In our study, only 1 patient had Gadoteric acid enhanced liver MRI and the majority of our patients had Gadopentate Dimeglumine enhanced liver MRI. Another difference between the previous studies and ours is that all of our studies were performed on a 1.5T magnet, which has lower intrinsic SNR. Some of the improved performance in Yu et al.'s study may have been confounded by the increased hepatocyte concentration/excretion of Gadoteric acid, and associated increase in the lesion-liver contrast against the background liver when compared to other gadolinium-based agents. The marginally lower performance of CAIPI-VIBE in our study compared to priors may be in part attributed to our use of a higher acceleration factor of 5 (compared to an acceleration factor of 4 or less used in above studies resulting in lower signal-to-noise ratio).^{6, 16} For our study, the higher acceleration factor and shorter scan time were designed to simulate timing for potential dual-phase arterial acquisition with the help of a senior scientist and an

application specialist from the vendor to optimize capture of the arterial phase imaging in the constraints of patient breath-hold time. Further, our study was performed at 1.5T versus the other reported studies using CAIPIRINHA performed at 3T.^{1, 6–8} The increased intrinsic SNR in 3T might have contributed in compensating the signal-to-noise ratio loss from a higher CAIPIRINHA-VIBE acceleration factor. It is certainly reasonable to assume that the optimal acceleration factor that can be used with CAIPIRINHA-VIBE would be dependent on the detailed parameters of the scan protocol including the field strength. As the acceleration factor increases, the SNR will be diminished. It may be correct to make the recommendation that an acceleration factor of up to 4 may be used on 1.5T, however, we do lack the appropriate data to make this recommendation.

There are several limitations to our study. First, we used combined imaging sequences as a standard of reference for detection of liver lesions rather than histopathologic confirmation. In addition, the lesions were not characterized for malignancy because no histopathologic confirmation or gold standard was present. Thus, assessment of malignancy was beyond the scope of this investigation should be considered in future research.

Second, our study included a relatively small number of patients. Many of the patients in our study were capable of holding their breath for both the CAIPI-VIBE and standard GRAPPA-VIBE sequence. Therefore, the potential advantage of CAIPI-VIBE for patients unable to fully comply with the GRAPPA-VIBE breath-hold acquisition may not have been fully reflected in our results. Nevertheless, we believe it is reasonable to expect that CAIPI-VIBE will perform better than GRAPPA-VIBE in patients who cannot be compliant with long breath-hold, based on our current findings that CAIPI-VIBE is comparable to standard VIBE in terms of image quality in patients who can hold their breath relatively well. This is also supported by the results of the study by Park et al.⁸, although they had some differences in study design compared to ours.

In conclusion, we found that CAIPIRINHA-VIBE is a feasible substitute for GRAPPA-VIBE in patients with limited breath-hold capacity. The radiologist may need to be somewhat cautious when interpreting CAIPI-VIBE on 1.5T liver MRI. Future evaluation of this new sequence may address some of its limitations. This study adds to the current literature that supports the use of CAIPIRINHA in acquiring optimal quality breath-hold sequences and overall optimal MRI in respiratory and motion challenged patients in addition to reducing overall MRI scan time.

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Figure 1.

MRI in a 63 year old man with metastatic neuroendocrine tumor. The liver edge is slightly blurred and was rated as score 1 (acceptable) on 5 minute delayed postcontrast CAIPI-VIBE (Figure 1a) and is otherwise very sharp and rated as score 2 (optimal or excellent visualization) on standard GRAPPA-VIBE (Figure 1b) images by majority of readers.

Figure 2.

MRI in a 51 year old woman with breast cancer. Breathing motion artifacts are noted affecting detailed visualization of liver parenchyma on the 5 minute delayed breath-hold postcontrast images. The artifacts were however less conspicuous and acceptable for diagnosis with score of 1 on short duration (6.9s) CAIPI-VIBE images (Figure 2a), and were otherwise rated as score 0 affecting diagnostic quality of relatively longer (15s) standard GRAPPA-VIBE images (Figure 2b). This example illustrates the advantage of CAIPI-VIBE over GRAPPA-VIBE in patients with limited breath-hold capacity.

Figure 3. MRI in a 51 year old woman with breast cancer. The right and middle hepatic veins are partially visualized and rated as score 1 (acceptable) on precontrast CAIPI-VIBE (Figure 3a) and were rated as score 2 (optimal or excellent visualization) on standard GRAPPA-VIBE (Figure 3b) images by majority of readers.

Figure 4. MRI in a 71 year old man with metastatic adenocarcinoma of lung shows a 1cm metastasis in left hepatic lobe. It was rated as score 1 (acceptable) on precontrast CAIPI-VIBE (Figure 4a) and was rated as score 2 (optimal or excellent visualization) on standard GRAPPA-VIBE (Figure 4b) images by majority of readers.

Figure 5. MRI in a 47 year old woman with metastatic medullary thyroid carcinoma shows a 1cm metastasis in right hepatic lobe. It was rated as score 2 (optimal or excellent visualization) on 5 minute delayed postcontrast CAIPI-VIBE (Figure 5a) as well as standard GRAPPA-VIBE (Figure 5b) images by majority of readers.

Table 1

Scan parameters for precontrast and 5 minute postcontrast CAIPI and GRAPPA VIBE

Sequences Parameters	Precontrast CAIPI-VIBE	Precontrast VIBE	5 min delayed contrast CAIPI-VIBE	5 min delayed contrast VIBE
TR/TE	4.1/2.4	4.2/1.9	4.1/2.4	4.1/2
Matrix	256×140	256×140	256×140	320×161
Acceleration factor	5	2	5	2
Slice thickness in mm	4	4	4	4
No. of slices	64	64	64	64
Respiratory control	Breath-hold	Breath-hold	Breath-hold	Breath-hold
Inter-slice gap	0	0	0	0
Slice oversampling	12.5%	50%	50%	50%
Phase oversampling	10%	30%	30%	30%
Flip angle in degrees	10	12	10	12
No. of averages	1	1	1	1
Fat suppression	Yes, lines per shot 36	Yes, lines per shot 42	Yes, lines per shot 36	Yes, lines per shot 29
Bandwidth	500Hz/pixel	400Hz/pixel	500Hz/pixel	400Hz/pixel
Slice partial fourier	5/8	6/8	5/8	6/8
Acquisition time in seconds	6.9s seconds	21 seconds	6.9seconds	15 seconds

Table 2

Scoring system for Image Quality Parameters. A score of 2 was considered optimum, a score of 1 was considered acceptable, and a score of 0 was suboptimal.

Image Quality Parameters	Score	Scoring system
Liver edge sharpness	0–2	0- significantly blurred 1- Slight blur, but acceptable 2- Sharp
Artifacts	0–2	0- No artifacts 1- Mild artifacts, image acceptable for diagnosis 2- Severe artifacts, image unacceptable for diagnosis
Fat saturation deficiency	0–2	0- Present in >10% of slices 1- Present in <10% of slices 2- No deficiency
Portal vein / Hepatic veins	0–2	0- Not visualized 1- Some segments or veins visualized 2- All segments / veins visualized
Lesion	0–2	0- Lesion not seen 1- Probable lesion present 2- Definite lesion present

Table 3

Comparisons of image quality scores rating between CAIPI-VIBE and GRAPPA-VIBE. N (1&2) represents the percentage of images with a score of 1 or above. N (0) is percentage of images with score of 0. There was no significant difference between CAIPI-VIBE and GRAPPA-VIBE with respect to image quality at both time points (precontrast and 5 minute-postcontrast) and across all image quality categories.

Time Point	Category	Modality	Acceptable/Optimal		Suboptimal	
			N (1&2)	%	N (0)	%
5 minute-Postcontrast VIBE	Artifacts	CAIPI	100	100.00	0	0
		GRAPPA	99	99.00	1	1.00
	Fat Saturation Deficiency	CAIPI	100	100.00	0	0
		GRAPPA	100	100.00	0	0
	Heptic Veins	CAIPI	97	97.98	2	2.02
		GRAPPA	99	100.00	0	0
	Liver Edge Sharpness	CAIPI	97	97.00	3	3.00
		GRAPPA	97	97.00	3	3.00
	Portal veins	CAIPI	100	100.00	0	0
		GRAPPA	100	100.00	0	0
Precontrast VIBE	Artifacts	CAIPI	99	99.00	1	1.00
		GRAPPA	95	95.00	5	5.00
	Fat Saturation Deficiency	CAIPI	100	100.00	0	0
		GRAPPA	99	99.00	1	1.00
	Heptic Veins	CAIPI	98	100.00	0	0
		GRAPPA	99	100.00	0	0
	Liver Edge Sharpness	CAIPI	95	95.00	5	5.00
		GRAPPA	94	94.00	6	6.00
	Portal veins	CAIPI	97	97.00	3	3.00
		GRAPPA	98	98.00	2	2.00

Table 4

Detailed comparative analysis of image quality scores for CAIPI-VIBE and GRAPPA-VIBE. A score of 2 was considered optimum, a score of 1 was considered acceptable, and a score of 0 as suboptimal.

			Score							
			0		1		2			
			N	%	N	%	N	%		
Time Point	Category	Modality								
5 minute-Postcontrast VIBE	Artifacts	CAIPI	57	57.00	43	43.00	0	0		
		GRAPPA	55	55.00	44	44.00	1	1.00		
	Fat Saturation Deficiency	CAIPI	71	71.00	29	29.00	0	0		
		GRAPPA	68	68.00	32	32.00	0	0		
	Heptic Veins	CAIPI	2	2.02	9	9.09	88	88.89		
		GRAPPA	0	0	7	7.07	92	92.93		
	Liver Edge Sharpness	CAIPI	3	3.00	55	55.00	42	42.00		
		GRAPPA	3	3.00	26	26.00	71	71.00		
	Portal veins	CAIPI	0	0	4	4.00	96	96.00		
		GRAPPA	0	0	6	6.00	94	94.00		
Precontrast VIBE	Artifacts	CAIPI	54	54.00	45	45.00	1	1.00		
		GRAPPA	52	52.00	43	43.00	5	5.00		
	Fat Saturation Deficiency	CAIPI	59	59.00	41	41.00	0	0		
		GRAPPA	52	52.00	47	47.00	1	1.00		
	Heptic Veins	CAIPI	0	0	14	14.29	84	85.71		
		GRAPPA	0	0	3	3.03	96	96.97		
	Liver Edge Sharpness	CAIPI	5	5.00	48	48.00	47	47.00		
		GRAPPA	6	6.00	38	38.00	56	56.00		
	Portal veins	CAIPI	3	3.00	7	7.00	90	90.00		
		GRAPPA	2	2.00	2	2.00	96	96.00		

Summary of liver lesion detection (LLD) by time point and sequence. The 5 min postcontrast CAIPI-VIBE (80%) was significantly worse than 5 min postcontrast GRAPPA-VIBE (85%) for LLD. However, no statistically significant difference in LLD rate was observed between precontrast CAIPI-VIBE (91%) versus precontrast GRAPPA-VIBE (95%). A score of 1 indicates 'probable lesion', score of 2 indicates 'definite lesion' and score of 0 means 'lesion not detected'.

Table 5

Liver Lesion Detection (LLD)		Seen (scores 1&2)		Not Seen (score 0)	
		N	%	N	%
Time Point	Modality				
5 minut-Postcontrast VIBE	CAIPI	164	80.39	40	19.61
	GRAPPA	173	84.80	31	15.20
Precontrast VIBE	CAIPI	185	90.69	19	9.31
	GRAPPA	194	95.10	10	4.90