# Optimized Caipirinha acceleration patterns for routine clinical 3D imaging

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**Introduction:**

An important technique for abdominal imaging is a breath-hold 3D fat-suppressed gradient-echo sequence (VIBE). It is usually acquired as one pre-contrast scan, followed by successive post-contrast scans after contrast injection. Typically, each breath-hold is approx. 22–25 sec., which is relatively long for sick or uncooperative patients. Shortening the scan often translates to reducing spatial resolution or coverage, which is undesirable. If shorter scan times are required without compromising spatial resolution/coverage, one method is to increase the parallel imaging acceleration factor (R). However, increasing R reduces SNR and may introduce image artifacts. Recently, a new acceleration method, Caipirinha [1], was introduced. Caipirinha alters the sampling pattern in k-space from a standard GRAPPA acquisition to control aliasing and make more efficient use of the coil sensitivities. As a result, the image artifacts are reduced, and so are the g-factor related SNR losses. Caipirinha may therefore reduce scan times by virtue of allowing use of higher R, without compromising image quality. This work explores the potential of Caipirinha for clinical abdominal imaging. The goal was to determine the optimal sampling pattern for a typical axial abdominal VIBE scan in order to reduce scan time.

**Methods:**

Caipirinha was implemented in a 3D VIBE sequence. Four volunteers and 8 patients were scanned on a wide-bore 3T Magnetom Verio (Siemens Healthcare) with one/two body and spine matrix coils (6 independent elements each, total of 18 elements max). Six sampling patterns were tested (Fig. 1): 210 (R=2, GRAPPA pattern), 310 (R=3, GRAPPA pattern), 131 (R=3), 132 (R=3), 220 (R=4), 221 (R=4) ($1^{st}$ number: in-plane acceleration, $2^{nd}$ number: through-plane acceleration, $3^{rd}$ number: delta kz shift in the sampling pattern). When delta kz = 0, the pattern is a standard GRAPPA pattern.

Imaging parameters were: TR/TE=4.3/1.9 ms, flip angle=9 deg., partitions=72, matrix= (168-220) x 256, resolution=1.3 x 1.3 x 3 $mm^3$, R=2, 3, 4. Slice oversampling of 10% was used for the 210 pattern, while 44% was used for all other patterns to minimize slice aliasing. For image assessment, SNR (mean/stdev) was measured in the middle of the liver on pre-contrast images in the 4 volunteers. Data were also processed to calculate the g-factor maps for each sampling pattern. The max g-factor of the g-map over the entire FOV in one slice was measured for each pattern. The ratio of the max. g-factor of each pattern and the max. g-factor of the 210 image was used for evaluation.

**Results:**

Images acquired using all sampling patterns are shown in Fig. 2 in one subject. Note the image artifacts with GRAPPA 310 pattern, which are significantly reduced by the Caipirinha patterns 131 and 132. These results were consistent in all subjects. The g-maps demonstrate the low amplitude and uniformity of g-factors in the Caipirinha patterns 131 and 132 as compared to 310. The 220 and 221 images and g-maps on the other hand showed little differences. Overall, the 131 pattern shows the lowest g-factors in the anatomy of interest – the high g-factors with 131 are outside the region of interest due to modified aliasing in Caipirinha. SNR comparisons (**210:**$14\pm3$, **310:**$6\pm1$, **131:**$15\pm3$, **132:**$14\pm4$, **220:**$13\pm3$, **221:**$13\pm2$) using paired t-tests showed minimal differences between 220 and 221 ($p=0.4$), while 131 outperformed 132 ($p=0.04$), and both 131 and 132 vastly outperformed 310 ($p<0.03$). The g-factor measure, calculated as a ratio of max. g to 210 as reference (**310:**$4.1\pm0.6$, **131:**$1.4\pm0.4$, **132:**$1.2\pm0.6$, **220:**$1.75\pm0.3$, **221:**$1.8\pm0.4$) also showed that 131and 132 were much better than 310, and that 220 and 221 were similar.

Although R = 4 images showed comparable performance to R=3 (131 and 132), increased artifacts were observed in 2 out of 12 cases. The increased artifacts seem to correlate with patient size – larger patient size results in more artifact power. The total **time savings with Caipirinha were 20% with R = 3, and 40 % with R = 4,** with little compromise in overall image quality as compared to R=2 images. More time savings could be realized if slice profiles are optimized further and slice oversampling reduced. Overall, the 131 pattern showed the most consistent results in all subjects scanned.

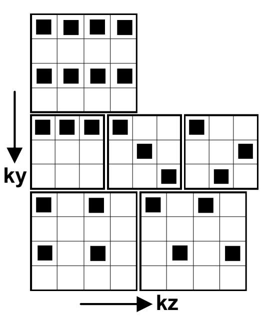


**Figure 1.** Caipirinha patterns. Left to right:
Top Row: 210
Middle row: 310,131,132
Bottom row: 220,221.

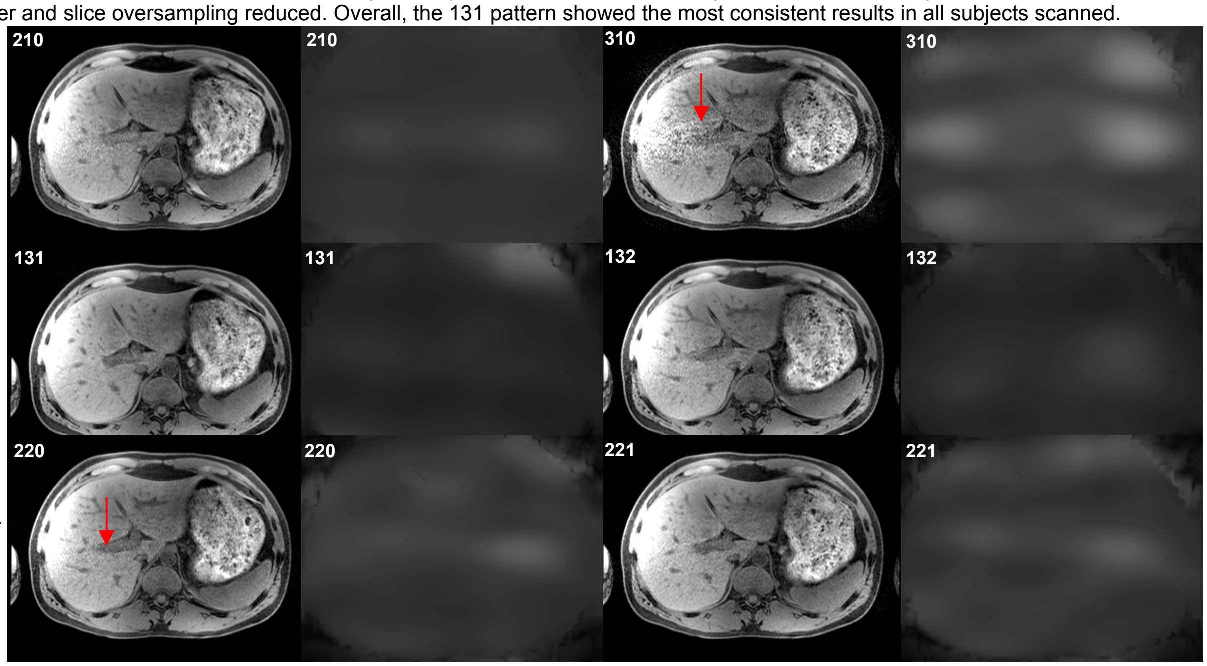


**Figure 3.** Comparison of images and g-maps acquired using different sampling patterns.

**Discussion:**

Shortening scan time in abdominal breath-hold scans is important for patient comfort and image quality consistency across patients. GRAPPA or SENSE methods are limited in acceleration by the SNR loss that results from parallel imaging. Caipirinha patterns were found to reduce image artifacts with R=3 and R=4 over GRAPPA. In this study, while we found that pattern 220 or 221 (R=4) could be used in most patients with very good image quality, the 131 sampling pattern achieved the most consistent results. Note that optimal Caipirinha sampling patterns are specific to the relation between the coil and the anatomy, so a separate optimization must be done if Caipirinha is used for different applications. In conclusion, Caipirinha sampling permits using higher acceleration with VIBE, resulting in shorter imaging time. The results are consistent, such that Caipirinha seems realistic for routine abdominal imaging.

**References:** 1. Breuer F, et al. MRM 2006 ; 55 :549-556.