Application of RF Subencoding Acquisition to Flow Compensated 3D half-Fourier FSE MRA

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Introduction
Fast imaging techniques using subencoding acquisition with multiple-element RF coils were first proposed around '91-'93 [1,2]. Since then modified techniques (e.g., SMASH and SENSE [3,4]) and many clinical applications have been reported.

Several FSE-based bright blood imaging techniques have been developed for non-contrast MR angiography [5-7]. ECG-gated 3D half-Fourier FSE allows visualization of blood vessels within a reasonable scan time [5]. By employing this technique, blood vessels oriented in the phase-encoding (PE) direction are well depicted; however, vessels oriented in the read-out (RO) direction have flow dephasing [7] and/or N/2 artifacts [6,8]. Recently, gradient moment nulling (i.e., flow compensation: FC) was applied to reduce such artifacts. However, intrinsic T2 blurring in the PE direction increases due to prolonged echo train spacing (ETS) in FC sequences [9].

In this study, we have applied RF subencoding acquisition to 3D half-Fourier-FSE with FC in order to shorten data acquisition time, and investigated its performance with comparative studies of non-FC sequences.

Methods
Normal "full-FOV" data and subencoding "half-FOV" data were obtained using FC and non-FC 3D half-Fourier-FSE sequences (Fig. 1). As the next step, the unfolding process [2] of factor 2 was applied for both of the half-FOV images.

Abdominal coronal images of normal volunteers were obtained on a 1.5-T clinical imager equipped with a 4-channel body array coil. Main parameters used are shown in Table 1. Other parameters were as follows: TR = 3-4 R-R intervals, number of slices = 36, section thickness = 2 mm, scan time = 2-3 minutes depending on an R-R interval. RO direction was superior-inferior and PE direction was right-left.

Results and Discussion
In the FC images, N/2 artifacts were effectively suppressed as reported in ref.9, and the signal intensities of blood vessels were uniform (Fig. 2a,b). The unfolded image also had no apparent artifact (Fig. 2c). T2 blurring in unfolded image was significantly improved compared with that of full-FOV image. On the other hand, apparent N/2 artifacts of the inferior vena cava were observed in the non-FC images (Fig. 2d,e, arrowheads), and the signal intensity was inhomogeneous. Note that the artifacts of the subencoding image are located in N/2 position of half-FOV (Fig. 2e). The unfolded image had several "N/4 artifacts" (Fig. 2f).

As shown in Fig. 2f, the artifacts had more complicated shape on the unfolded images in the RF subencoding acquisition technique. Therefore, suppressing flow artifacts before unfolding (i.e. during data acquisition) is important in subencoding flow imaging. In the half-Fourier-FSE sequence, T2 blurring in PE direction increases with prolonged data acquisition time for each excitation . By using subencoding acquisition, the blurring can be reduced due to the shortening of data acquisition time. [3].

Conclusion
We have obtained 3D non-contrast MR angiograms with notably less blurring and less flow-related artifacts, by applying subencoding acquisition to flow-compensated 3D half-Fourier-FSE MRA.

Table 1 Parameters used in this study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FC</th>
<th>non-FC</th>
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<tr>
<td>ETS</td>
<td>6 s</td>
<td>5 s</td>
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<tr>
<td>Data Acq Time</td>
<td>930 ms</td>
<td>890 ms</td>
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<tr>
<td>Acquire FOV</td>
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<tr>
<td>Acquire Matrix</td>
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<td>256 x 256</td>
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Fig. 1 Diagram of FC and non-FC FSE Pulse Sequences

Fig. 2 (a)-(c) Images obtained by FC sequences: (a) full-FOV, (b) half-FOV (subencoding), (c) unfolded image from (b). (d)-(f) Images obtained by non-FC sequences: (d) full-FOV, (e) half-FOV (subencoding), (f) unfolded image form (e). Non-FC images (d)-(f) have apparent N/2 artifacts (arrowheads).

References