Restoration of within-FOV aliasing in Propeller MRI using kt-Blast
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Introduction
Propeller MR imaging [1] has the benefit of low sensitivity to bulk motion. While the true field-of-view (FOV) of Propeller is approximately circular due to the rotating blade sampling pattern in the k-space, the apparent FOV shown in the prescription of Propeller acquisition is currently rectangular. Signals from outside the true FOV (i.e., corners of the rectangular FOV) can produce aliasing along various directions in different blades (termed the within-FOV aliasing [2]), leading to signal loss or ghosts. Appropriate placements of the saturation bands solve the aliasing problem by eliminating the signals outside the circular FOV [2], but with loss of the information at the corners of the rectangular FOV. Here we propose an alternative reconstruction method for Propeller imaging based on an algorithm similar to kt-Blast to restore the information within the entire rectangular FOV. Phantom experiments were conducted to verify the effectiveness of the proposed method.

Theory
As long as the imaged object is located inside the conventionally prescribed rectangular FOV, the first Propeller blade without rotation can be reconstructed without aliasing artifact. However, when the blades rotate, the object falling outside the rotated rectangular FOV (dotted line in Fig.1) produces aliasing (the white arrows) [2]. The intensity of the aliased pixel \( \rho_{\text{alias}} \) contains contribution from the intensity at the original position \( (\rho_1) \) and the intensity of the pixel located one FOV apart \( (\rho_2) \). To separate \( \rho_1 \) and \( \rho_2 \), the low-resolution image reconstructed from first blade (i.e., the one without aliasing) can be treated as a training image to estimate the relative contribution of \( \rho_1 \) and \( \rho_2 \) contained in \( \rho_{\text{alias}} \) in a way similar to kt-Blast reconstruction using the following equation [3]:

\[
\rho = M^T \rho^\text{true} (M^T M)^{-1} \rho_{\text{alias}} - (1), \quad \text{where } \rho = \begin{bmatrix} \rho_1 \\ \rho_2 \end{bmatrix} \quad \text{and} \quad M = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}
\]

Then all the rotated blades with aliasing can be corrected, with subsequent Propeller reconstruction [1] applied to map all pixels back to their original positions.

Materials and Methods
A rectangular phantom filled with water was used for experiments, with three bottles of fat-water emulsion solutions containing diluted gadolinium contrast agent at different concentrations placed at the center and two corners of the container. Scanning was performed on a 3T SIEMENS scanner with Propeller imaging using fast spin-echo readout. The scanning parameters were: TR/TE = 400/9.7 ms, FOV = 220mm, slice thickness = 4mm, Blade size = 32x256. The number of blades was 18 and rotate angle between each blade was 10˚.

Results
Figure 2 shows the phantom scan results. Some blades showed aliasing at the corner (2a), resulting in signal loss in an arc shape at the corners of the phantom (2b). The low-resolution image reconstructed from the first blade (2c) rotated to the angle of an aliased blade (2d) was then used to compute the parameters for use in Eq.(1). Fig.2e shows the reconstruction result for this originally aliased blade image, but now without aliasing. The Propeller image obtained with our aliasing correction is shown in Fig.2f. Compared with Fig.2b, the signal loss at the corner is successfully compensated in Fig.2f.

Discussion
We have demonstrated Propeller image reconstruction with successful restoration of information from the entire rectangular FOV, using an algorithm similar to kt-Blast which is also a de-aliasing method in nature. It can also be applied on the abdominal MRI or sagittal and coronal plane which may suffer from the aliasing artifact. The proposed method does not need additional sequence modifications or extra acquisition time, and is hence applicable to all existing Propeller images if the k-space data from all blades are preserved. The proposed method currently has slight limitations only at object boundaries, because the compensation quality is highly dependent on the training image which is of low resolution. The training blade having point-spread-function blurring due to k-space undersampling differs from the aliased blade in terms of the orientation of the blurring pattern. Other than this minor pitfall, the proposed approach shows effectiveness in reconstructing Propeller images with rectangular FOV.

References