PROPELLER (BLADE) technique to upper abdominal MR imaging

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Learning objectives

The aim of this poster was to learn the technical principles and features of the Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction (PROPELLER, BLADE in the MR systems from Siemens Medical Solutions) technique during its application for upper abdominal imaging and to show the advantage in image quality and the clinical usefulness.

Background

In upper abdominal MR imaging, artifacts reduce image quality, leading to a loss of diagnostic information. Motion artifacts, especially ghost artifact can lead to a loss of image clarity, reduce anatomic detail, and hamper the detection of pathological findings within the abdominal region. Also, they often blur the liver edge, and obscure the depiction of intrahepatic vessels, making it difficult to recognize liver lesions in the left lobe or under the diaphragm in the presence of ghosting and cardiovascular artifacts. The BLADE MR technique proposed by Pipe et al. is known to be a type of self-navigated data acquisition technique, in which k-space data are acquired in blades to produce oversampling at the center of k-space. The BLADE MR image offers a significant advantage from the point of offering targeted correction for the major in-plane movements of rotation and translation. The method has the advantages of oversampling at the center of the k-space, and results in a better signal-to-noise ratio (SNR) (Fig. 1).

Images for this section:
Fig. 1: Illustration of BLADE k-space data acquisition. A single blade in k-space, composed of L phase encoded lines corresponding to a full image set with very low resolution in the phase encoding direction (a). Each blade contains phase encoding lines. A complete set of trajectories for a BLADE data, composed of concentric rotated stripes (b).
**Imaging findings OR Procedure details**

**BLADE imaging technique**

BLADE is based on the PROPELLER MR imaging acquisition and reconstruction method. In BLADE, the k-space is covered by a series of blades, and each width of a blade has $L$ (L = number of lines per blade) very low phase-encoding lines in a conventional rectilinear k-space trajectory. During the acquisition process, the direction of each blade of the series is rotated around the k-space center. The rotation angles $A_n$ and the number of blades $N$ are chosen such that the complete series covers the k-space. For turbo spin echo (TSE), the echo train length (ETL) is decided such that a complete blade is filled after a single 90° excitation pulse. One advantage of BLADE compared to other k-space trajectories is that a centered circle of the k-space (with diameter $L$) is reacquired for every blade. The BLADE technique enables to make calculations from a low resolution image from the center of each blade to obtain motion correction effect.

**TSE BLADE parameters**

For the application of the technique, the important parameters are "Echo time (TE)", "Turbo Factor", "width of blade", "blade coverage", "number of blades", "matrix", and "motion correction".

A complete blade is filled after a single 90° excitation pulse. Similar to a conventional TSE sequence, the TE is defined as the temporal distance between the excitation pulse and the echo with the smallest amplitude of the phase-encoding gradient and determines the T2 contrast of the image. The Turbo Factor of BLADE is equal to the ETL of the TSE sequence when parallel imaging is not used. In BLADE, the Turbo Factor also determines the number of phase-encoding lines of one blade; and if parallel imaging such as iPAT is not used, the width of the blade is equal to the Turbo Factor while if parallel imaging is used, the width of the blade is not necessarily equal to the Turbo Factor indicating the actual acquired lines per blade (Fig. 1, 2).

**MR image artifact reduction and quality improvement in the upper abdomen with the BLADE**

In the BLADE images, image artifacts including ghost artifact, sharpness of liver edge, and image quality are improved compared to those without BLADE (Fig. 3, 4). On the other hand, streak artifacts often appear in radial scans (Fig. 5).

**Motion correction effects including streak artifact and image quality of the BLADE image in the upper abdominal region using different scan conditions**
In upper abdominal BLADE MR imaging, it was possible to reduce artifacts and obtain better image quality by increasing the k-space coverage with parallel imaging in the same scanning time (Fig. 6, 7).

*Improved hepatic detection by BLADE*

In the BLADE images, detectability of hepatic lesion is improved compared to those without BLADE (Fig. 8, 9). MR imaging without only the BLADE method had some false-positive and false-negative findings because of poor image quality and artifacts. The BLADE method is expected to improve detection of hepatic lesions.

**Images for this section:**
**Fig. 1:** In BLADE MR imaging, the number of excitations (blade) needed to adequately cover k-space is $N = \# / 2 \times M / L = \text{blade coverage} \times M / L$, where $N$ is the number of blade, $M$ is the matrix size and $L$ represents ETL.
**Fig. 2:** Schematic drawing of the k-space trajectory for each BLADE condition. Three different values of ETL, width of a blade, and k-space coverage condition as one blade data are shown: ETL/width of a blade/ k-space coverage: 19/30/100(a), 30/30/100(b), and 30/52175(c). (a) and (c) were performed with parallel imaging (iPAT) (dashed long lines) whereas (b) did not use iPAT (thick solid long lines). In (c), there is a wider width of the blade, shortening the k-space and covering 175% of the blade to ensure the same scanning time.
**Fig. 3:** This figure shows fat-saturated T2-weighted TSE axial images with a respiratory trigger obtained from a normal volunteer. The conventional image shows blurred resolution of liver edge and poor depiction of intrahepatic vessels (a). Much better sharpness of liver edge and clearer depiction of intrahepatic vessels were seen on the BLADE MR image (b).
Fig. 4: This figure shows fat-saturated T2-weighted TSE axial images with a respiratory trigger obtained from a normal volunteer. The conventional image shows obscure depiction of organs such as spleen, kidney, pancreas, and intestine (a). The depiction of the organs was improved on the BLADE MR image (b).
Fig. 5: Streak artifacts often appear in the BLADE image.
Fig. 6: Images of motion artifact in a 61-year-old man with chronic liver damage. Transverse fat-saturated T2-weighted TSE MR images with respiratory triggering using the BLADE technique. Three different ETL, width of a blade, and k-space coverage conditions (ETL/width of a blade/ k-space coverage were (a) 19/30/100, (b) 30/30/100, and (c) 30/52/175) indicate different motion artifacts (such as respiratory motion and vascular pulsation); ETL/width of a blade/ k-space coverage in (c), i.e., 30/52/175 gives the best motion correction effect.
Fig. 7: Abdominal images of streak artifact in a 48-year-old woman with rectal cancer, performed to rule out liver metastasis. Transverse fat-saturated T2-weighted TSE MR images with respiratory triggering using the BLADE technique with different ETL, width of a blade, and k-space coverage conditions (ETL/width of a blade/ k-space coverage were (a) 19/30/100, (b) 30/30/100, and (c) 30/52/175) demonstrate different streak artifacts. In (c), i.e., 30/52/175, streak artifact is reduced the most.
Fig. 8: This figure shows fat-saturated T2-weighted TSE axial images after superparamagnetic iron oxide-enhanced (SPIO) administration with a respiratory triggering obtained in a 48-year-old woman with hepatocellular carcinoma. (a) The MR image with only PACE method depicts the hepatic tumor in segment II less clearly because of ghosting artifacts, although hepatic cyst in segment IV is apparently seen. (b) The hepatic tumor in segment II is detected clearly using the BLADE method.
Fig. 9: This figure shows fat-saturated T2-weighted TSE axial images after superparamagnetic iron oxide-enhanced (SPIO) administration with a respiratory triggering obtained in a 55-year-old woman as a follow-up examination for hepatocellular carcinoma (HCC) with liver cirrhosis and ascites. (a) The MR image with only PACE method shows it is difficult to evaluate hepatic lesions minutely because of poor image quality. (b) The BLADE MR image shows besides the post-therapic (radio-frequency ablation) hepatic lesion for HCC in segments IV and VIII, hepatic solid lesion to be suspected as recurrent HCC in segment VIII is clearly seen.
Conclusion

1. PROPELLER is a variant of radical scanning techniques which can reduce artifacts induced by in-plane rotation and translational motion.

2. Compared to conventional methods, PROPELLER is promising for reducing image noise and artifacts and obtaining better image quality in the upper abdomen.

3. To obtain better image quality, it is important to use increased blade width and k-space coverage rather than decreasing them.

4. Optimized PROPELLER T2-w imaging should replace conventional T2-w imaging due to its better image quality and superior ability of lesion detection.

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References


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