3D center-out EPI with cylindrical encoding

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Target audience. Pulse-sequence programmers, physicists interested in radial sampling, 3D hybrid EPI techniques, and ultra-short echo times.

Purpose. Recently, a two-dimensional (2D) EPI variant dubbed DEPICTING [1] was introduced. It allows the acquisition of highly resolved images at very short echo time (*TE*) by sampling *k*-space in two shots along center-out trajectories with phase blips of opposite sign. Purpose of the current feasibility study is the adaptation of this method to three dimensions by volume selective excitation, and the acquisition of multiple center-out EPI half-planes with rotating EPI phase blips. Thus, the three-dimensional (3D) *k*-space is encoded in cylindrical fashion, i.e. as in standard EPI along the read direction and radially in the planes perpendicular to it.

Methods. The sequence was implemented as depicted in Fig. 1. Following a volume-selective excitation pulse of flip angle α and a dephasing gradient solely along read direction, an EPI half-plane is sampled with a phase-blip gradient (G_{Blip}) that forms an angle θ with the *x*-axis. After acquiring N_{rs} *k*-space lines (N_{rs} is the number of radial samples), a spoiling gradient is applied. The acquisition of EPI half-planes is performed within a loop while the angle θ is rotated by N_{spokes} angular steps. Before the actual image acquisition, a variable number of loop passes are performed without data acquisition (dummy scans) to approach the steady state followed by one pass with data acquisition and $G_{\mathrm{blip}} = 0$ (template scan) for the correction of the Nyquist ghost artifact. Because *k*-space is sampled on a cylindrical grid in a center-out fashion, we term the proposed 3D variant of DEPICTING as "3D center-out EPI with cylindrical encoding".

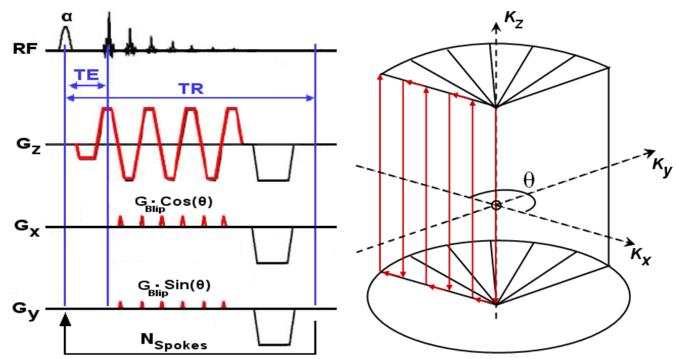

Fig. 1: Schematic diagram of 3D center-out EPI with cylindrical encoding (left) and the corresponding *k*-space trajectory (right).

The preliminary data acquired for Fig. 2 were collected from a structural water phantom at 3T (TIM Trio, Siemens, Erlangen, Germany). 3D center-out EPI data were obtained with a matrix of $N_{\mathrm{read}} = 128$, $N_{\mathrm{rs}} = 64$, and $N_{\mathrm{spokes}} = 201$. N_{spokes} is chosen π times larger than N_{rs} to ensure adequate *k*-space density at the intended image matrix of 128×128×128 [2]. Correction of the Nyquist ghost was performed in hybrid space, i.e. after flipping of even echoes and FFT along read direction, based on the template scan. Subsequently, an inverse FFT along read direction was applied to obtain a Nyquist-corrected 3D *k*-space. Coordinates of the cylindrical *k*-space points were interpolated onto a Cartesian grid by use of the Non-uniform Fast Fourier Transform (NUFFT) algorithm introduced by Fessler and Sutton [3]. Overly dense points near the *k*-space center were corrected by a density compensation function (DCF) [4].

Results. Figure 2 shows a preliminary axial image from a data set acquired by 3D center-out EPI with cylindrical encoding (right). For comparison, an image obtained with (Cartesian) 3D FLASH (left) is shown as a geometrical reference. An image obtained with 2D EPI is also shown to demonstrate the typical distortion artifacts of EPI images. For the proposed 3D variant of DEPICTING, a similar degree of distortion is obtained. However, these distortions differ between Cartesian and cylindrical encoding due to the change of the orientation of the phase blips between shots. As in the original 2D implementation of DEPICTING [1], such distortions may be corrected based on the information from a separate field-map scan (e.g., employing a multi-frequency reconstruction).

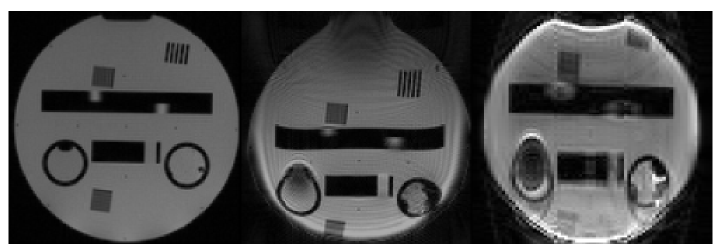

Fig. 2: Axial images obtained from a structural water phantom with 3D FLASH (left), 2D EPI (middle) and 3D center-out EPI with cylindrical encoding (right).

Discussion and Conclusion. The feasibility of "3D center-out EPI with cylindrical encoding" was demonstrated. Echo-planar based cylindrical sampling and the N_{spokes}-fold oversampling of the central *k*-space line are expected to provide a lower susceptibility to subject motion than in conventional Cartesian 3D encoding. Robustness might further be improved by randomizing the sampling order of the EPI half-planes. As the central *k*-space line is collected with every shot, 3D data can be dynamically updated with high temporal resolution (i.e., the time required for one EPI readout), which may be exploited in cine applications. Unlike traditional EPI techniques, the center-out trajectories achieve ultra-short *TE*. Further optimization of the image reconstruction, such as the inclusion of intersegment and geometric distortion correction is required for improved image quality.

References

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