PETAL Imaging for Reduced Flow Sensitivity Compared to Spiral Methods

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INTRODUCTION: Center-out k-space trajectories for data collection, such as projection reconstruction (PR) and spiral imaging, are generally less sensitive to flow-related artifacts than most Cartesian-based methods due to the lack of in-plane gradient moments in the center of k-space and the ability to minimize TE. Spiral imaging is generally a much more efficient technique than PR, requiring far fewer TR's to fully sample k-space for a given FOV and resolution. However, with longer spiral acquisitions the gradient moments build up during data readout, so that peripheral (high spatial frequency) areas of k-space may be corrupted in the presence of rapid, pulsatile, or disordered flow. A new k-space trajectory for data collection is presented here which balances this particular trade-off (efficiency vs. flow sensitivity) between spiral and PR methods. The method, termed Parallel Encoded Triangles in an Azimuthal Lattice (PETAL) imaging, is roughly 1/2 as efficient as spiral imaging, but results in greatly reduced flow sensitivity at the edges of k-space.

METHODS and RESULTS: The base trajectory for PETAL imaging is shown in Fig. 1(a); it covers, in each TR, a triangular piece of k-space, starting in the center of k-space and concentrically moving out to the edges. Subsequent TR's rotate this path to fill in all of k-space, as seen in Fig. 1(b). The motivation for this path is the reduction in gradient amplitudes toward the end of the data collection, keeping gradient moments lower throughout k-space. Spiral acquisitions have the opposite gradient characteristic - the gradient amplitude increases toward the end of the data acquisition. As a result, as seen in Fig. 1(c-f), PETAL imaging has less gradient moments than does spiral imaging for a fixed acquisition time and FOV/resolution (PETAL plots are the thin black lines, spiral plots are the thick gray lines). This results in less distortion of the computed point spread function (PSF) for flow (Fig. 1(g)). PETAL imaging has been implemented into a 2D TOF sequence on a GE 1.5T scanner - an example of a data set on a normal volunteer is seen in Fig. 1(h).

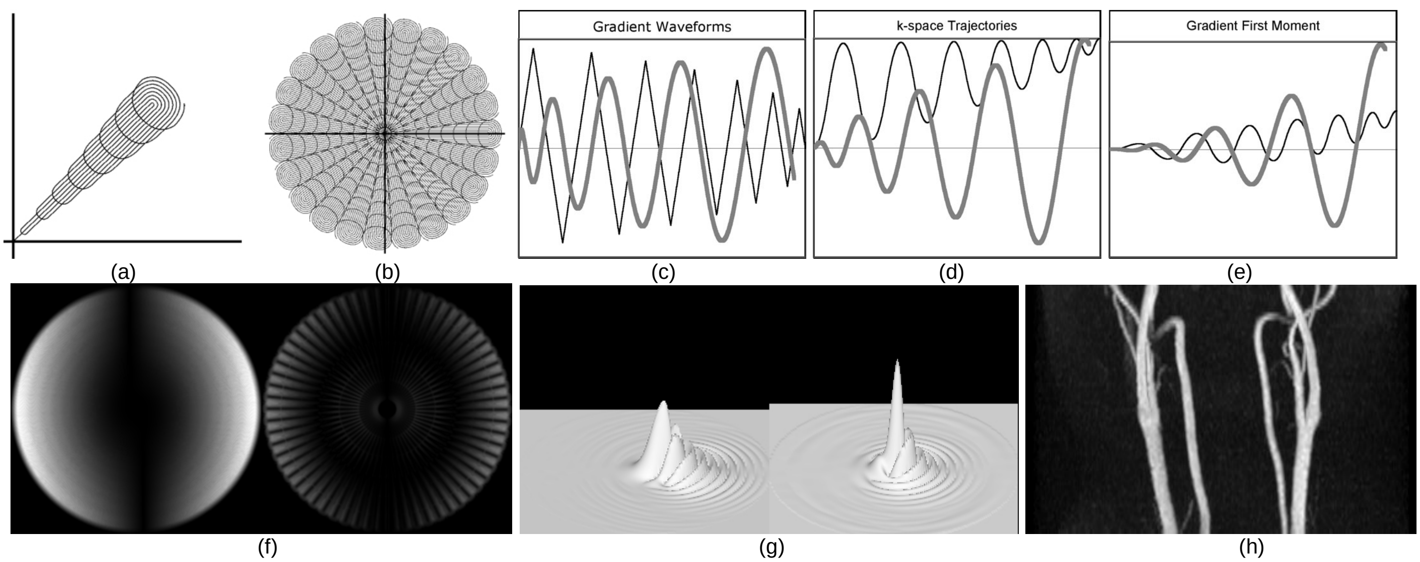

Fig. 1. PETAL k-space trajectory for (a) a single TR and for (b) a complete scan. The PETAL radial readout gradient (thin black line) and a single spiral readout gradient (thick gray line) are shown in (c), along with (d) their resulting k-space locations and (e) first moments vs. acquisition time. The first moments in the left-right direction are plotted (f) in k-space for the entire set of trajectories for spiral (left) and PETAL (right) imaging for a fixed acquisition time, and the corresponding calculated PSF for rapid flow in that direction are shown (g) for spiral (left) and PETAL (right). A MIP of a set of 2D TOF images of the carotid arteries using PETAL is also shown in (h).

DISCUSSION: PETAL imaging is on average about 1/2 as efficient as spiral imaging, in terms of average trajectory speed. This is because the net amplitude of the encoding gradients is on average roughly 1/2 that of the corresponding amplitude for spiral gradient waveforms. The benefits for PETAL imaging lie in the fact that it remains much more efficient than Projection Reconstruction methods, and has less motion sensitivity than spiral imaging. For imaging rapid flow, such as in cardiac imaging or imaging around stenoses, this may prove beneficial. *Future Work*: We are currently implementing comparable PETAL and spiral sequences for a comparison of visualization of rapid flow. The off-resonant effects of PETAL are also being investigated - here, rather than a purely radial increase in off-resonance phase (like spiral) that leads to pure blurring, off-resonance has an oscillating azimuthal component that tends to disperse the PSF energy. It is believed (but not verified) that this is the reason for the reduction of the background fat signal apparent in Fig. 1(h) compared to conventional Cartesian methods