Dual-Projection Sequence for Fast Volumetric Imaging of Contrast Enhanced Tubular Structures

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Introduction:

Recent advances in fast contrast enhanced vascular MR imaging and catheter tracking (ref) have allowed the exploitation of vascular interventional MRI (e.g. 1,2,3). Among the capabilities of MRI is three dimensional (3D) and/or multislice imaging for volumetric appreciation of the area of the procedure. However, since 3D or multislice imaging is too slow for guiding a vascular intervention, single slice methods are preferred (1,2,3). In this work we present a dual projection imaging (DPI) technique for the collection of two temporally matched orthogonal projections for fast 3D appreciation of the targeted CE vasculature or catheters.

Materials and Methods

Dual Projection Pulse Sequence: The underlying principal of the DPI sequence is the fast acquisition of two orthogonal projections in a manner that they are spatially matched to each other even when the structure moves (e.g. coronary or abdominal vessels). With DPI this is achieved with the two projections sharing the same phase encoding steps and axis, as shown in Fig. 1. For each phase encoding step (axis Y), two echoes are collected, one for each projection, with the readout gradients applied along the conventional "slice selection" (axis X) and "frequency encoding" directions (axis Z). To ensure that the spins are at the origin of the k-space before the second echo, the read-out dephasing gradient is repeated along the read-out axis of the first echo.

3D Reconstruction: 3D reconstruction from the two projections was also evaluated. The two projections of the CE structure were segmented by edge detection and linking based on the high structure-to-background contrast. Since the first projection has the spatial information of the structure on X and Y axes, while the second projection on Y and Z axes, the projections on the two planes were matched along the common phase encoding direction. The extracted structure was then back-projected in a 3D space defined by the X, Y and Z axes.

Phantom Study: The DPI was tested for volumetric imaging of Gd filled vessel-mimicking tubing mounted on a stationary spherical and on a 3 degrees of freedom moving phantom. DPI was collected with a $TR/TE_1/TE_2/50^o$ = 5.47ms/1.65ms/3.59ms/50°; slice = 250mm FOV = 250x250mm^2; matrix=256x256. The 3D reconstruction was performed off-line using software developed in Matlab.

Results:

Figure 2 shows a DPI on the spherical phantom depicting the two projections and the reconstructed 3D structure together with the segmented one from a standard multislice set. The accurate matching of the reconstructed and the original object are clear, as well as the differential T2* signal reduction on the two projections. Figures 3 and 4 show reconstructed frames from the moving phantom. In fig. 3, the structure is accurately reconstructed. However, in fig. 4 the used simple back-projection results to "ghost" structures in the reconstructed image (Fig. 4B) when compared to the original (Fig. 4A). This is due to the vessel turning back along the Y axis. Depending on the shape of the structure, a possible solution is to change the orientation of the encoding and read-out axes relative to the structure. High CNR is critical for the operation of this simple segmentation and back-projection approach. By sharing the phase encoding axis, the two projections are acquired faster and the corresponding k-space lines of the two projections are as temporally matched as possible. This is in contrast to sequential collection of the two projections, which can result to their spatial mismatch.

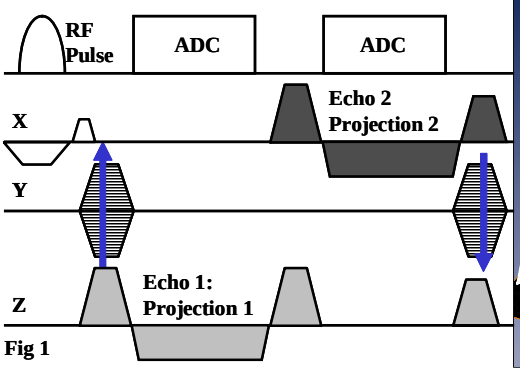
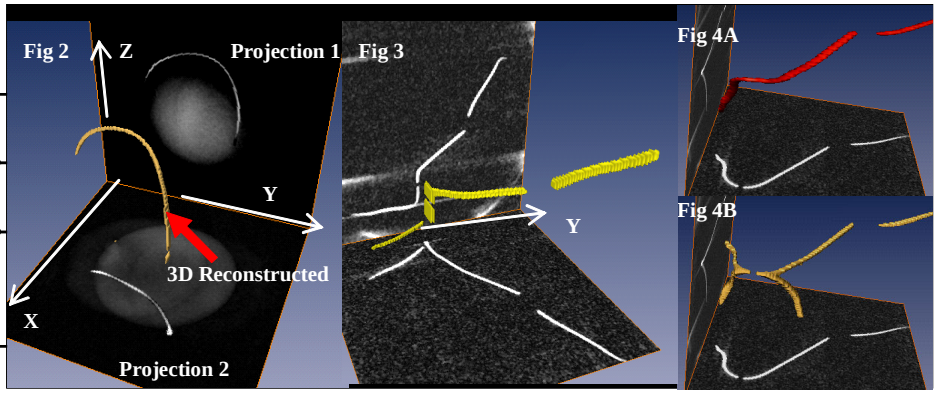


Fig 1



Conclusions

We propose fast volumetric imaging of contrast enhanced tubular structures with the simultaneous collection of two orthogonal projections. The DPI, providing spatial and temporal matching of the two projections, proved efficient in imaging moving vessel phantoms. It also accurately reconstructed the original 3D object as long as it had a non overlapping profile along the phase axis. DPI maybe applied for 3D catheter visualization and contrast enhanced vessels. Studies are underway to evaluate it for in vivo imaging.

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References:

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