MULTIPHASE 3D CARDIAC IMAGING WITH VASTLY UNDERSAMPLED ISOTROPIC PROJECTION IMAGING (VIPR) AND RETROSPECTIVE ECG GATING

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Abstract: Cardiac exams today require skilled localization to consecutively study different regions of the heart. Here we investigate the use of VIPR (V*astly Undersampled* I*sotropic* PR*ojection Imaging*), a 3D Projection Reconstruction (PR) technique, for 3D multiphase imaging of the entire heart. VIPR provides isotropic resolution over a spherical volume for data reformatting in arbitrary orientations without loss in spatial resolution and simplified scan prescription. The total scan time was reduced to a single breath-hold by angular undersampling. ECG gating was perfomed retrospectively off the recorded R-wave locations to adjust the number of reconstructed cardiac phases to the supported SNR.

Introduction: Angularly undersampled PR can reduce imaging time while preserving high spatial resolution [1]. Such undersampling results in a reduced SNR and streak artifacts or pseudo noise from objects of high signal intensity, which is tolerable in some applications with high SNR. Undersampled PR is particularly attractive for cardiac imaging because high spatial and temporal resolution are required. Barger et al. [2] introduced a method for 3D cardiac imaging which uses projections to encode the k_x-k_y plane and spin-warp for slice encoding. Here we report our initial results using a trajectory with projections in all three k-space dimensions for multi-phase imaging of the whole heart in a single breath-hold.

Materials and Methods: In VIPR every readout passes through the center of k-space [3]. Fig. 1(a) shows how the projections are aligned so that the endpoints lie evenly distributed on the surface of a sphere. Data are acquired as two half echoes during one readout for improved scan efficiency. Each left half of the echo samples an even projection. Once the center of k-space is acquired the amplitude of the gradient is changed so that the right half of the echo samples the adjacent odd projection [4]. The missing data are synthesized using a homodyne reconstruction technique. This method permits acquisition of twice as many projections in approximately the same scan time to reduce the artifact level.

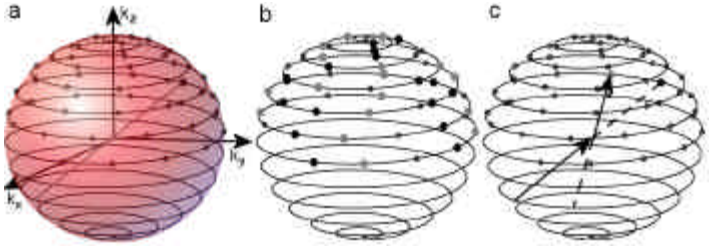

Fig. 1 *The endpoints of the projections lie on a sphere (a). They are sampled in an interleaved fashion (black, grey and white circles) (b). Two half echoes (solid lines) are sampled in one readout and missing data (dashed lines) are synthesized (c).*

The sequence was implemented on a 1.5 T GE CVi scanner (GE Medical Systems, Waukesha, WI) with peak gradient amplitudes of 40 mT/m and a maximum slew rate of 150 mT/m/ms. Three healthy human volunteers and one patient were imaged in True-FISP (fast imaging with steady precession) mode using a cardiac phased array coil after giving informed consent. Data were also acquired with a SPGR (spoiled gradient echo) sequence during the intravenous injection of Gadodiamide (Omniscan, Amersham Health, Inc.) with a dose of 0.3 mmol/kg body weight and an injection rate of 1.0-1.5 ml/s. A total of 15,000 projections (30,000 half echoes) with a readout length of N_r = 128 samples were acquired in 20 interleaves over a spherical volume with a diameter of 40 cm. Other imaging parameters included: TR/TE = 3.1/1.2 ms, flip angle = 25° (SPGR) and 45° (True FISP), bandwidth = 62.5 kHz, and scan time = 46 s. ECG gating was performed retrospectively as the location of the R-waves in respect to the projections were recorded. Images were reconstructed for 7-10 cardiac phases without view sharing on an offline workstation using a regridding algorithm.

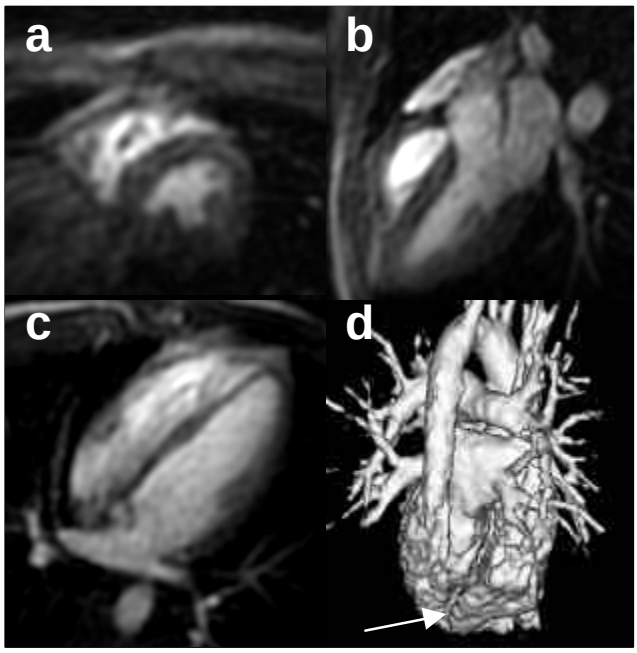

Fig. 2 *Reformatted SPGR images: short axis (a) and vertical long axis (b) views during systole and four chamber (c) and volume rendered (d) views during diastole. Note the good separation of the ventricles in the volume rendered image (arrow).*

Results: Reformatted images from one volunteer study are shown in Fig. 2 for systole and diastole. Since the acquired resolution is isotropic, any desired reformatting plane can be selected after scan completion without loss in spatial resolution. Fat tissue close to the surface coils was of high signal in the True FISP images and contributed significant undersampling artifacts (not shown).

Conclusions: In this preliminary work we have demonstrated our initial results with a novel technique for 3D, multiphase, single breath-hold cardiac MR which provides isotropic resolution over the entire heart. These properties result in a simplified scan presciption without the need for double oblique scan planes. Compared to 2D techniques with better in-plane resolution, VIPR does not compromise the through-plane resolution, which might be benefitial for post-processing tasks such as volume measurements. Retrospective ECG gating allows for the adjustment of the temporal resolution depending on the supported SNR after scan completion. We are currently investigating fat suppression and techniques such as UNFOLD [5] for radial sampling to address the undersampling artifacts for the True-FISP sequence. We are also developing methods to acquire data from an ellipsoidal FOV with isotropic resolution for improved efficiency. In addition, each projection provides information that can be used as a 'built-in' navigator for motion correction [6]. Potentially, data can be acquired during free breathing to extend imaging time. The additional projections could reduce undersampling artifacts or improve the temporal resolution

References:

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