Reducing the Scan Time of Time-Resolved, 3D Phase Contrast Imaging with 2D Autocalibrated Parallel Imaging

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INTRODUCTION

Time-resolved 3-dimensional phase-contrast MR imaging (3D-PC MRI) has developed as an active area of research for vascular imaging [1]. The ability to acquired directional flow information along all three principle axes has led to investigations of the role of altered hemodynamics in vascular pathologies[2], quantification of flow in the major intracranical vessels [3], and research into the feasibility of using this technique to generate wall shear stress (WSS) measurements [4]. While 3D-PC MRI shows potential in a wide range of applications, in general the clinical adoption of this approach for routine vascular imaging has been hampered by the long acquisition times inherent in the technique. Several groups have addressed this issue by using parallel imaging to accelerate data acquisition in one dimension [3,4]. In this work we demonstrate the ability to perform auto-calibrated parallel imaging in both the in-plane and slice directions to significantly reduce the overall scan time.

MATERIALS AND METHODS:

All imaging was done at 1.5T using Signa scanners (GE Healthcare, Milwaukee, WI, USA). The sequence used for the time-resolved flow measurements was a 3D spoiled gradient-recalled echo (SPGR) phase contrast sequence modified to collect k-space data suitable for an auto-calibrated parallel imaging reconstruction. A typical imaging protocol involved imaging in the axial plane with an eight channel cardiac coil (GE Healthcare, Milwaukee, WI, USA). Coverage was provided with 72, 2mm thick slices, and zero-filling was used in the reconstruction to produce 144 final images per cardiac phase. The in-plane field-of-view (FOV) was 22 cm with a matrix of 256 points in the readout direction and 192 phase encodes. A fractional echo was used to reduce the echo time (TE), and the typical repetition time (TR) and TE were 5.0 ms and 1.9 ms, respectively. In each R-R interval four pairs of (ky,kz) phase encodes were repeatedly acquired. For each (ky,kz) pair four sequential TRs were acquired with different flow sensitivities, and as a result the intrinsic temporal resolution of the data was 4*4*TR, or 80ms. Gadolinium contrast had been given for a prior scan and thus was present during the exam. After the completion of the study the data were retrospectively interpolated into 20 cardiac phases distributed equally across the R-R interval.

Parallel imaging was performed in the phase and slice direction using an outer reduction factor of 2×2. In addition, the corners of (ky,kz) space were not acquired. To provide autocalibration data for the reconstruction, a region of 24×20 central phase encodes in the ky×kz direction was fully sampled. This prescription reduces the total number of (ky,kz) pairs necessary for a complete study from 9648 (this reflects the use of a fractional phase FOV of 0.7) to 2208. Had parallel imaging only been used in the in-plane direction, this number would have been 3936. Because four (ky,kz) phase encode pairs were acquired in each R-R interval, 552 heart beats were required to complete the scan. After the accelerated data were interpolated into the different temporal phases, unaliasing was performed using the Autocalibrating Reconstruction for Cartesian sampling (ARC) method [5] using a 3-dimensional reconstruction kernel. Time efficient reconstruction was made possible by incorporating the ARC algorithm directly into the off-line reconstruction code.

RESULTS

Figure 1 shows representative images from the above protocol used in a clinical examination of a 7 year old female with repaired tetralogy of Fallot. The high resolution and wide anatomic coverage permits comprehensive multiplanar reformations.

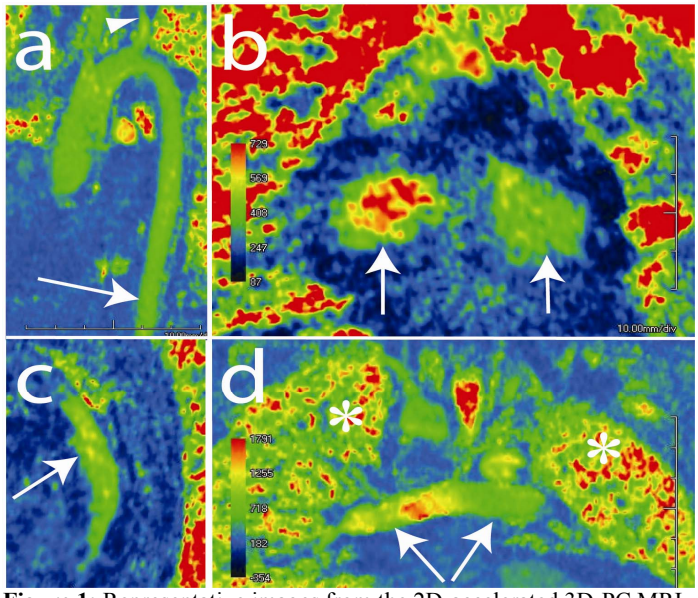

Figure 1: Representative images from the 2D-accelerated 3D-PC MRI study. a) systolic aortic flow from an oblique sagittal view shows extensive coverage from arch vessels (arrowhead) to distal thoracic aorta (arrow). b) magnified short-axis view of diastolic flow through the atrioventricular valves (arrows) shows high resolution. c) Regurgitant pulmonic flow (arrow) from an oblique sagittal view, and d) systolic flow in the branch pulmonary arteries (arrows) from an oblique coronal view. Note extensive anatomic coverage as evidenced by lungs (*).

CONCLUSION

Time-resolved 3D-PC MRI has shown great research potential in a wide variety of areas, and yet its clinical adoption has been slow due to the lengthy acquisition times. We have shown that using parallel imaging in both phase encode directions reduces the scan time in a typical exam by approximately 77% (compared to 59% with 1D acceleration alone). This reduction can be used to improve patient compliance without sacrificing the coverage needed for a comprehensive vascular imaging protocol.

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