Image Quality Improvements in Whole Body MRA of the Aorta by Employing Accelerated, Non-Contrast Enhanced, Cardiac Gated 3D SSFP

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Purpose

MR angiography (MRA) of the large vessels is a common cardiovascular MR application in a routine clinical setting. The conventional first pass approach is based on contrast enhancement due to the application of contrast media (1). The comparatively short time intervals associated with contrast agents passage require rapid imaging techniques for continuous bolus tracking or appropriate timing for bolus chasing. Common clinical concerns raised by the traditional approach are the (i) dependence on contrast agents and (ii) image artifacts associated with cardiac and vessel motion. A non-accelerated 2D gated SSFP evaluation has shown efficacy for dissection and aneurysm of the thoracic aorta (2) , but does not have the reformatting versatility of a 3D sequence. This study examines the clinical feasibility of cardiac gated, breath-hold MRA of the aorta using a non-contrast enhanced, flow independent 3D steady state free precession (SSFP) technique. For this purpose an ECG gated 3D FIESTA technique was implemented. Sensitivity encoded parallel imaging was applied to overcome scan time constraints. Novel multi-channel coil arrays were employed in order to achieve whole body coverage from the aortic arch down to the bifurcation without the need to reposition the coil or the patient.

Methods

Volunteer studies (N=8) were conducted on a 1.5 T TwinSpeed system (GE Medical Systems, Waukesha, WI, USA). A 10-element phased array coil (GORE, Newark, DL, USA) and a torso-pelvic phased array coil prototype comprised of 12 elements were used for large FOV coverage. For parallel imaging coil sensitivity maps were determined using a gradient echo sequence. A prospectively ECG-gated 3D SSFP (FIESTA) sequence was developed. Fat saturation was used for background suppression and to enhance the dynamic range. For parallel imaging a net acceleration factor=2 was applied. An in-plane FOV of (48x48) cm^2 was used to cover a region enclosing the aortic arch and the bifurcation. A 3D multi-oblique volume consisting of 40 slice partitions was prescribed. For each slice partition data acquisition was completed in a single heartbeat leading to a breath-hold duration, which is clinically acceptable. The data acquisition window was placed into the mid-diastolic cardiac rest period to minimize the impact of cardiac and aortic motion. No contrast media were administered when using the 3D-FIESTA sequence. For comparison a conventional contrast enhanced 3D gradient echo sequence (c=0.2 mmol/kg body weight) was applied. Surface coil intensity correction was performed.

Results

The S-I coverage of both coils facilitated the acquisition of large FOV images of the aorta using both the conventional contrast enhanced approach and the new fat saturated, ECG-gated 3DFIESTA sequence. The intrinsic contrast and flow independent characteristics of the 3D SSFP technique yielded angiograms of the aorta with high spatial resolution as illustrated in Fig. 1 b. For comparison Fig. 1a depicts the MRA derived from a contrast enhanced gradient echo acquisition exhibiting cardiac motion artifacts which manifest itself as ghosting in the maximum intensity projection (Fig. 1a) and the volume rendered view (Fig. 1d). Cardiac and aortic motion related image artifacts, which can occur in the contrast enhanced non-gated gradient echo images (Fig. 1a) are suppressed in the accelerated, cardiac gated 3DFIESTA images as demonstrated in Fig. 1b,d. While a dependence on appropriate timing of contrast delivery is eliminated, the 3D SSFP technique yields non-selective bright-blood images.

Conclusions

The feasibility of breath-hold, non-contrast, whole body MRA of the aorta using a 3D SSFP technique has been proven in a volunteer study. Motion artefacts are substantially reduced via cardiac gating without exceeding scan time requirements for breath-hold acquisitions. The 3D SSFP preserves versatile reconstruction options while eliminating a reliance on contrast media. The latter has practical, economic and safety implications. In summary, the initial results indicate that 3D FIESTA may provide benefits for clinical whole body aortic MRA applications. We anticipate extending the applications development to patient studies for the detection of aortic pathologies.

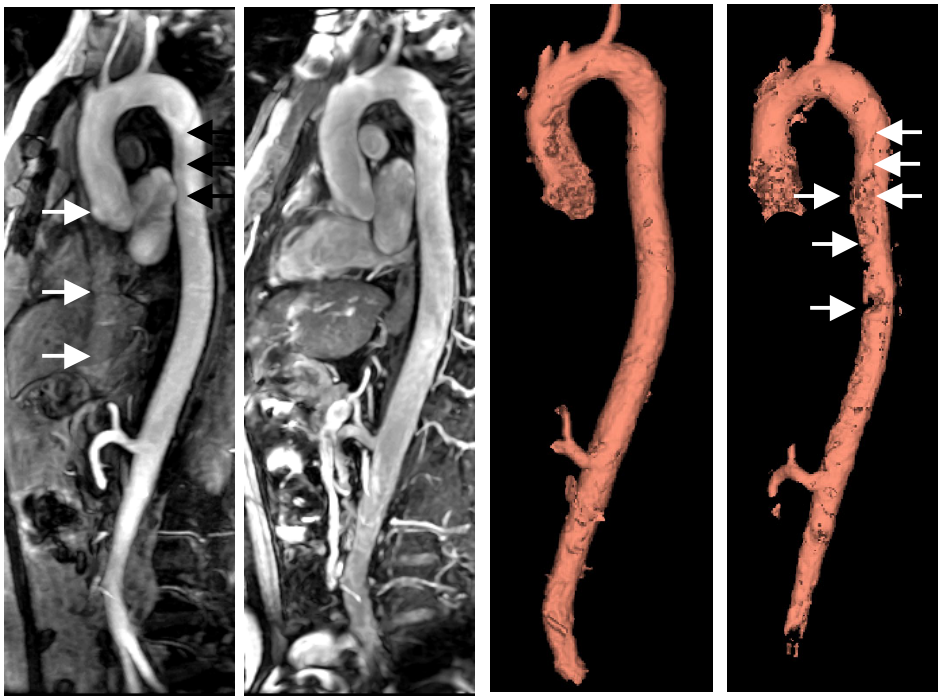

Fig. 1: MR angiograms (a,b: maximum intensity projection, c,d: volume rendering) of the aorta covering an 48 cm FOV along the superior-inferior direction. A standard contrast enhanced gradient echo technique revealed cardiac and aortic motion artefacts as highlighted by the arrows in the MIP image (a) and the volume rendered view (d). These artefacts were eliminated by using an ECG-gated, non-contrast enhanced 3DFIESTA sequence as demonstrated in the MIP image (b) and the volume rendered view (c) derived from the 3DFIESTA data set.

References:
1) Prince M.R. et. al, J. Magn. Reson. Imag. 3, 877-881 (1993)
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