3D TOF Angiography using Real Time Optical Motion Correction with a geometric encoded marker

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INTRODUCTION: Correction of motion artifacts is an ongoing challenge in MRI. Sadly, motion is often worst in patients that are acutely ill and in which time cannot be afforded to repeat failed exams. This is the case, for example, in patients suffering from acute ischemic stroke or intracranial hemorrhages. In these patients 3D Time of Flight (TOF) angiograms are often performed, but their image quality is often technically borderline or even inadequate due to profound patient motion. This, in turn, makes it often difficult to assess vessel occlusion or recanalization with sufficient confidence. Another group of patients in which TOF MRAs often fail are children. To mitigate motion artifacts different retrospective and prospective approaches have been suggested, thus far. However, these approaches rely frequently on the need to acquire extra MR navigator data, which can substantially increase sequence TR or require ample time before/after the contrast preparation period/readout segment to accommodate these navigators. This is particularly challenging for short-TR SPGR sequences that are typically used for TOF MRAs. Here, a radically different approach is proposed in which external pose information is used which allows one to keep the short-TR features of the TOF intact. Specifically, first *in-vivo* results of a study will be presented that uses a prospective motion-correction approach which adapts scan geometry to patient pose changes in real-time and which extract these pose data from an MR-compatible optical motion correction system [1,2].

MATERIALS & METHODS: A MR-compatible mono-vision camera system mounted on an 8-channel receive-only head coil and was combined with a 2D geometric marker, which was placed on the subject's forehead to allow tracking of head motion. The external tracking processor was running a motion detection software developed in-house, which analyzed the camera's video stream and fed the updated pose data over a high-bandwidth network connection back to the scanner's sequencer at an update rate of ~30Hz. This allows one to adjusts in quasi-real time the prescribed TOF slab with a latency of ~50msec between the detection of pose change and adaption played out on the scanner. To register the frame of reference of the optical arrangement with that of the MR scanner, a 30sec semi-automatic cross-calibration was performed (*3D SPGR, α=25°, FOV=12cm, 256x256x44, NEX=2, TR/TE=5.2/1.8msec)* using a calibration phantom at the beginning of the study. • <u>TOF Pulse Sequence</u>: An axial 3D spoiled gradient echo sequence (SPGR) (*α=30°, FOV=24cm, 192x192x56, TR/TE=33.8/6.8msec, 1.4mm slice thickness*) with magnetization transfer (MT)-based tissue suppression (α=930°, 0.25 duty cycle) and a positive ramped RF excitation (TONE) pulse with support for aforementioned adaptive motion-correction was implemented on a 1.5T GE Signa Excite unit (GE Healthcare). • <u>*Experiment*</u>*:* A healthy volunteer (male, 28y) underwent three consecutive scans each consisting of a single 7.7cm 3D slab that covers the Circle of Willis whereby for each acquisition instructions were given to perform a specific motion pattern: **(a)** to remain still, **(b, c)** to perform head motion as much as permitted by the coil. Instructions to change position were given via intercom to assure reproducibility between both experiments. Motion was tracked for all 3 experiments to assure that the motion of the two motion experiments were of comparable extent.

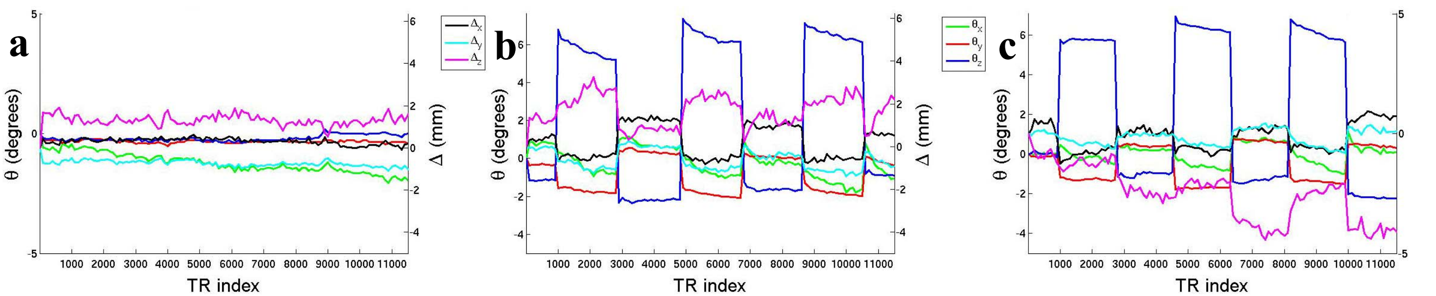

Figure 1 - The motion patterns for the experiments, which were recorded for each acquisition and used for the real-time the motion correction. As requested the volunteer tried to perform either no motion (a) or a specific instructed motion pattern (b & c). The motion pattern (c) was used to correct for the head movements and resulted in Figure 2, whereby the motion pattern (b) was tracked to ensure similar movements in the motion corrected vs. uncorrected motion case.

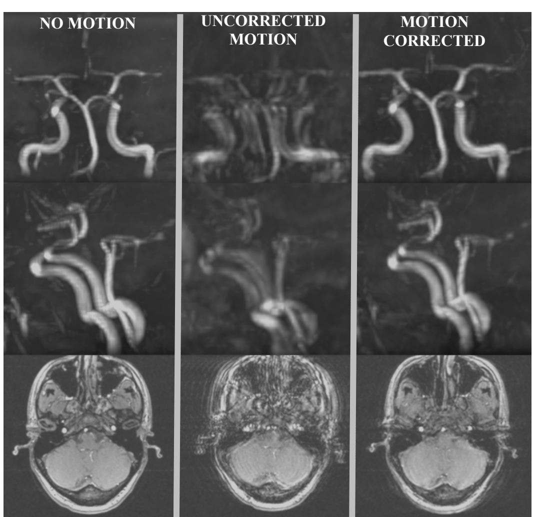

Figure 2: 3D TOF cut-out MIP's of the Circle of Willis (top & middle row) and the corresponding axial raw images (bottom row) reconstructed without (middle column) and with (right column) real time motion correction. The reference image (left column) was obtained in the absence of motion and without motion correction. The artifacts are evident when the motion correction is not applied (middle column). With real-time motion-correction active one can significantly reduce motion-induced artifacts.

RESULTS: Figure 1 shows the pose changes (i.e. 3 translation, 3 rotation) over time for all 3 motion experiments. Of note is that even for the case of 'no motion', the subject was not completely still. Translational motion of up to 1.98mm and 1.7° were observed. As expected, the motion parameters recorded for both motion experiments where in sufficient agreement with each other and should allow a fair comparison between both motion experiments. Figure 2 shows the TOF raw data and maximum-intensity-projections (MIP) that correspond to the 3 experiments. Clearly, both raw images and cut-out MIPs were best on the 'no motion' case, whilst the 'uncorrected motion' correction was deemed technically inadequate and without any diagnostic quality. With the prospective motion correction active even for such a severe case of motion both the raw images and corresponding MIPs were of excellent diagnostic quality. When compared to the 'no motion' case, the image appeared slightly blurrier but even distal branches of the anterior and posterior circulation could be well delineated on the motion-corrected scans, which is seen best on the corresponding MIPs.

DISCUSSION: The preliminary results from this study on adaptive motion-correction of 3D TOF MRA scans indicate that the proposed system is very effective in correcting motion-induced artifacts. The optical tracking can detect pose changes at a very high frame rate and with great precision and accuracy. This is ideally suited for short-TR applications, such TOF MRA, and bears great potential to compensate even large-degree motion in very uncooperative patients. Further improvements in angiographic quality can be anticipated when to this research MRA sequence features, such as multi slab, parallel imaging, and flow compensation is added.

References: [1] M Aksoy et al., Proceedings of the 16th Annual Meeting of ISMRM 2008, [2] M Aksoy et al, Proceedings of the 17th Annual Meeting of ISMRM, 2009.

Acknowledgements This work was supported in part by the NIH (1R01EB008706, 1R01 EB008706S1, 5R01EB002711, 1R01EB006526, 1R21EB006860), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation and Oak Foundation.