Simultaneous Stereoscopic 3D-Visualization of Vascular Structures and a Passive Catheter in Real Time

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PURPOSE: Conventional 2D-X-ray fluoroscopy or DSA only provide projection images of the vessels during intravascular catheter interventions, and expose both patient and interventionalist to ionizing radiation. To enable MR-guided intravascular procedures, in this work, an acquisition and display concept for stereoscopic images is presented that acquires fast projections images at different stereo angles. These images are displayed on a modified 3D monitor to visualize vascular structures and a passive catheter in 3D in real-time.

MATERIALS AND METHODS:
Stereoscopic sequence: For real-time acquisition of a stereo image pair, a stereoscopic double echo (DE) FLASH sequence with view angle tilting between the first (left view) and the second (right view) echo acquisition [1] was implemented on a clinical 1.5 T MR-system (Siemens Magnetom Symphony, Siemens, Erlangen, Germany). To improve the temporal resolution, parallel imaging, line sharing, partial Fourier, and asymmetric echo acquisition were employed. Dephasing along the slice excitation was applied to improve the vessel-to-background contrast.
Real time stereo image display. Stereo images were displayed in real time on a shielded MR-compatible 3D LCD polarization monitor (ZM-M215W, Zalman, Garden Grove, CA, USA). Therefore, images were line-interleaved on a separate workstation for 3D-visualization on the polarization display close to the magnet (Fig. 1) [2].
Flow phantom experiment. An aorta phantom (Fig. 2 A) was connected to a peristaltic pump (water flow of about 12.5 ml/s). For passive catheter tracking, an approximately 9 F tube was inserted into the phantom and flushed with a contrast agent (CA) solution (500 mM Gd-DTPA:H_2O = 1:20). Stereo image pairs ($TR/TE_1/TE_2$ = 5.0/1.4/2.6 ms; α = 30°; FOV = 320×320 mm²; matrix = 204×256; slice thickness = 40 mm; BW = 1030 Hz/px; stereo angle = 12°, partial Fourier factor = 6/8; GRAPPA-factor = 2 with 35 reference lines; 75% asymmetric echo; 2/3 line sharing) of the phantom were acquired continuously during several injections of a 5 ml-bolus of CA solution while the CA-flushed tube was moved inside the phantom. The SNR in the stereo image pairs of both, the CA-flushed tube tracking as well as the CA solution injection were calculated. To access the spatial precision of the tube tip 3D-visualization, the left and the right view of a selected stereo image pair showing the tube was overlaid with a MIP of a high resolution dataset (3D-FLASH). In the combined image, the distance between the individual tip positions was analyzed.

RESULTS AND DISCUSSION: Stereo image pairs of the CA injection (Fig. 3) and the movement of the CA-flushed tube (Fig. 4) were acquired with the same parameters, which lead to an image update rate of 2.7 Hz at a resolution of 1.6×1.3 mm². The SNR of the stereo images showing the CA injection and thus, the vascular 3D-structure of the phantom amounted to 4.8/3.8 for the left/right view. This 20% SNR difference is tolerable for 3D depth perception [3] and typical for the stereoscopic DE-FLASH sequence [1]. It is caused by the T2*-weighting between the first (left view) and the second (right view) echo acquisition and is further increase due to flow turbulences during CA injection. In comparison, the SNR of the stereo image pairs of the passive tube tracking was found to be 3.1/2.8 for the left/right view (10% difference), respectively (data not shown). Altogether, the SNR of ≥ 3 was sufficient in the binary contrast stereo image pairs to delineate the 3D-structure of the tube as well as of the vascular structure in real time with the MR-compatible 3D-monitor. The tube tip in the projected high resolution image was found to be exactly between the tube tip image of the left and the right view (Fig. 2 B), which is expected from the view angle tiling. In the future, the SNR difference could be reduced prior to stereo image display by means of image processing to enhance 3D depth perception.

CONCLUSION: We successfully demonstrated the feasibility of real time 3D-visualization of both vessel structures and a passive catheter to provide 3D-information during MR-guided intravascular interventions.

REFERENCES: [1] Brunner A, et al., *Magn. Reson. Mater. Phy.* (2012) [2] Brunner A, et al., *Proc. IMRI* (2012) [3] Julesz B,et al., *Science* (1964)

This work was supported by the DFG under grant no. Bo 3025/2-1.

Fig. 1: Setup of the aorta flow phantom experiment. The MR-compatible 3D-monitor with the polarization goggles was operated near the magnet's bore.

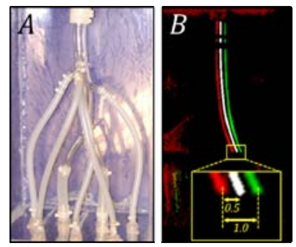

Fig. 2: A) Aorta phantom. B) Overlay of the left (red) and the right (green) view of a selected stereo image with a projected high resolution image to compare the tube tip positions.

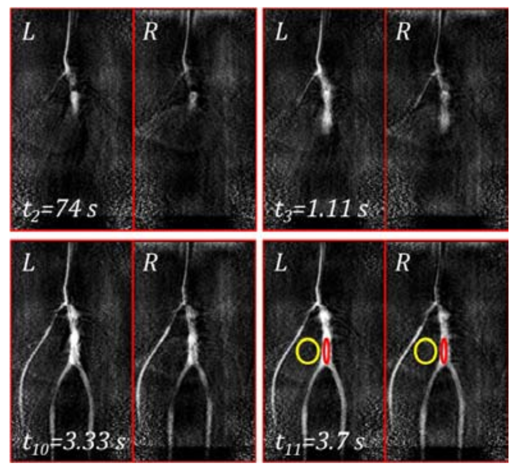

Fig. 3: Selected stereo image pairs of the CA injection into the phantom. Note the time t_i after injection. SNR-ROIs: signal (red), noise (yellow). L/R = left/right view.

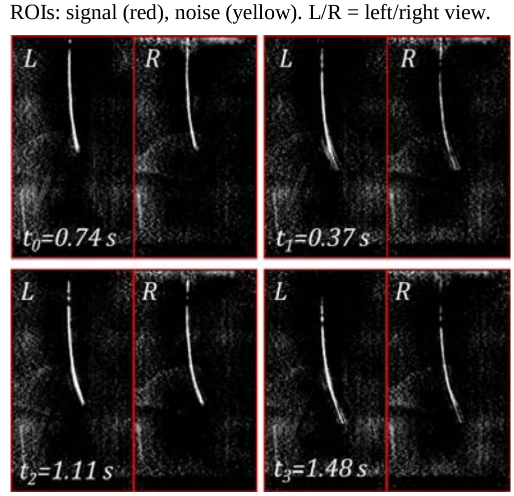

Fig. 4: Consecutive stereo image pairs showing the movement of the CA-flushed tube inside the phantom with an update rate of 2.7 Hz (c.f. Fig. 2A and 3).