Clinical Performance of a Spatiotemporally Accelerated Motion-corrected Pediatric 3D Free-breathing Time-resolved Contrast-enhanced MR Angiography

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Purpose: Contrast-enhanced MR Angiography (CE-MRA) is ideal for pediatric abdominal vascular imaging due to the lack of ionizing radiation. However, pediatric CE-MRA is usually limited by motion and compromised spatiotemporal resolution. General anesthesia (GA) with periods of suspended respiration is often necessary, and in many practices, CT is utilized instead. Recently, a fast free-breathing time-resolved CE-MRA method has been developed [2] with the potential to significantly reduce the depth of GA without compromising image quality. In this work, we aim to determine the reliability of this method to depict various abdominal vessels with adequate diagnostic image quality for pediatric abdominal MRA.

Methods: *Patient recruitment & image acquisition*: With IRB approval we retrospectively identified 27 consecutive pediatric patients (16 males and 11 females; mean age 3.8 yrs, range 14 days to 8.4 yrs) referred for CE-MRA at our institution from November 2013 to January 2014, who had undergone the following image acquisition on a 3T GE MR750 scanner with a commercially available 32-channel cardiac or torso coil: a multi-phase 3D self-navigating SPGR sequence with fat suppression and variable density radial view ordering sampling pattern [3] were used during the contrast injection. The acquisition parameters were: TE 1.2-1.4 ms, TR 3.0-3.4 ms, bandwidth 100 kHz, slice thickness 1.0-2.4 mm, and S/I FOV 26-38 cm. The average acquisition time for each temporal phase was 8.5 s (range: 5.5-14.1 s). All imaging was performed completely free-breathing. Single dose contrast diluted to 10 mL was power injected at 1 mL/sec. *Image reconstruction*: a soft-gated locally low-rank parallel imaging method was performed to reconstruct highly accelerated free-breathing datasets [2]. *Image evaluation*: two cardiovascular radiologists who were blinded to patient history/diagnoses independently assessed the reconstructions. The overall image quality of thirteen abdominal arteries were assessed on a five point scale with pre-set criteria for the following structures: celiac artery (CA); left gastric artery (LGA); common, proper and right hepatic arteries (CHA, PHA, RHA); splenic artery (SA); right phrenic artery (RPA); superior and inferior mesenteric arteries (SMA, IMA); renal artery (RA); right common, internal and external iliac arteries (RCIA, RIIA, REIA). 95% confidence intervals of the proportion of diagnostically adequate cases (score ≥ 3) were calculated using Wilson score method with continuity correction. Inter-observer agreements between the two readers were analyzed using weighted kappa coefficients (almost perfect 0.8-1; substantial 0.6-0.8; 0.4-0.6 moderate; fair 0.2-0.4; slight 0-0.2; poor <0).

Results: Depending on the level of GA administered, different respiratory support was applied for the recruited patients: 8 endotracheal tube (ETT), 7 laryngeal mask (LMA), 10 nasal cannula (NC), and 2 none (awake). The results of the image evaluation are shown in Fig. 1. The mean scores are shown on top of the bar graphs. Except LGA and RPA, the mean scores of the other arteries were above diagnostic criteria. The proportions of diagnostic cases, 95% confidence intervals of the proportions, and inter-observer agreements are shown in Tab. 1. For most evaluated arteries, the two readers achieved fair to substantial agreement. Representative images of a 4yr patient are shown in Fig. 2. High spatiotemporal resolution is evidenced by the sharp delineation of up to the second order branches of hepatic arteries and the contrast dynamics captured in the image series.

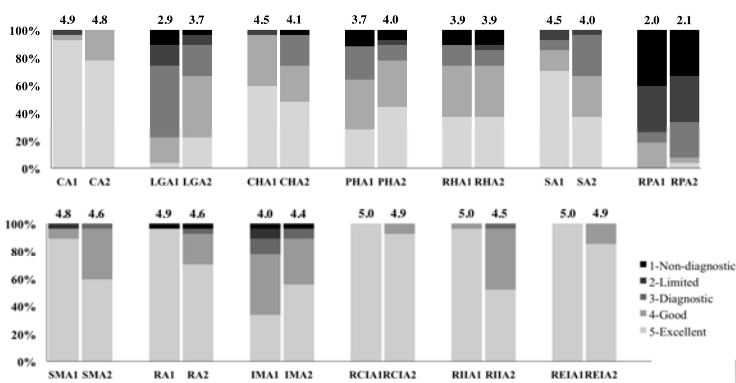

Fig. 1. Evaluation results for all arteries with mean scores on top of the bar graphs for two readers. All structures except LGA and RPA were diagnostic.

Anatomic Structure	Diagnostic Proportion and 95% Confidence Interval (%)		Inter-observer Agreement
	Reader 1	Reader 2	
CA	96, 79-100	100, 85-100	Fair
LGA	74, 54-90	89, 70-100	Fair
CHA	96, 79-100	96, 79-100	Moderate
PHA	81, 61-95	89, 70-100	Moderate
RHA	89, 70-100	85, 65-97	Substantial
SA	92, 74-100	96, 79-100	Moderate
RPA	26, 12-47	33, 17-54	Substantial
SMA	96, 79-100	100, 85-100	Slight
RA	96, 79-100	96, 79-100	Substantial
IMA	89, 70-100	96, 79-100	Fair
RCIA	100, 85-100	100, 85-100	Poor
RIIA	100, 85-100	100, 85-100	Poor
REIA	100, 85-100	100, 85-100	Poor

Tab. 1. 95% confidence interval for proportion of cases with diagnostically acceptable depiction of each artery and inter-observer agreement.

Discussion: One subject in this study had metallic foreign bodies, which created an imaging artifact that limited the delineation of most arteries. The poor inter-observer agreement of RCIA, RIIA and REIA was because reader 1 gave the highest score 5 to almost all cases (with probability 1), which yielded low kappa coefficients. The average image quality of RPA and LGA was limited due to their small size and susceptibility to residual respiratory motion artifacts.

Conclusion: Pediatric spatiotemporally accelerated motion-corrected 3D free-breathing time-resolved CE-MRA is highly likely to yield diagnostic image quality for most abdominal vessels.

References: [1]. T Grist, et al. Pediatr Radiol 2005; 35: 26-39. [2] T Zhang, et al. J Magn Reson Imaging 2014. DOI: 10.1002/jmri.24551. [3] J Cheng, et al. J Magn Reson Imaging 2014. DOI: 10.1002/jmri.24785.

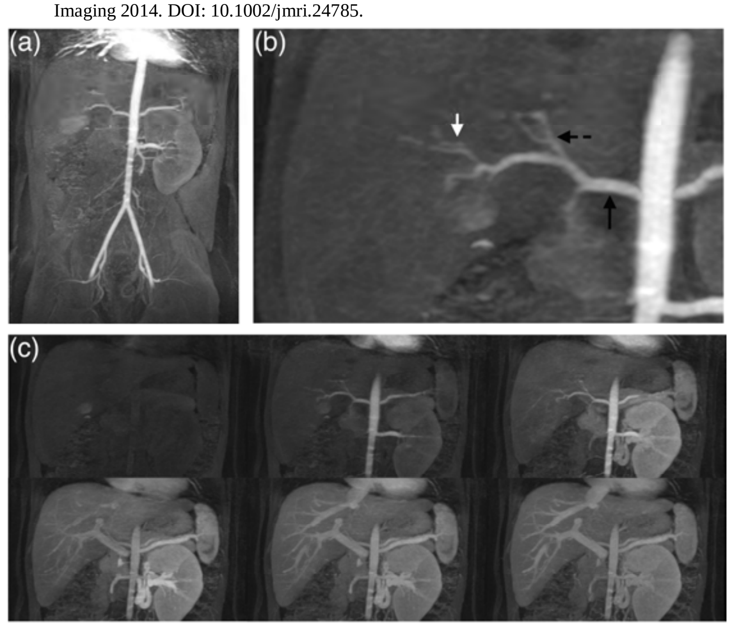

Fig. 2. Representative MRA of a 4-year-old patient. (a) An arterial phase MIP image; (b) cropped and zoomed MIP image; high spatial resolution is evidenced by the sharp delineation of the branches of hepatic arteries (arrows); (c) pre-contrast and five sequential phases after contrast injection, reflecting high temporal resolution.