Fast Aortic Input Function Extraction at High Temporal Resolution for DCE-MRI

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Purpose: Many pharmacokinetic models used in DCE-MRI require a subject-based aortic input function (AIF) typically obtained from the reconstructed MR images that are used for diagnosis. Accurate measurement of AIF may require at least 1s temporal resolution[1], which would compromise image spatial resolution. A recently developed low-rank reconstruction method based on the variable density view ordering and sampling (VDRad) strategy[2] allows data to be reconstructed at different temporal resolutions but at the cost of increased reconstruction times. Here, we present a faster method for extracting high temporal resolution (HTR) AIFs from DCE-MRI data and compare it to the low-rank reconstruction method.

Methods: DCE-MRI datasets were acquired using the VDRad method, which is a 3D Cartesian sampling strategy that samples the central k-space with increased density and frequency. The clinical images were reconstructed using a low-rank reconstruction method to achieve diagnostic image quality[3]. The high temporal resolution AIFs (HTR-AIFs) were reconstructed using the method outlined in Fig 1. First the data was binned into smaller temporal frames (Fig 1a), to provide even better temporal resolution. However, the resulting k-space has a densely sampled central region and a sparsely sampled outer region. This causes image blurring similar to only sampling the central k-space. Blurring in the image domain also distorts the measured AIF by "mixing" it with the surrounding tissue signal. In order to correct this distortion, the k-space was split into 2 complementary regions (Fig 1b). Images were reconstructed for each region individually (Fig 1c) and the average signal within the aortic ROI was calculated. Here, the low pass (LP) region causes **constructive** interference between the aorta and the surrounding tissue, and the high pass (HP) region causes **destructive** interference, just like an edge detector kernel. The signals were normalized to compensate for the sampling pattern differences. The signals were scaled after removing the baseline to match the start and end points (Fig 1d). The LP and HP signals were mixed with a proportionality constant α to get the final HTR-AIF estimate (Fig 1e). Since the tail of the AIF changes slowly, measurements in this section are not affected by large temporal footprint. We used a low temporal resolution view-shared reconstruction to get a reference signal (i.e. ground truth) for the tail section and used it to find the correct proportionality constant α.

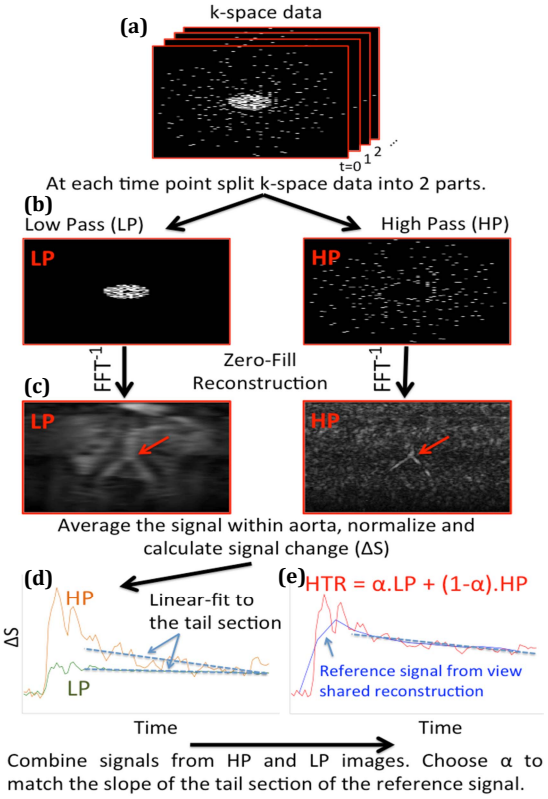

Fig. 1. *HTR-AIF method outline.*

Experiments: Pediatric subjects were scanned on a GE 3T scanner using a 32-channel torso coil. VDRad parameters: 15º flip angle, ±100kHz bandwidth, TR = 3.3ms, matrix = 192x180, FOV = 320x256 mm, slice thickness = 2.4 mm, 80 slices, and 6.2x acceleration. Injection protocol: single dose contrast diluted to 10ml was power injected at a rate of 1ml/s. The dataset was reconstructed using both the HTR-AIF method and the low-rank method at temporal resolutions of 1.25s, 3s, and 6s. The reconstructions were performed and timed on a 2.6GHz 8-core machine. The HTR-AIF method was also validated using digital phantom simulations as described previously[4].

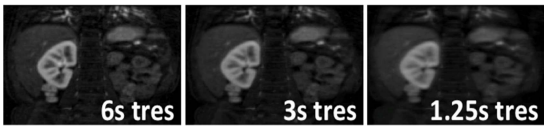

Fig. 2. Images reconstructed by low-rank method.

Results/Discussion: Low-rank reconstruction results at different temporal resolutions are shown in Fig 2. As the temporal resolution improves, the spatial resolution decreases and images get blurry. The signal change curves calculated from the reconstructed images are shown in Fig 3 along with the HTR-AIF estimates at the same temporal resolution. As the temporal resolution increases, the two signals start to differ in peak height but the overall shape looks similar. At 6s temporal resolution the AIF has only 1 main peak. However at 3s and 1.25s temporal resolutions the peak of the second pass also becomes visible, as expected for fast contrast injection rates. For quantitative analysis, 3s resolution is a reasonable choice considering that there is not much difference between 3s and 1.25s curves. Generating 6s, 3s, and 1.25s AIF curves with low-rank took 30min, 1hr and 2.5hr respectively. The HTR-AIF estimates for the same temporal resolutions took 1.5min, 2.5min, and 5min. The HTR-AIF method validation results are shown in Fig 4. HTR-AIF method overestimated the peak value by 1.6%.

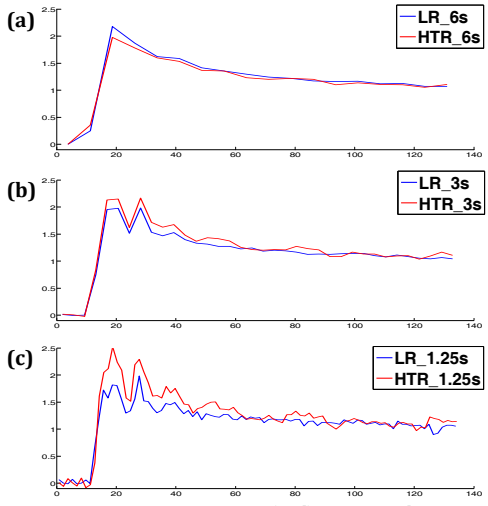

Fig. 3. HTR-AIF estimates (red) compared to AIF estimates from low-rank images (blue) at (a) 6s, (b) 3s, and (c) 1.25s temporal resolutions.

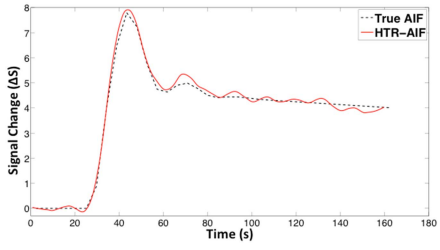

Fig. 4. Simulation results: 1.5s HTR-AIF (red) vs. ground truth (black)

Conclusion: We have presented a fast method for computing high temporal resolution AIFs and demonstrated its feasibility on pediatric subjects. The method was similar in signal quality to low rank reconstruction but was 25 times faster.

References: [1]E. Henderson et al. Magnetic resonance imaging, vol. 16, no. 9, pp. 1057–1073, 1998. [2] Cheng JY et al. Proc ISMRM Workshop on Data Sampling and Image Recon., Sedona, AZ; 2013. [3]T. Zhang et al. Journal of Magnetic Resonance Imaging, Dec. 2013. [4]U. Yoruk et al. ISMRM 22nd Annual Meeting, p0412, 2014