Post processing correction of ghosting artefacts in arterial input function determination for fast Dynamic Contrast Enhanced MRI

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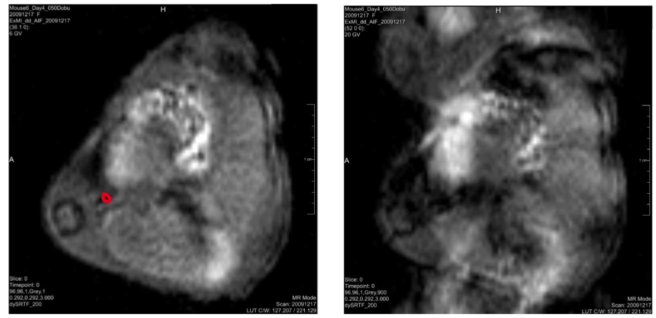

Fig. 1: Example for a correctly aquired frame (left) and a frame affected by ghosting. Shown is an axial slice of a mouse placed between heart and kidneys. The red circle marcs the ROI used to measure the AIF.

Introduction: Dynamic Contrast Enhanced (DCE) -MRI is an important tool for monitoring and evaluating therapeutic effects in anti-angiogenic therapeutics for cancer treatment [1]. The evaluation requires highly reproducible parameters, which depend on an accurately measured arterial input function (AIF) for DCE-MRI measurements [2,3]. Furthermore, the AIF has to be sampled at a high temporal resolution, especially for small animals like mice or rats, which have much higher heart rates than humans. Frequently, fast MRI measurements are contaminated with ghosting artefacts resulting from reconstruction errors caused by quick signal change by cardiac as well as bowl movement or changes in contrast agent concentration.

Fig. 2: Selected ROIs outside the mouse to identify images affected by ghosting.

Methods and Materials: Two different strategies were used to allow for the ghosting artefacts in the data: Firstly, regions of interest in the air surrounding the mouse were selected (see Fig. 2) and all time-points in which the signal intensity average exceeded the mean of the “air signal” by the factor of two were removed from the data. Secondly, the ghost image in the data is extracted and re-added to the original data since the signal of the ghost image is “missing” in the correctly reconstructed image. Most of the artefacts are “N/2” artefacts and the ghost is shifted by half of the image width in phase encoding direction. Thus, the ghost can simply be extracted by splitting the image in the middle of that direction and swapping the upper and lower half. The influence of the original data is minimized by creating a mask from a volume not affected by ghosting (see Fig. 3). The reconstructed “ghost image” is then added to the original data for each image. The quality of the correction methods is estimated by cropping a later phase of the AIF to assure a even distribution of contrast agent in the vessels and then fitting a biexponential function to the original data, to the data with ghosted images removed and to the data with the ghost signal re-added. Since the concentration time course should be smooth in this late phase, the root mean square per time-point (RMS_{tp}) error of the fitting should give a measure for the success of the ghost correction.

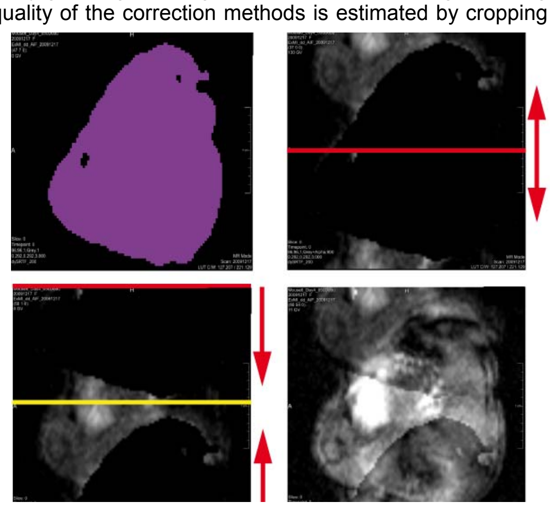

Fig. 3: Ghosting correction by re-adding the ghosted image. Top left: Mask generated from unaffected image to mask the correct data in the ghosted images. Top right: Masked ghosted image. The red line indicates the splitting edge. Bottom left: reassembled image showing the “ghost mouse” at the yellow line. Bottom right: Sum of original and ghost image used to extract the AIF.

Series of T1 weighted images were acquired using the clinical 3T MRI scanner Philips Achieva and a 4 cm mouse coil. (Philips, SN1095) After a short pre-contrast period, Gd-DTPA was administered in the tail vein. The measurements were acquired over a period of 11.5 min with a temporal resolution of 0.77 s using a saturation recovery turbo FLASH sequence. 17 measurements were performed on 6 different mice. 7 measurements had to be excluded because of movement of the artery. In each of the remaining datasets, the AIF was selected manually by a region of interest in the *aorta abdominalis* below the spine. The resulting curve was cropped so that the contrast agent was evenly distributed

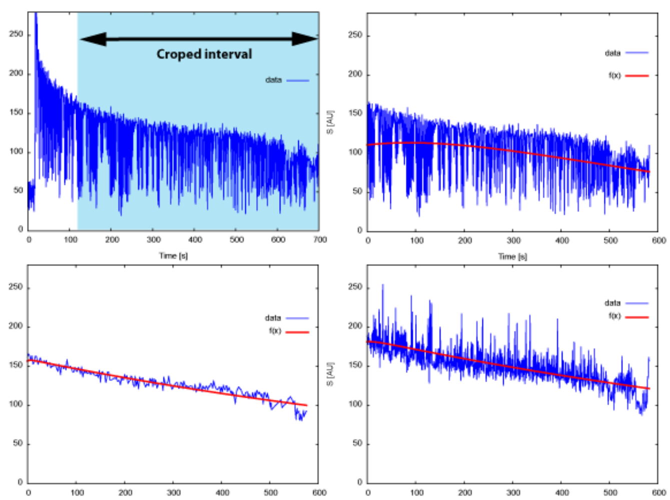

Fig. 4: Extracted AIF. Top left: original AIF. The blue box and the arrow indicate the selected interval. Top right: curve for the selected interval and the fitted biexponential function. Bottom left: the curve and fit for the removal method. Bottom right: curve and fit for the add-ghost method.

Results: The RMS_{tp} error of the original data was **29,5±8**, the RMS_{tp} of the series with the ghosted images simply removed yielded **4.97±1%** with only **40±14%** of the images remaining. The adding of the ghosted image yielded **13.3±2%** RMS_{tp} error. As expected, the fit for the removed frame yielded the best fits for the data. The adding method showed an increase in signal (see Fig. 4), which is probably resulting from adding also non ghosted images. Both methods are very fast and do not require noticeable processing time.

Discussion and Conclusion: Two methods allowing for ghosting correction in fast DCE-MRI images aere presented. Both methods reduce the distortions of the AIF significantly. The removal of frames yielded the better results but at the cost of more than half of the images being removed. This is especially problematic in the early phase of measurement when the contrast agent is arriving. The second method shows higher variations but will also be applicable in the early phases. Currently the method is applied to each image regardless of present ghosting and constraining the method only to affected images might improve the performance of the method. Moreover, the linear combination of ghost and correct image will allow to apply a similar method in areas where the ghosts overlaps the correct data.

References: [1] Padhani AR, et al., Br J Radiol. 2003; 76(1):560-80. [2] Cheng HM et al, JMRI 2008; 28(3):736-43. [3] Buckley DL, et al., MRM 2002; 47:601-606.