THE ROLE OF TEMPORAL RESOLUTION IN DETERMINING PHARMACOKINETIC PARAMETERS FROM DCE-MR DATA

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Introduction: In diagnostic DCE-MRI of the breast, spatial resolution is favored over temporal resolution. This means that temporal resolution is commonly 40-120s (1, 2). A study performed by Kuhl et al. (3) showed that the loss of dynamic information in the context of descriptive curve-type classification (i.e., into type I, II, or III (4)) by decreasing temporal resolution from 69s to 116s was diagnostically irrelevant, whereas the resulting increase in spatial resolution improved the diagnostic performance. While we considered the impact of a variation in temporal resolution on descriptive curve-type classification in previous work (5), we now focus on the loss of dynamic information in the context of pharmacokinetic modeling (using the Kety two-compartment model (6)). To do so, a realistic approach to temporal downsampling is presented, i.e. *low-temporal resolution (LTR)* series are derived from a *high-temporal resolution (HTR)* original. This approach involves a reorganization of the k-space data. The initial experiment is performed on data from model tumors in rats.

Animal and imaging protocol: DCE MR imaging was performed at 4.7 T (Bruker) on Copenhagen rats with implanted tumors (AT6.1) on the hind limb. Contrast agent (dose = 0.2 mmol/kg) was injected ~30 s after the beginning of the T_1-w GRE acquisition (TR/TE = 40/3.5 ms, flip angle = 30°; phase encoding order = linear; temporal resolution = ~ 5 s). Data acquisition continued for 10 minutes after injection.

Methods: Starting from an *HTR* series, *LTR* equivalents were derived via a reorganization of the k-space data that mimics an acquisition with linear phase-encoding order. For instance, to simulate a temporal resolution of 15s, the first, second, and third 1/3 of the k-space lines were, respectively, taken from the raw *HTR* data acquired at 5, 10 and, 15s. A smooth transition from one portion of the k-space data to the next was realized by linearly weighted interpolation. *LTR* equivalents were obtained up to a temporal resolution of 85 s. The method approximates contrast dynamic behavior within the time-span of one *LTR* image; this in contrast to downsampling by dropping intermediate images (7). Changes in signal intensity over time (after contrast injection) were transformed to changes in contrast agent concentration by making use of the precontrast signal intensity in muscle reference tissue with known T_1 (8). The arterial input function (AIF) was derived from the contrast agent uptake in muscle in the original series and literature values for K^{trans} and v_e. In order to avoid additional influences in the estimation of the parameters, the same AIF was used in fitting the two-compartment model to the *LTR*-series. The accuracy of the fit followed from maximum likelihood estimation.

Results: Figure 1 shows (in black) the values for K^{trans} (top) and v_e (bottom) derived at various temporal resolutions with the k-space reorganization method for a region-of-interest in the tumor. The results demonstrate that with decreasing temporal resolution, K^{trans} and v_e get progressively under- and overestimated. For instance, if we compare K^{trans} and v_e obtained at a 60s-resolution to the values derived from the *HTR* data; we see, respectively, a -17% and +2.8% error. To enable a comparison, we added in grey the results of downsampling by dropping intermediate images.

Conclusion: Our downsampling technique, that involves the reorganization of k-space data, is assumed to be more realistic than downsampling by dropping intermediate images, which is the method performed by e.g. Aref et al. (7). With our method we show that a reduced temporal resolution results in significant errors in pharmacokinetic parameters, which may lead to an incorrect classification of the tumor kinetics. In comparison to downsampling by dropping intermediate images, our method reports larger errors of K^{trans} and v_e at low temporal resolution. Therefore, the influence of temporal resolution appears to be greater than reported in the past (7).

Future work: The present work was performed with rodent model data because it was more readily available. In the future, we will perform similar analysis of patient data, to determine whether there are some cancers that are distinctive at *HTR*, but become non-distinctive at *LTR*. It would also be of interest to investigate the morphological appearance of images at different temporal resolutions. We may also be able to simulate the difference in noise accumulation at different temporal resolutions.

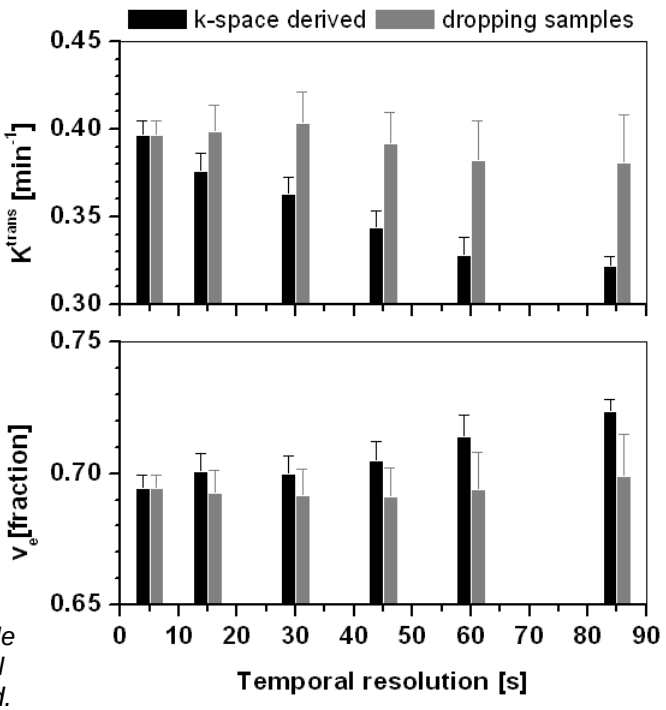

Figure 1: *Parameters K^{trans} and v_e (Basic Kety model) of an example curve plotted against temporal resolution. With decreasing temporal resolution, K^{trans} and v_e get progressively under- and overestimated.*

References: (1) Hendrick, Chicago International Breast Course 2007; (2) Kuhl, Radiology, 2007; (3) Kuhl et al., Radiology, 2005; (4) Kuhl et al., Radiology, 1999; (5) Heisen et al., ISMRM 2007; (6) Tofts et al., JMRI, 1999; (7) Aref et al., MRI 2007; (8) Medved et al., JMRI, 2004.