Retrospective Resolution Adaption for DCE MRI Using 3D Golden Angle Radial Acquisition

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Introduction: In dynamic contrast-enhanced (DCE) MRI, pharmacokinetic modelling (PK) is used to quantify tissue physiology. For fitting accuracy, high temporal resolution is required whilst high spatial resolution yields morphological information and high resolution PK maps. However, both are not compatible. The maximum allowed spatial resolution to assure accurate model fitting depends on the shape of the signal-time curve S(t). It has been previously reported for example, that increase temporal resolution on the upslope of the signal-time curve improves model fitting[1]. However, contrast agent is administered only once and S(t) is not *a priori* known. Furthermore, S(t) may vary largely from voxel to voxel. Therefore, an approach to needed to retrospectively resample the signal-time curve on a voxel-specific basis. To realize this approach, a 3D radial sampling scheme is employed. A 3D golden angle (GA) radial sequence[2] acquires *k*-space center and contrast information is contained within each profile. Additionally, due to the golden angles, images can be reconstructed at arbitrary time points with arbitrary spatial resolutions. Here, 3D GA radial imaging is used to retrospectively adapt the spatial resolution to S(t) throughout the time interval to achieve the maximal feasible spatial resolution whilst preserving fitting accuracy. This is performed for each voxel in a region of interest (ROI) individually.

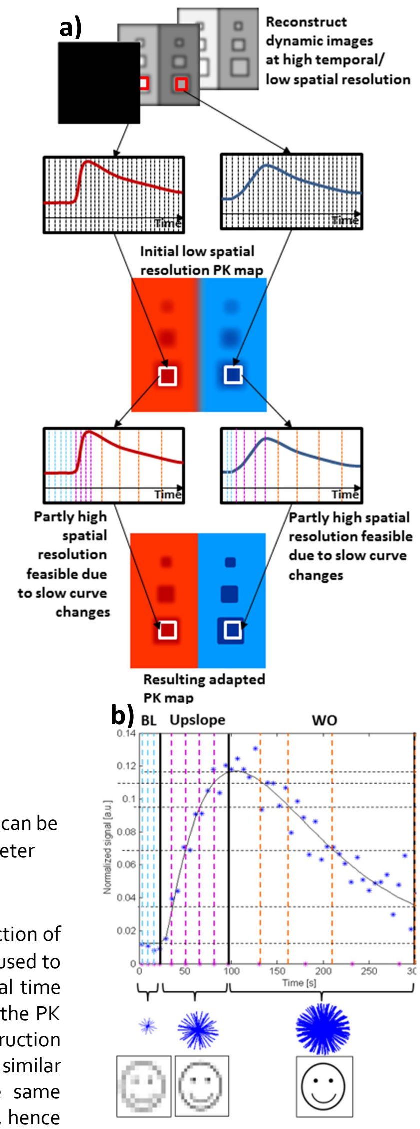

Figure 1: Process of retrospective resolution adaption

Methods: Using a FLASH sequence with 3D GA sampling, perfusion phantom data are acquired, in which contrast-enhanced signal time curves can be described by the gamma-variate function[3]:

$\Gamma(t) = \varepsilon$ for $t \leq \tau$ and $\Gamma(t) = \varepsilon + (\Gamma_{max} - \varepsilon) e^{\alpha\left(1 - \frac{(t-\tau)}{(t_{max}-\tau)}\right)} \left(\frac{(t-\tau)}{(t_{max}-\tau)}\right)^{\alpha}$ for $t > \tau$. Data are reconstructed using gridding[4]. The number of profiles N_{sp} required to reconstruct an image of a specific resolution is set to 10% of the Nyquist criterion. At the 10% level, streaking artifacts were found to be still tolerable[5]. The retrospective resolution adaption process is described in figure 1. First, images are reconstructed equidistantly at high temporal and low spatial resolution. The function $\Gamma(t)$ is fitted to each voxel, yielding an initial low spatial resolution PK map. It is assumed that the onset and peak time remain similar for higher spatial resolutions. For each voxel, the initial curves are divided into 3 phases (figure 1.b): Baseline (BL), upslope and wash-out (WO). In the next reconstruction iteration, BL remained sampled at high temporal resolution for accurate onset time fitting. The upslope is divided into N_{div} = 5 temporally equidistant time intervals. The WO phase is divided into the same signal intervals as the upslope. From the length of the time intervals, the numbers of spokes and the corresponding spatial resolutions according to the Nyquist criterion are determined. Data from these time intervals are reconstructed. The corresponding fitting times are chosen to lie in the center of each interval. To account for scaling during gridding and the FFT, each image has to be globally multiplied by a scaling factor. PK maps of the adapted images are generated and visually compared to the initial PK maps.

Result: The Γ_{max} and t_{max} maps from the initial low spatial and the adapted resolutions are shown in figure 2. It can be seen that the spatial resolution for the adapted images is improved, whilst fitting remains stable. The other parameter maps are not shown, since they do not yield an improvement in spatial resolution.

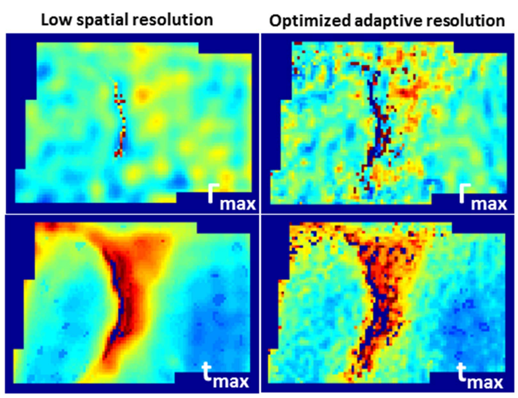

Figure 2: PK maps of parameters Γ_{max} and t_{max} resulting from low spatial and adaptive resolution reconstructions

Discussion: In this work, retrospectively reconstruction of data acquired with a golden angle radial sequence is used to adapt the resolution of individual voxels to the signal time curves. An improvement of the spatial resolution of the PK maps for some parameters is achieved. The reconstruction speed can be increased when clusters of voxels with similar onset and peak time are reconstructed from the same datasets. *k*-space center is sampled with each profile, hence temporal blurring occurs. In this work, only profiles from similar signal values are combined to minimize temporal blurring. However, reconstruction methods such as KWIC[6], reconstructing *k*-space center only using profiles relevant to the contrast, would be of advantage. Gridding is a very basic reconstruction method. The temporal resolution could be in general improved by using more advanced reconstruction technique such as non-Cartesian parallel reconstruction[7] or compressed sensing[8].

References: 1) Jansen, et al. Phys Med Biol.2010;55:473-485. 2) Chan R , et al.Magn Reson Med.2009;61:354-63.3) Chan A, et al.IEEE.2004;1067-1070.4) Jackson J, et al.IEEE.1991;10:473-8. 5) Stehning C, et al.Magn Reson Med.2004;52:197-203.6) Song H, et al.Magn Reson Med.2001;46:503-09.7) Pruessmann K, et al. Magn Reson Med.1999;42:952-62. 7) Grimm R, et al. Proc. ISMRM 2011. 8) Donoho D, et al.IEEE.2006;54(6):1289-1306