A Simulation Study of the Flexible TWIST View Sharing Impact on the Breast DCE MRI

Yuan Le[1], Marcel Dominik Nickel[2], Randall Kroeker[2], Christian Geppert[2], Brian Dale[2], Hal D. Kipfer[3], and Chen Lin[1]
[1]*Radiology and Imaging Science, Indiana University School of Medicine, Indianapolis, Indiana, United States,* [2]*Siemens Healthcare, North Carolina, United States,* [3]*Radiology and Imaging Science, Indiana University School of Medicine, Indiana, Indiana, United States*

Target Audience Radiologists, MRI physicists and scientists.
Introduction TWIST (Time-resolved angiography With Stochastic Trajectories) view-sharing has received increasing attention in studies of breast DCE-MRI[1-5]. Simulation studies is very helpful in finding out how accurate the enhancement curve/pattern is represented in images acquired with under-sampling techniques such as TWIST, and the most appropriate under-sampling strategy for certain types of application[6-8]. This study aims to provide such information for the optimization and error estimations in breast DCE-MRI with TWIST.

Methods A digital 'phantom' of 36x36x13 cm^3 (448x448x162) was generated with three spherical uniform 'lesions' of 5 mm diameter with typical 'persistent', 'plateau' and 'wash-out' type of enhancement respectively, and one composite lesion of 10mm diameter with a mixture of three types of enhancement (Fig. 1), all embedded in non-enhancing 'breast tissue'[9]. A modified TWIST technique with more flexible view sharing (Fig.2) was simulated. The simulation method is similar to a previously published kidney DCE-MRI study[8]. TR = 5.6 ms, GRAPPA factor = 2, phase/slice resolution= 80%/ 70%; partial Fourier in frequency/phase/slice direction = 80%. K-space views were shared from the nearest available time point while backward sharing was preferred. The percentage of the central k-space region size was A = 10%, 20%, 30%, 40%, 50% and 100%; the peripheral region k-space update rate was B =10%, 12.5%, 20%, 25%, 33% and 50%. Each set of images was reconstructed to 448x448x162. To calculate the error, all measured enhancement curves were interpolated onto the same grid of time points. Average RMS error of the enhancement curve: $RMS_{all} = \frac{1}{N}\sum_{n=1}^{N}(1/T\sqrt{\sum_{t=1}^{T}(enhancement_{measured}(t) - enhancement_{True}(t))^2})$ (N being the number of voxel inside the lesion), and the RMS error at the peak of the wash-out curve:
$RMS_{peak} = (1/N\sqrt{\sum_{n=1}^{N}(enhancement_{measured}(t) - enhancement_{True}(t))^2}$ were measured for each lesion.

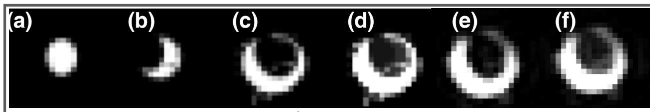

Figure 1. The middle section of the composite lesion with three partially overlapping regions with (a) persistent; (b) plateau; (c) wash-out enhancement. The whole lesion (d), simulated acquisition with A =100% (e) and simulated acquisition with A = 10% and B = 10% (f) at the peak of wash-out curve.

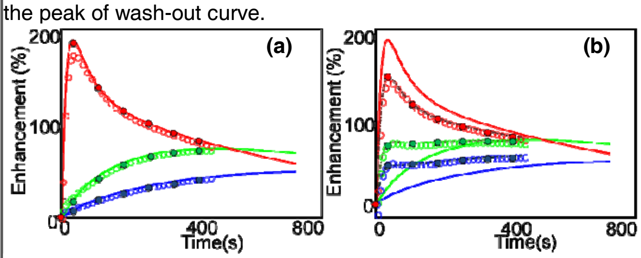

Figure 3. Measured enhancement in (a) three 5 mm spherical lesions with persistent, plateau and wash-out type of enhancement, and (b) the persistent, plateau and wash-out part of the 10 mm composite lesion. Circles are acquired with A = 10% and B = 10%, solid points are with A = 100%. Solid lines show the 'true' enhancement. Dash lines in (b) show the theoretical weighted average enhancement, which almost overlapped with the measured data.

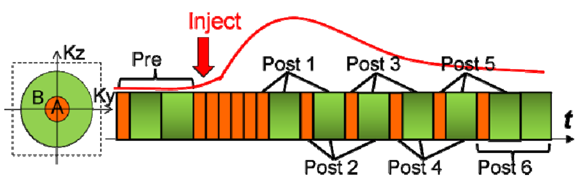

Figure 2. A full k-space ($AB_1B_2..B_n$) pre-contrast acquisition , a series of (A) only before the peak of enhancement, several (AB_i) after the peak of enhancement and another full k-space acquisition at the end (In this Figure we have 6 post-contrast as an example).

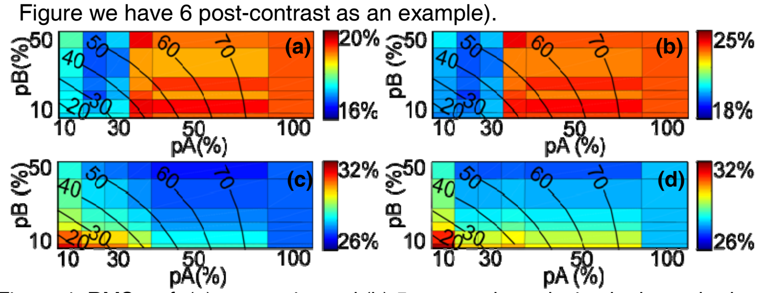

Figure 4. RMS_{all} of (a) composite and (b) 5 mm wash-out lesion both reached a minimum at A = 20% and B = 20%; while the RMS_{peak} in (c) composite and (d) 5 mm wash-out lesion have a lower error region with high A and B (A = 50%, B=50%). Contours show the time needed for each partial acquisition (unit: s).

Results Fig.1e and 1f show a decrease of spatial resolution with A=10% compared with A=100%. A decrease of the peak enhancement value on the wash-out curve with A=10% and B=10% is shown in Fig. 3, while the measured curves for 'plateau' and 'persistent' types of enhancement were almost identical between different As and Bs. The RMS error in the 5 mm lesion is slightly higher than that of the composite lesion. RMS_{all} was the lowest with A =20% and B =20% (Fig. 4 a-b), while the RMS_{peak} was the lowest with A=50% and B = 50% (Fig. 4 c-d).

Discussions In this study we assumed that the first TWIST partial acquisition (AB_i) is timed accurately at the peak of the washout curve. The error may increase if the peak cannot be accurately determined. The representation of the wash-out type of enhancement and the enhancement in the composite tumor were impacted more by the selection of A and B than that for the persistent and plateau type of enhancement. Multiple local minima and maxima of the error exist in the tested range for A and B; which may be caused by the difference in the temporal foot print for the acquisition of each A or B region along the curve. RMS_{all} and RMS_{peak} allow assessment of the accuracy of the enhancement kinetics and morphological patterns, therefore can be used to guide the selection of optimal under-sampling parameters such as A and B.

Reference
1.Herrmann, et al., ISMRM. 2010, p. 2503. 2.Janka, R., et al., in *ISMRM.* 2010, p. 4553. 3. Tudorica, L.A., et al., MRI, 2012. 30(9): p. 1257-67. 4. Mann, R.M., et al., *ISMRM.* 2011, p1016. 5. Le, Y., et al., *ISMRM.* 2012, p. 1043. 6. Le, Y., et al., *ISMRM.* 2012,p. 2404. 7. Le, Y., et al., *ISMRM.* 2013, p. 3375. 8. Song, T., et al., MRM, 2009. 61(5): p. 1242-8. 9. Agrawal, G., et al., Cancer, 2009. 115(7): p. 1363-80.