FREE-BREATHING PERFUSION MEASUREMENT USING RESPIRATORY MOTION PREDICTION

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Target audience: Users of arterial spin labeling sequences in the abdomen affected by respiratory motion.

Purpose: To implement free-breathing perfusion MRI in the abdomen using pseudo-continuous arterial spin labeling (pCASL) and respiratory motion prediction (RMP) based on an artificial neural network (ANN) algorithm.[1]

Methods: An unbalanced pCASL sequence (TR/TE: 8000/18 ms, Label time/Transit delay: 2.0/2.0 s, Label FA: 28.7 degree, G_{lmax}: 11 mT/m, $\langle G_l \rangle$: 0.8 mT/m, slice thickness: 6 mm, 12 axial slices, FOV: 280x210 mm^2, Matrix: 64x48, Partial Fourier: 7/8) with a 2D spiral pencil-beam excitation navigator (TR/TE: 100/3.5 ms, FA: 10 degree, Duration: 6.2 ms, Radius: 10 mm, Resolution: 0.5 mm) and a real-time RMP algorithm was implemented on a 3T Siemens mMR scanner (VB20P) (Fig. 1). The ANN was trained for 60 seconds and updated by the navigator echoes during each transit delay. The 1D diaphragm motion in the z-direction was supplied to the ANN that predicted the kidney motion and generated the offset frequencies to ensure each axial slice captured its respective section of the kidney to minimize errors between label and control pairs.

Ten pairs of control and label images were acquired. High perfusion values were windowed.[2] The optional TR fill time was set to longer than the sum of transit and acquisition (prediction) duration so that the accuracy of the prediction could be calculated for this study.

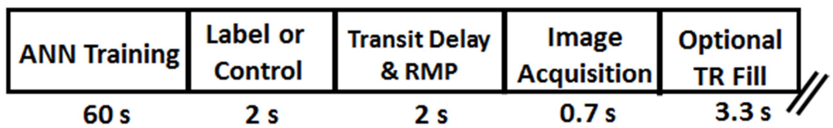

Figure 1: Pulse sequence schema.

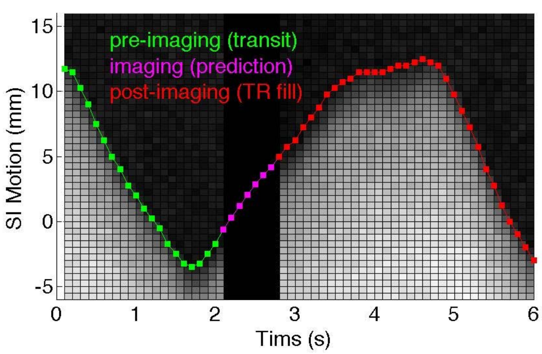

Figure 2: Example of ANN RMP shows diaphragm boundary displacement before (●) and after (●) image acquisition and the ANN prediction during (●) imaging.

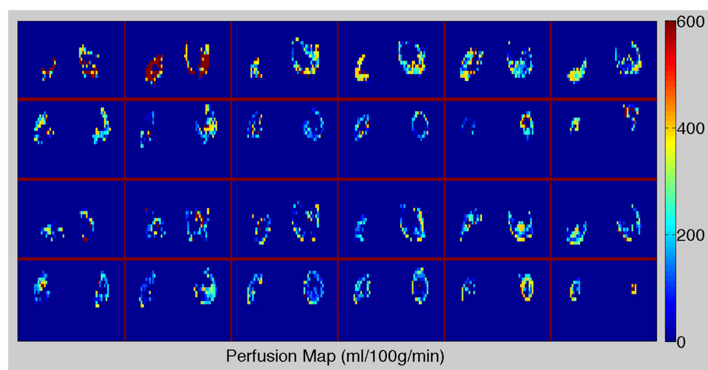

Figure 3: Renal perfusion maps for 12 slices from free-breathing ANN (top 2 rows) and breathheld acquisition with respiratory feedback (bottom 2 rows) shows general consistency between techniques.

Results and Discussion: After successful training, the ANN accurately predicted the diaphragm motion with a mean absolute error of 0.8 mm for 1120 predictions (Fig. 2). Satisfactory perfusion results were obtained from a healthy volunteer compared to breathhold acquisitions using respiratory feedback with five pairs of control and label images (50 second breathhold) and TR of 5 seconds (Fig. 3).

Conclusion: This is the first demonstration of free-breathing pCASL of the kidneys using RMP and demonstrates agreement with breathhold results. The ANN algorithm predicts well under most circumstances but can also lead to excessively high perfusion values in the perfusion maps. Additional issues must be addressed associated with the moving slice acquisitions e.g., B_1 and B_0 inhomogeneities, and in-plane displacements. In principle, data that falls outside of the prediction or image quality tolerances can be discarded based on the navigator history while still providing the benefits of free-breathing perfusion MRI (e.g., time savings and patient comfort). The timing can be further optimized to shorten the TR, transit delay, and training period.

References: [1] Dai W et al. Continuous flow-driven inversion for arterial spin labeling using pulsed radio frequency and gradient fields. Magn Reson Med 2008;60:1488-1497. [2] Martirosian P et al. FAIR True-FISP perfusion imaging of the kidneys. Magn Reson Med 2004; 51:353-361.