Automated Detection of the Arterial Phase in TRACER Reconstructed Dynamic 3D Contrast Enhanced Liver Imaging

Mitchell Anthony Cooper[1,2], Bo Xu[1], Shan Hu[2], Silvina Dutruel[2], Martin R. Prince[2], Yi Wang[1], and Pascal Spincemaille[2]
[1]*Biomedical Engineering, Cornell University, Ithaca, New York, United States,* [2]*Radiology, Weill Cornell Medical College, New York, New York, United States*

TARGET AUDIENCE: Researchers and clinicians interested in dynamic contrast enhanced imaging of the liver.

PURPOSE Capturing the arterial phase is crucial for the optimal detection and characterization of liver tumors using dynamic contrast enhanced imaging. Recently, TRACER, a method for high temporal liver imaging was proposed which uses a spiral readout in conjunction with a non-linear reconstruction to reconstruct 3D images with a sub-second temporal frame rate. It was demonstrated that this reconstruction increased the likelihood of capturing the arterial phase after bolus injection (1). However, the reader is now presented with a large number of images Here we adapt a previously proposed algorithm (2) to automatically select the optimal arterial phase from a series of 3D dynamic contrast enhanced hepatic images reconstructed with TRACER.

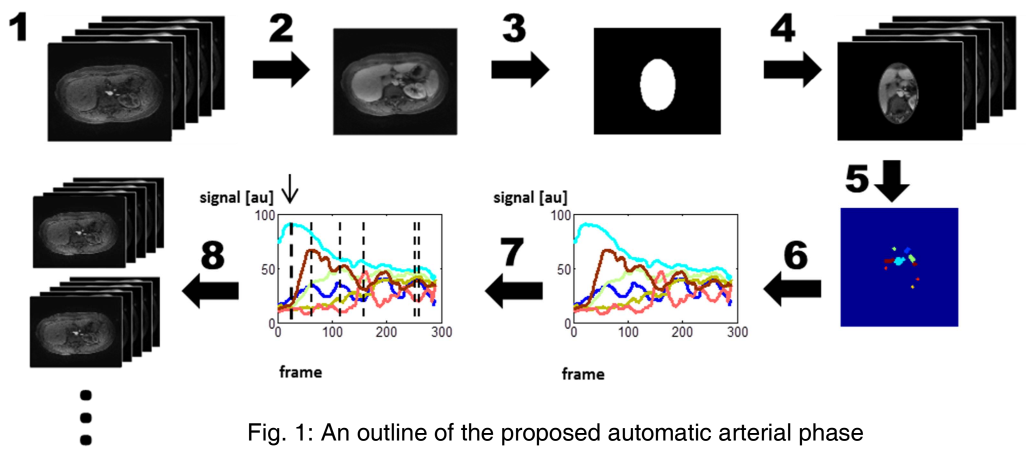

Fig. 1: An outline of the proposed automatic arterial phase detection algorithm.

METHODS The proposed algorithm consists of the following steps (shown in figure 1):
(1) TRACER is used to reconstruct a 2D+time set of images M_t of a single slice at the center of the prescribed 3D volume **(2)** The resulting image is then time-averaged resulting in M_{avg} **(3)** An elliptical mask surrounding the aorta is computed whose center and axes are the center of mass and half the radius of gyration of M_{ave}, respectively. **(4)** This mask is applied to each M_t and pixels whose signal temporal standard deviation falls below a threshold are removed. **(5)** A k-means clustering is performed to divide the pixels into clusters depending on their temporal signal evolution. In this algorithm, correlation is used as a distance and 6 clusters are assumed. Due to the numerical instability of the k-means algorithm, it was repeated 30 times with different starting points. The result with the lowest sum over the distances was chosen. This significantly improved the reproducibility over multiple runs of the algorithm. A morphological opening is performed on each of the 6 resulting pixel clusters or masks. **(6)** For each of the 6 pixel masks, the median signal over the mask is computed at each time point. **(7)** For each of the 6 resulting time curves, the curve with the first signal peak (global maximum) is retained and the temporal location of that peak is assumed to indicate the optimal arterial phase. **(8)** TRACER was used to reconstruct the rest of the volume up to the optimal arterial phase.

The algorithm was retrospectively performed on N = 40 (17 male, 23 female, age 56±13y) consecutive clinical dynamic spiral LAVA acquisitions (1,2). Dynamic spiral LAVA acquisition parameters were: 48 leaves, 256x256x(34-60) acquisition matrix, 5mm slice thickness, 32-46cm FOV 32-48cm, ±62kHz bandwidth, Magnevist/Eovist (Bayer Healthcare) injected at a dose based on patient weight, 6 acquired phases reconstructed to 288 phases with TRACER, ~1min total scan time. Each patient was instructed to hold his or her breath as long as possible. The technologist then guided the patient to start a new breath-hold while scanning continued. This was repeated until scanning ended. An experienced reader compared the appearance of the image automatically selected to have the maximum aortic signal by the proposed algorithm to the image with the maximum aortic signal selected by hand. The reader was blinded to the selection (automatic vs. hand) and chose whether the two images were equal or whether the automatic/manual arterial phase was better, defined as having better hepatic artery to background signal contrast.

RESULTS The automatic detection provided equal or better image quality of the peak arterial phase compared to hand selection in 38 cases. Hand selection of the arterial phase was better in 2 cases.

DISCUSSION The proposed algorithm worked well on 95% of cases. In the two cases where the algorithm failed, there was a non-arterial curve with a maximum before the arterial curve.

CONCLUSION This algorithm provides an automated method for determining the peak arterial phase in 4D high temporal resolution datasets that consists of a large number of temporal images.

REFERENCES 1) Xu, B. et al. Mag.Res.Med. 2013;69(2):370-381 2) Spincemaille et al. ISMRM 2013. 1536. 3) Agrawal M . Journal Magn. Res. Imag. 2013;37(5):1129-1136.