Normal Saline Injections with Dynamic Inversion Recovery Pulse Sequences: Dynamic Parameter Mappings with Signal Polarity Correction

Hernan Jara[1], Asim Z Mian[1], Osamu Sakai[1], Stephan Anderson[1], Jorge A Soto[1], and Alexander M Norbash[1]
[1]*Boston University, Boston, Massachusetts, United States*

Purpose: Normal saline (NS) has recently been demonstrated as a safe and promising T_1-lengthening contrast agent for dynamic-MRI of the head and brain, with the potential for tissue perfusion assessment and quantification by hemodilution analysis. In these preliminary studies, a dynamic inversion-recovery turbo-spin-echo (*dynIR-TSE*) pulse sequence was run during and after an NS injection, thus generating four-dimensional (4D) series of modulus images. Since for any given tissue, the pixel values of the modulus images are positive-rectified, the NSI signal changes can be positive or negative depending on the dynamic relationship between the time of measurement ($TI + TEeff$) relative to the *instantaneous IR signal null point* ($T_{(null)}(t) = ln(2)\, T_1(t)$) (see **Fig.** 1a below). The purpose of this work was to develop mathematical algorithms that take into account the polarity of the signal changes for generating accurate maps of the dynamic parameters: maximum enhancement (maxENH), area under the curve (AUC), time to peak (TTP) and mean transit time (MTT).

Methods and Materials: In this prospective, IRB-approved, and HIPAA complaint study, 17 patients were imaged using a 1.5T MRI unit (Philips Achieva-XR, Best, The Netherlands) using the quadrature body coil and a 16-channel phased array head coil for TX and RX respectively. The dynIR-TSE scans were run repeatedly for up to five minutes with the NS injection (duration 25s) given after a short delay post pulse sequence start. Up to 100cc of NS were injected through an antecubital vein at rates of 3-4ml/s: 3ml/s employed in patients with a 22 Gauge needle; 4ml/s in those with a 20 Gauge needle) using a power injector (Medrad Spectris Solaris, Bayer Healthcare, Warrendale, PA). The key imaging parameters of the *dynIR-TSE* pulse sequence were in the following ranges: TI=600-900ms, TR=1.6-2.1s, TEeff=4.6-10ms, voxel 1 x 1.5 x 7-10 mm^3 leading imaging volumes of 7-14 slices and temporal resolutions in the 16-20s. The 4D data sets were DICOM transferred to a PC-Windows™ personal computer for analysis with algorithms programmed in Mathcad (2001i, PTC, Nedham, MA). In a first computational step, the developed maxENH, AUC, TTP, and MTT mapping algorithms form one-dimensional vectors as functions of time for each pixel location. In the subsequent steps, the algorithms identify the signal polarity and calculate the corresponding dynamic parameters based on Boolean conditions comparing the minimum and maximum pixel values as well as on thresholds of minimal pixel values.

Results: All patients successfully completed the NS injection and the five-minute dynamic-MRI scan without experiencing any adverse effects or expressing any discomfort associated with the research portion of the MRI exam. Good image quality maps were generated for all patients: see **Fig**. 1b below for typical image quality in the absence of significant patient motion. Processing times of 3-5min were measured depending on matrix size, number of slices, and dynamic time points interrogated.

Conclusion: Time efficient computer algorithms with inversion-recovery polarity correction have been developed and tested with *in vivo* dynIR-TSE brain datasets. These algorithms can process 4D spatio-temporal image datasets offline with short computational times of less than five minutes and therefore could be useful in the clinic for analyzing 4D spatio-temporal datasets obtained with dynamic IR pulse sequences to monitor signal changes resulting from T_1-lengthning contrast agents such as normal saline. Such algorithms could be useful for the quantification of perfusion using normal saline as contrast agent.

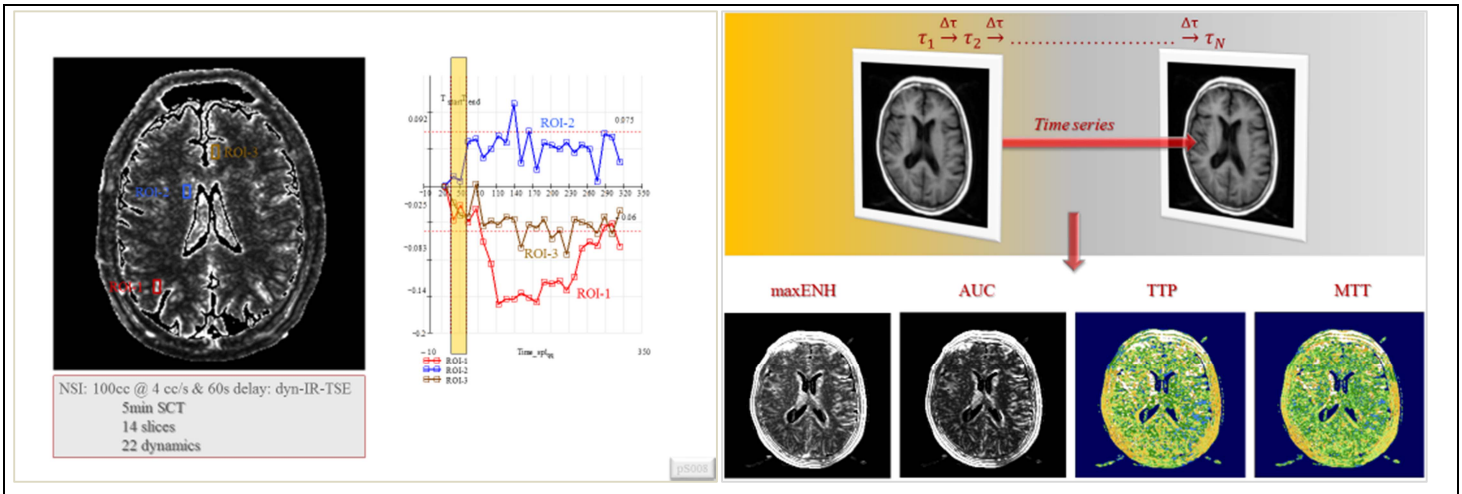

Figure 1: a) Typical maxENH map expressed in percent change relative to pre-injection level. Three ROIs have been positioned in regions of enhancement and the time curves, which are color labelled accordingly, exemplify regions with positive relative signal change (ROI-2-caudate) and regions of negative relative enhancement (ROIs-1&3-cortical GM). **b)** Logical diagram illustrating the steps followed by the maxENH, AUC, TTP, and MTT algorithms: 1D vectors of time series are form the interrogated with Boolean conditions.