Investigation of a Logistic Model for T2* Dynamic Susceptibility Weighted (dscMRI) Perfusion Studies

G. M. Wardlaw[1,2], R. Wong[3], C. Boylan[4], R. Rebello[4], and M. D. Noseworthy[2,5]

[1]Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, ON, Canada, [2]Brain-Body Institute, St. Josephs Healthcare, Hamilton, ON, Canada, [3]Dept. of Oncology, Juravinski Cancer Centre, Hamilton, ON, Canada, [4]Dept. of Diagnostic Imaging, St. Josephs Healthcare, Hamilton, ON, Canada, [5]Electrical and Computer Engineering, School of Biomedical Engineering, McMaster University, Hamilton, ON, Canada

Introduction: Perfusion MRI study of tumours involves either assessment of T1 (dynamic contrast enhanced MRI, dceMRI), or T2* changes (dynamic susceptibility contrast MRI, dscMRI) following administration of a gadolinium bolus. T1 approaches suffer from limited spatial coverage and increased time to adequately sample the bolus washout [1].

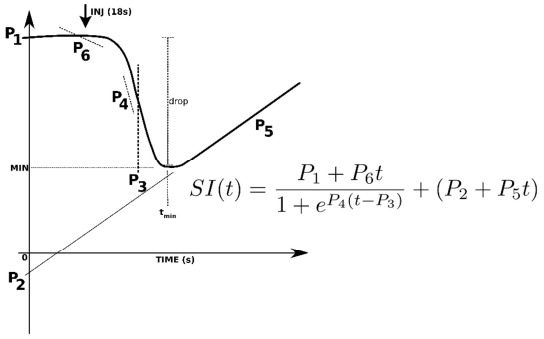

FIGURE 1: Schematic representation of T2* bolus passage and parameters used to describe baseline (P_1), trailing slope/wash-out ($P_5t + P_2$), time to maximum attenuation rate (P_3), maximum attenuation rate (P_4), and baseline correction (P_6). Fitting equation is also shown.

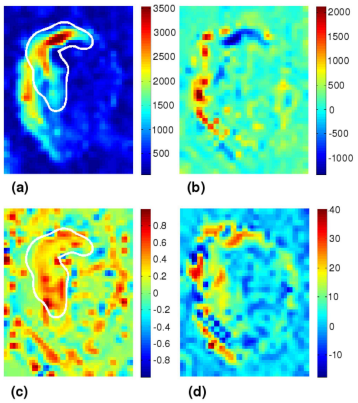

FIGURE 3: Logistic parameters P_1(a), P_2 (b), P_4 (c) and P_5 (d). P1 and P4 correlate well with hypervascular region of invasion shown as outlined in Figure 2. P2 and P5 outline gross tumour features.

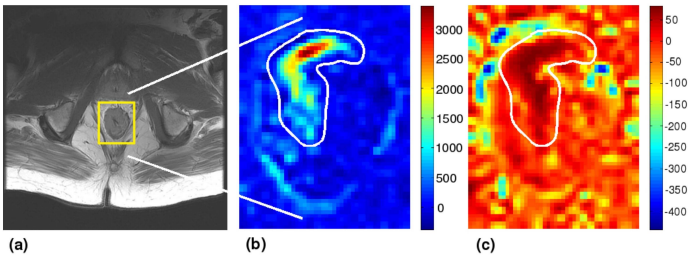

FIGURE 2: Anatomical slice highlighting rectal mass (a) along with corresponding T2* bolus Maximum Signal drop, MSD (b) indicating highly vascular intratumour region (outlined). Percentage Baseline Signal Loss, PBSL outlining region of increased T2* contrast wash-out (c) which has been correlated with tumour malignancy and poor prognosis. In this case, MSD and PBSL maps identify hypervascular region of tumour invasion which was clinically confirmed.

Furthermore a pre-contrast T1-map is required in modeling [2]. In comparison, dscMRI techniques can capture bolus first-pass kinetics and have the advantage of greater spatial coverage with no requirement for a pre-injection T1-map [1]. Additionaly, many proposed pharmacokinetic models suffer from numerous assumptions that can dramatically affect accuracy [3]. Alternatively, logistic approaches to characterising bolus enhancement curves have successfully discriminated benign versus malignant lesions using T1-based dceMRI [4,5]. Here we propose a logistic dscMRI model adapted from a T1 logistic equation [5] that has the benefit of both extended spatial coverage and absence of complexities associated with pharmacokinetic models. This method produces 6 individual maps via a 6-parameter logistic equation that completely describes the T2* bolus passage: A baseline variable (P1), trailing/wash-out slope and intercept (P5t + P2), time to maximum attenuation rate (P3), maximum attenuation rate (P4) and a baseline correction parameter (P6), as shown in Figure 1. Maps of maximum signal drop (MSD) and percentage baseline signal loss (PBSL) are easily calculated similtaneously with minimal effort and provide good diganostic reference.

Methods: In a study approved by our local research ethics board, patients with confirmed rectal tumours were assessed using a T2* weighted GRE EPI sequence (TR/TE=1500/21.8ms [6], flip=90°, FOV=22cm, matrix=96x128 , 6 slices, 5mm thick, 60 temporal phases). Contrast (Gadovist, Bayer Healthcare) was injected at a rate of 5mL·s^{-1} (0.11 mmol/kg) using a Medrad power-injector with a 20mL saline flush and injection delay of 18s. Data was fitted pixel-wise using a constrained Levenburg-Marqhardt fitting algorithm developed in Matlab (The Mathworks, Natick VA).

Results: Figure 2 shows an example rectal cancer case along with corresponding maximum signal drop (MSD) and percentage baseline signal loss (PBSL) maps. MSD maps calculated from T2* bolus curves have been correlated with relative cerebral blood volume (rCBV) in various grades (BBB disruption) of tumours [7, 8] and similar regions were histologically verified as hypervascular [9]. MSD has also been linked to malignancy in breast tumours [10], similarly PBSL maps have been linked to tumour malignancy [11]. Combining MSD and PBSL also helps assess angiogenesis and microvascular leakage [12] or differentiation of tumour from metastasis [13]. In this case, clincal reports outlined a "focal breech through the muscularis propria at the 11 o'clock position". Undoubtedly, this is the region of increased vascularity and contrast wash-out outlined in Figure 2(b), (c). Logistic maps of baseline parameter P1 and P4 correlate well with these clinical findings, showing increased baseline and maximum attenuation rate (contrast wash-in) values in the same region (Figure 3).

Conclusion: Descriptive quantities of tumour microvasculature using a T2*-GRE EPI scan can be obtained rapidly with increased spatial coverage while avoiding complicated physiological modeling schemes. This model can be applied over any region of interest (ROI), however, full slice maps better capture tumour heterogeneity. Previous work has shown that logistic parameters P2, P4 and P5 are successful in differentiating benign versus malignant lesions [5]. For this case, baseline parameter P1 and P4 correspond well to clinical results and seem to be good descriptive candidates. However, P2 and P5 do indeed highlight gross tumour features and define tumour boundaries well, perhaps implying similar diagnostic utility. Future work with large tumour populations and correlated pathology is underway.

References: **[1]** Dynamic Contrast Enhanced MRI In Oncology, Springer, 2005;pp.28-29 **[2]** MRM 1995;33:564-568 **[3]** MRM 2002;47:601-606 **[4]** Radiology 1999;211:101-110 **[5]** MRI 2004;22:467-473 **[6]** MRI 2004;22:929-935 **[7]** JMRI 2000;11:114-119 **[8]** Inv Radiol 1999;34:75-81 **[9]** Radiology 1999;211:791-798 **[10]** IEEE:Med Imag 2001;20(12):1293-1301 **[11]** Neuro Imag Clin Am 2006;16:137-147 **[12]** AJNR 2005;26:1446-1454 **[13]** AJNR 2007;28:1078-1084