

Comparison of permeability estimates derived from DCE-MRI and DCE-CT data in a rodent stroke model

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Introduction: The blood-brain barrier (BBB) is a functional concept to describe unique features of intracranial blood vessels that prevent many substances in the systemic circulation from entering the brain. In the setting of acute ischemic stroke, loss of BBB integrity is believed to be a precursor to hemorrhagic transformation [1]. CT and MR imaging may evaluate BBB integrity by detecting leakage of intravenously administered contrast media into the extravascular space. When dynamic contrast-enhanced (DCE) MRI or CT is combined with a suitable pharmacokinetic model, one can quantify and spatially map BBB integrity throughout the brain. In this study we measured and compared DCE-MRI and DCE-CT permeability ratios in a rodent stroke model. We hypothesize that permeability ratios obtained using both modalities should be comparable when using the same pharmacokinetic model.

Materials and Methods: The study was approved by the animal care committee at our institution. Five male Sprague-Dawley rats (age 8 to 10 weeks) underwent right MCA occlusion surgery using the procedure described by Longa et al [2]. The occlusion was maintained for 60 to 70 minutes, at which point the suture was removed to allow reperfusion. Imaging with DCE-CT and DCE-MRI was scheduled sequentially approximately 24 hours after reperfusion. Contrast agents were delivered via tail vein catheterization. DCE-CT images were acquired on a pre-clinical CT scanner (Locus Ultra; GE Healthcare; Milwaukee, WI, USA). A 1mL bolus of iodine contrast (Visopaque, 300mg/mL) was injected over the first 15 seconds of the DCE-CT scan (80kV, 95mAs, voxel = 0.15x0.15x0.45mm). The first 30 frames were taken at 1 second intervals, followed by 15 frames acquired every 10 seconds. Next, DCE-MRI was performed on a 7T small animal magnet (Biospec 70/30 USR, Bruker Biospin GmbH; Rheinstetten, Germany) with dedicated rat brain receiver coil. A gadolinium based contrast agent (Gadovist, 2mmol/mL) was injected at a rate of 60uL over 12 seconds during the DCE scan (TR/TE = 4.83/1.87ms, matrix = 128x128x8, FOV = 32x32x8mm, volumes = 42, time = 4:55min). In addition, structural T1 and T2 weighted images were acquired to identify the stroke region. Imaging data were co-registered and analyzed offline using an in-house software tool (MR Analyst v2.1; University of Toronto; Canada) implemented in MATLAB v7.11 (Mathworks; Natick, USA). Symmetric pairs of ROIs were manually defined representing the stroke and the contralateral areas within each imaging slice. Mean permeability (KPS) of each selected region for each modality was calculated based on a two-compartment pharmacokinetic model of the tissue signal in relation to the arterial input function sampled at the sagittal sinus [3]. Ratios between the mean KPS in the stroke and contralateral regions were then determined for each slice. A linear regression was performed to compare the KPS ratios between imaging modalities. Statistical significance was defined by a p-value less than 0.05.

Results: Three out of five datasets were included in the analysis (one animal did not survive surgery and one set of data was discarded due to severe motion corruption). Among the remaining datasets, stroke infarcts were identified in 15 slices. Figure 1 shows the KPS ratios of CT against MRI for each slice. The regression analysis revealed a moderate correlation ($R^2 = 0.35$), which was statistically significant ($p = 0.02$).

Conclusion: Permeability (KPS) measures derived from DCE-MRI and DCE-CT using the same pharmacokinetic model show similar results suggesting that they have comparable utility. Not only were both modalities able to detect increased permeability in the stroke hemisphere, but the ratios are also reasonably correlated. This study provides evidence that DCE data from both modalities may be interchangeable and opens up the possibility for multi-modal DCE studies. Further studies are needed to assess the robustness of this method.

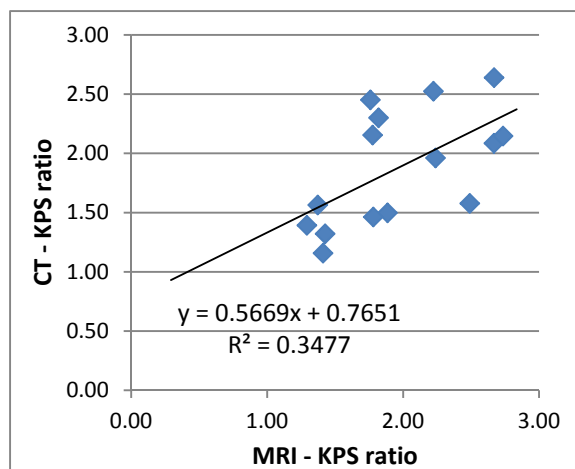


Figure 1. KPS ratios of stroke versus contralateral regions acquired using MRI and CT.

References: 1. Kassner A, Roberts TP, Moran B, et al. AJNR Am J Neuroradiol 2009; **30**:1864-69. 2. Longa E, Weinstein P, Carlson S, et al. Stroke 1989; **20**:84-91. 3. Roberts H, Roberts TPL, Brasch RC, et al. AJNR Am J Neuroradiol 2000; **21**:891-99.