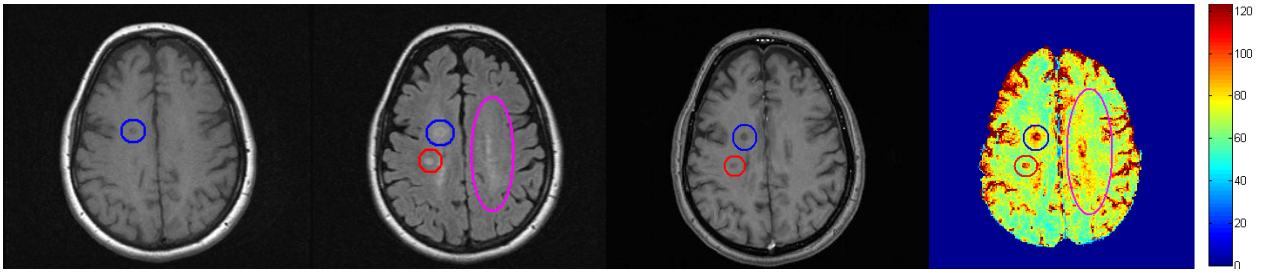
In-vivo Quantitative Measure of Black Hole Severity in Multiple Sclerosis with Gradient Echo Plural Contrast Imaging

P. Sati[1], A. H. Cross[2], and D. A. Yablonskiy[3]

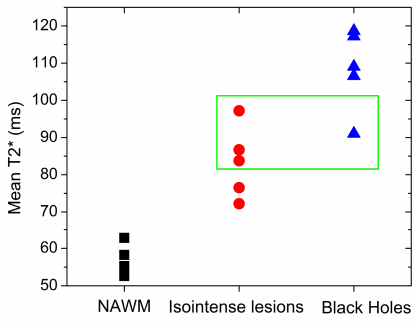
[1]Department of Radiology, Washington University School of Medecine, St Louis, MO, United States, [2]Department of Neurology, Washington University School of Medicine, St Louis, MO, United States, [3]Department of Radiology, Washington University School of Medicine, St Louis, MO, United States

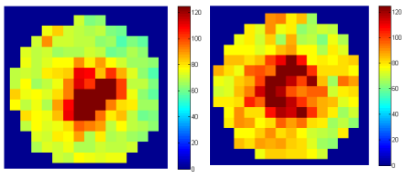
Introduction: Among the different types of MS brain lesions observed by MRI, black holes are thought to be most associated with significant tissue destruction including axonal loss [1]. Black holes are usually detected as hypointense areas compared to the normal appearing white matter (NAWM) on T1-weighted (T1w) images generated by conventional turbo-spin-echo (SE) MRI sequences. Unfortunately, these images, being only *qualitative,* provide limited information about lesion severity and have limited value for predicting lesions evolution over time. A recently introduced new MRI technique, named Gradient Echo Plural Contrast Imaging (GEPCI) [2-3], demonstrated substantial improvement in image quality and MRI acquisition time as compared to clinical sequences for evaluation of MS white matter lesions in humans [4]. In this abstract, we present preliminary results showing that GEPCI technique can be used as an efficient tool for *quantitative* assessment of black hole severity and has potential to be used to evaluate the level of tissue injury in MS lesions.

MRI method and Image analysis: Brain images of 5 Relapsing Remitting MS (RRMS) subjects were acquired using a Siemens 1.5T Magnetom Sonata system. Standard clinical 2D T1w, T2w and FLAIR images were first obtained with a resolution of about 1×1×3mm^3 and total acquisition time 15min49s. 3D version of GEPCI sequence was then used with a similar resolution and 8min32s acquisition time. From GEPCI dataset, quantitative T2* maps and T1w images were generated by post-processing methods. T1wSE and FLAIR images were first scrutinized in order to detect black hole lesions (hypointense on T1wSE and hyperintense on FLAIR) and isointense lesions (hyperintense on FLAIR but isointense on T1wSE). Regions of interest (ROIs) containing the lesions were then defined semi-automatically on the GEPCI T1w images by using a threshold based two times noise level. ROIs in NAWM (without "dirty" white matter) were also defined in order to serve as a reference. For each ROI, the corresponding mask was applied to GEPCI T2* map and a mean T2* value was calculated.



T1WSE **FLAIR** **GEPCI T1w** **GEPCI T2* map** (ms)





Results: An example from one RRMS patient is shown in the figure above: a black hole is circled in blue and an isointense lesion is circled in red. Note that the "dirty" white matter seen on FLAIR image (pink ellipse) is also clearly depicted in GEPCI T2* map. We note that GEPCI technique is more sensitive for detection of MS lesions than T1wSE, and is as sensitive as FLAIR - all the lesions are detected on both T1w GEPCI image and T2* map. Focusing on T2* mapping data from the 5 RRMS subjects, the mean T2* relaxation time constant versus the type of lesion (NAWM, isointense lesion or black hole) is plotted in the figure at left. Data for 5 different ROIs of each type show that the black holes have the highest T2* values and NAWM have the lowest T2* values. This result is consistent with previous work assessing the mean values of T2 times in black holes and NAWM using a multi-spin-echo sequence [5]. Interestingly, black holes also show a variation in the mean T2* values which might correspond to different degree of tissue damage severity. We hypothesize that higher T2* values will correlate with more severe tissue damage. This hypothesis is supported by the lower T2* values of isointense lesions which are considered as less severe than black holes [1]. The observed slight overlap between the two lesion groups (data inside green rectangle) might correspond to lesions evolving in damage severity (healing black hole or worsening isointense lesion). Moreover, the T2* mapping data can be analyzed on a pixel-by-pixel basis which could provide additional information on the pathophysiological development of MS lesions. As an example, the two black-hole ROIs shown on the left have different spatial distributions of pixels with very long T2* times (left: centered ovoid shape; right: open-ring shape) which might correspond to different patterns, or stages, of lesion development.

Conclusion: We propose a new approach using GEPCI for an accurate quantitative evaluation of severity of black holes as well as simultaneous estimation of total WM lesion load in MS patient's brain. This quantitative approach can be applied in a clinical acceptable time (8min32s) compared to other current T1- and T2- mapping techniques (4.5 hours as mentioned in reference [5]). Moreover, the T2* mapping provided by GEPCI has a potential to provide new information about the lesion severity and their potential development over time.

References: **1.** van Walderveen MAA *et al.*, Neurology (1998) 50:1282-1288; **2.** Yablonskiy DA, ISMRM (2000); **3.** Bashir A and Yablonskiy DA, ISMRM (2006); **4.** Sati P, Cross AH, Bashir A, Yablonskiy DA., World Congress on MS (2008); **5.** Papanikolaou N *et al.*, Eur Radiol (2004) 14:115–122.