Statistical Model for Predicting MS Cortical Lesion Detection Rates Based on Lesion Size and MRI Contrast and Resolution

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Introduction: In Multiple Sclerosis, cortical lesions assessment is considered a potentially better marker for disease burden and progression than conventional white matter lesion assessment. However, because of their small size and low contrast relative to adjacent normal appearing cortex, cortical lesions are difficult to depict in vivo [1-4], and no objective measures verifying their presence exists [5,6]. The objective was to develop a statistical model based on comparison of MRI with histology of MS brain specimens for estimation of cortical lesion detection rates using lesion size and MRI contrast and resolution as predictors.

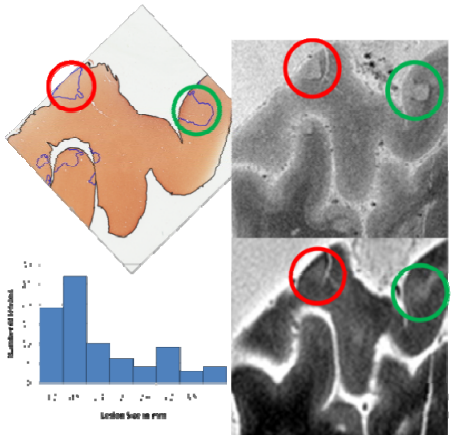

Fig 1: MBP stain, 3D-FFE-high, and WHAT-high images; lesion size histogram

Methods: Formalin fixed MS brain specimen were imaged and subsequently processed for immunohistochemical labeling with Myelin Based Protein (MBP) [7]. Histological sections were evaluated for number, size and type of cortical lesions. MRI was acquired with two methods, T2*/susceptibility weighted 3D-fast field echo (FFE) and white mat ter attenuated fast gradient echo (WHAT), and at multiple resolutions. Low resolution parameters were selected analogous to *in vivo* parameters and less than 15 minute scan time; high resolution settings were selected to give comparable SNR in 2-3hrs scan time. Lesions were marked on the MRI by 2 readers prospectively without knowledge of histology. A third reader compared these MRI findings to histology. SNR and CNR were measured. In addition, a computer simulation model was built, by superimposing circular lesions with size distributions corresponding to those measured in histology and a range of CNR on normal brain specimen MRI. The binary counting statistics (seen/not seen) was analyzed by logistic regression resulting in a parameterized model for lesion detection rates as a function of lesion size and MRI contrast and resolution.

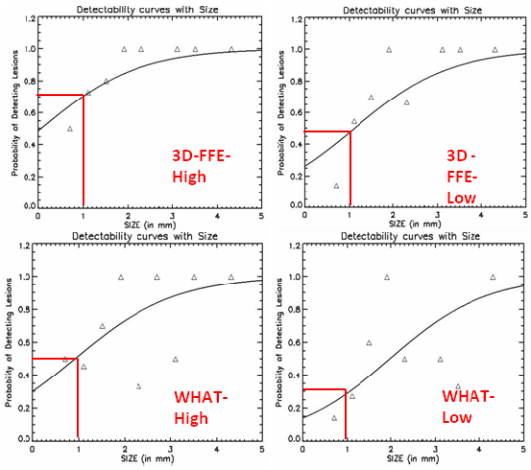

Fig 2: Observed lesion detection probability by lesion size for different sequences and logistic regression model

Results: *Figure 1* shows example histology and MRI and the lesion size distribution. A total of 82 lesions were included in the analysis. *Figure 2* shows the probability for lesion detection, i.e. the ratio of lesions seen by MRI and seen in histology, binned by lesion size. The solid line represents the logistic regression model for each individual MRI method with size as predictor (statistical significance $p<0.05$). For 1mm cortical lesions, the detection probability is highest with 3D-FFE high resolution (probability:60%, 0.15x0.15x0.3mm^3, CNR=3.4) and decreases with resolution (WHAT-high, probability:50%, 0.25x0.25x0.5mm^3, CNR=7.4, 3D-FFE low, probability:45%, 0.25x0.25x0.5mm^3, CNR=3.4, WHAT low, probability:30%, 0.25x0.25x1.0mm^3, CNR=4.3). Logistic regression of the simulated data gave similar c urves.

Conclusion: Comparison of lesion numbers and characteristics on MRI and histology allows for building a statistical model for lesion detection probability. This model can be extended with the help of simulated lesion images to predict lesion detection rates for in vivo conditions for a various MRI acquisition methods.

References: [1] Tallantyre, JMRI 2010 [2] Mainero, Neurology 2009, [3] Kollia, AJNR 2009, [4] Hammond, NeuroImage 2008, [5] Schmierer ISMRM09 1139,1152, 2692, [6] Geurts, J Neurol 255, 18, 2008, [7] Pitt, Arch Neurol 2010