

Quantitative voxel-based analysis of T1-weighted MRI signal intensity

D. F. Abbott^{1,2}, G. S. Pell^{1,2}, H. Pardoe^{1,2}, and G. D. Jackson^{1,3}

¹Brain Research Institute, Florey Neuroscience Institutes (Austin), Melbourne, Victoria, Australia, ²Department of Medicine, The University of Melbourne, Melbourne, Victoria, Australia, ³Departments of Medicine and Radiology, The University of Melbourne, Melbourne, Victoria, Australia

Introduction: We recently introduced an objective voxel-based approach for assessment of qualitative image modalities, which we call Voxel-Based Iterative Sensitivity (VBIS) analysis [1]. We demonstrated and validated the technique for T2-weighted signal intensity. Here we demonstrate that VBIS is also an effective method to directly assess the signal intensity of T1-weighted MRI.

Abnormalities in the brain generally manifest on MRI as changes in shape (morphometry) or changes in the nature of the tissue (signal intensity). Voxel-based statistical analysis approaches are able to objectively detect such changes throughout the brain. For example, Voxel Based Morphometry (VBM) [2] and Voxel Based T2-relaxometry (VBR) [3] can detect subtle changes in tissue volume and T2 signal intensity respectively. Whilst VBM can be applied to any imaging modality with sufficient contrast between tissue classes (such as T1-weighted MRI), a fully quantitative modality is usually required for the direct detection of signal intensity changes. Thus the application of a voxel-based approach for direct detection of signal differences in T1-weighted MRI would not normally be considered. The intensity of conventional T1-weighted images depends on multiple factors such as shim, coil loading and receiver gain settings, and can vary markedly across imaging sessions and subjects. Whilst quantitative T1-relaxometry may be able to avoid these problems, sequences to achieve this at high-resolution and a reasonable imaging time are not routinely available on clinical scanners. We therefore sought to determine the sensitivity of the Voxel-Based Iterative Sensitivity (VBIS) approach when applied to T1-weighted images.

Methods: A group of 24 patients (mean age 38 ± 12 (SD) years, 11 women) with typical left hemisphere hippocampal sclerosis (HS), recruited from the comprehensive epilepsy surgery program at Austin Health, was compared to a group of 97 healthy controls (mean age 31 ± 9 (SD) years, 52 women). These subjects' T1-weighted MRI, eight-echo T2-relaxometry and extracted single-echo T2-weighted images had previously been analysed using VBM, VBR and VBIS-T2 respectively [1]. Here we report results of VBIS applied to the T1-weighted images (VBIS-T1). The T1-weighted structural images were acquired with a T1-prepared 3D high-resolution SPGR sequence (TE=2.7 ms; TR=13.8 ms; flip angle = 20°; T1=500 ms; voxel size: 0.48x0.48x2 mm).

The VBIS approach adaptively optimises the relative global scaling of images to maximise sensitivity to regional effects. VBIS requires three iterations, with the global scaling factor ultimately used being derived from the half of the within-brain voxels that are the most stable (i.e. those that have the least variance), with the exception of voxels that may actually contain a significant effect. To determine the effectiveness of VBIS for T1-weighted images, we compared the group of patients to the group of controls and calculated a sensitivity map: a map of the minimum mean signal difference at each voxel that would be detectable at P<0.05 (1-tailed t-test corrected for multiple comparisons). We compared this map to a similar map determined when using a simple (non-iterative) global intensity scaling approach. We also examined the VBIS-T1 results for areas of significant signal increase or decrease at P<0.05 (2-tailed t-test corrected for false discovery rate).

Results: A sensitivity map of the VBIS-T1 approach is shown in figure 1(a). Sensitivity is generally greater in subcortical areas. The VBIS approach is generally more sensitive at detecting changes in T1-weighted signal than the use of simple global intensity normalisation to correct for global signal variance (figure 1(b) and table 1). Notice that though the scaling factor used in VBIS is based on the best half of voxels, this scaling factor improves the mean sensitivity of both the best and poorest half of voxels.

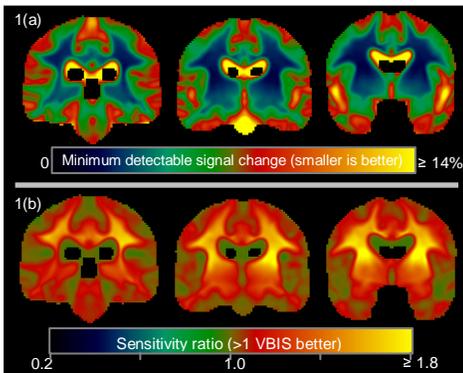


Figure 1(a): Map of sensitivity (minimum detectable signal change) of VBIS-T1 (smaller is better) shown in 3 coronal slices. **1(b):** Ratio of sensitivity achieved with simple global normalisation to that achieved with VBIS (VBIS is better where ratio is > 1).

Table 1: Mean sensitivity (minimum % signal change detectable, smaller is better) achieved using VBIS compared to simple global intensity normalisation.

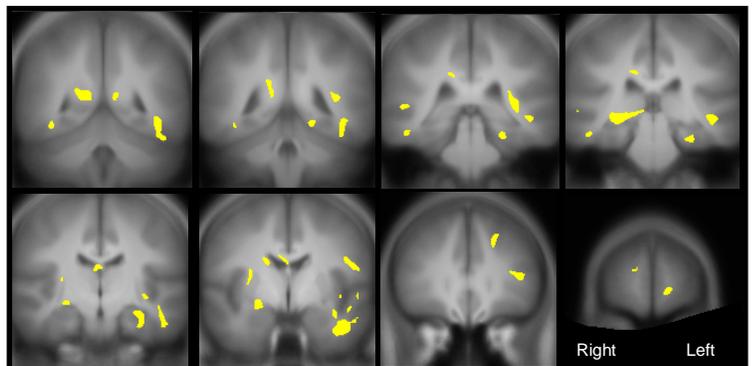
Mean (StDev)	All within-brain voxels	Best half of voxels	Poorest half of voxels
Global norm.	7.4 (2.3)	5.6 (1.1)	9.1 (1.8)
VBIS	7.0 (2.6)	5.0 (1.4)	8.9 (1.9)

References:

- Abbott DF, Pell GS, Pardoe H, Jackson GD. "Voxel-Based Iterative Sensitivity (VBIS) analysis: methods and a validation of intensity scaling for T2-weighted imaging of hippocampal sclerosis". NeuroImage (in press)
- Ashburner J & Friston KJ. "Voxel-based morphometry--the methods". Neuroimage 2000;11:805-821
- Pell GS, Briellmann RS, Waites AB, Abbott DF, Jackson GD. "Voxel-based relaxometry: a new approach for analysis of T2 relaxometry changes in epilepsy". Neuroimage 2004;21:707-713

In the group of patients with left hippocampal sclerosis, compared to the group of healthy controls, VBIS-T1 revealed regions of significant decrease in T1-weighted signal only (figure 2). On the left (ipsilateral to the hippocampal sclerosis) we see changes in the hippocampus, extensively in the white matter core of the temporal lobe, extending down the fusiform or temporo-occipital sulcus to the occipital lobe, and in the frontal lobe, consistent with known areas of seizure spread and temporal lobe connections. On the right (contralateral side) changes are more focal, confined to the medial limbic structures including posterior hippocampus, and a small amount of the medial occipital region. This pattern is consistent with structures known to be involved in temporal lobe seizures and suggests a high degree of sensitivity of VBIS-T1 to structural pathology and likely secondary effects of seizures.

Figure 2: Significant decrease in T1-weighted signal in the patients compared to controls (there were no voxels with significant signal increase).



Conclusion: VBIS is an effective method to directly assess the signal intensity of T1-weighted MRI. It revealed significant abnormality in a group of left HS patients as expected on the side of the sclerotic hippocampus, and also detected subtle pathology on the right that is often not evident using conventional quantitative measures.