Semi-Automated Segmentation of Microhemorrhages Revealed by SWI

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Introduction: Conventional clinical neuroimaging is notoriously insensitive to milder traumatic brain injury (TBI). Recently susceptibility weighted imaging (SWI)[1] has been shown to be 3-6 times more sensitive to microhemorrhages in TBI than gradient echo $T2^*$ weighted imaging[2]. Furthermore, lesion count and volume have been shown to correlate with clinical outcome[3]. Manual methods are labor intensive and operator dependent. Automated and semi-automated methods are more efficient and objective. We hypothesize that an automated method of lesion segmentation will also prove to correlate with clinical severity, indexed by posttraumatic amnesia duration (PTA), in a group of heterogeneous TBI patients.

Materials and Methods: SWI images were collected on a group of well-characterized, non-penetrating TBI patients (n=16; age range =17-57 years; 36.2±13.4 M±SD) and healthy normal volunteers (n=14; age range =23-45 years; 27.5±5.7 M±SD). TBI cases ranged in chronicity (3 days to 15 years post-TBI) and severity (mild-severe by admission Glasgow Coma Scale (GCS), and were imaged as a part of a multi-imaging protocol on a Siemens Sonata 1.5 T scanner. A fully flow compensated, 3D axial, high resolution, gradient-echo SWI sequence was used to collect magnitude and phase data with 85/35 ms [TR/TE], $\alpha = 25°$, $N_x = 512$, $N_y = 256$, with a resolution of 0.5 mm x 0.5 mm x 2.0 mm and 64 slices. A semi-automated method of lesion segmentation was used which involved statistical comparison (Z-score) of TBI images to an SWI atlas which was an averaged image from 14 normal controls, each spatially normalized into MNI305 space. A variance map was also created from the 14 controls. False positive artifacts caused by enlarged ventricles, brain contour mismatch between TBI and atlas and signal inhomogeneity were removed using sequential information from T1, T2 and FLAIR images which did not reveal microhemorrhages. Finally, manual editing of images in MRIcro (www.sph.sc.edu/comd/rorden/mricro.html) was performed to further remove blood vessels using venogram images (SWI mIPx4) and remaining artifacts from SWI images. Final patient statistical maps were thresholded at $Z \geq 1$ to extract voxels which likely represented microhemorrhage or residual iron products from remote hemorrhage. We then correlated SWI lesion burden with PTA, which is a good indicator of functional outcome[4].

Results: In general, this semi-automated method successfully identified microhemorrhages. Figure 1(a-c) shows three slices (Z=38, 58 and 68 MNI space) from a TBI patient (GCS=3). Several areas of hypointensity are evident throughout the images particularly on the left. Figure 1(d-f) shows the lesions after segmentation by the algorithm. Microhemorrhages that were not segmented by the algorithm occurred adjacent to sulci or were large enough that they were present on conventional images and therefore were masked out of the final Z map. False positive still occurred but were greatly reduced at higher Z thresholds. Figure 2 shows a strong association (R=0.70, Pearson) between lesion volume and PTA for the 16 TBI patients, despite heterogeneity in severity (mild-severe) and chronicity (3d-15yrs post TBI)

Figure 1.

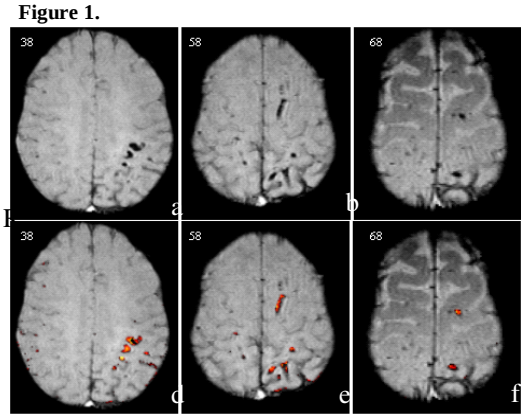

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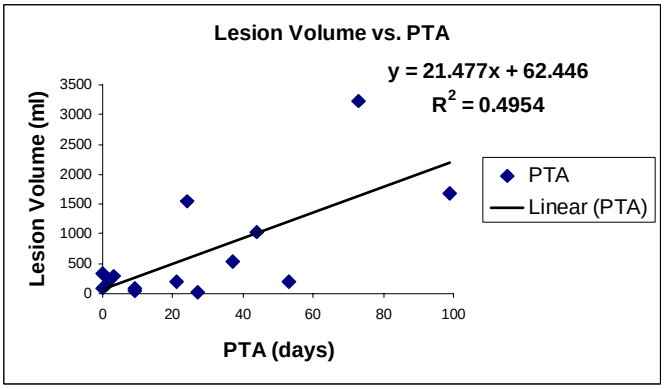
Figure 2



Conclusion: Our preliminary efforts at developing an automated segmentation algorithm for microhemorrhages on SWI suggest that the use of multi-channel information provided by conventional images to reduce non-lesional sources of hypointensity are highly effective. Furthermore, this semi-automated method of lesion segmentation proved to have strong clinical utility. Future studies will be aimed at improving sensitivity and specificity and combining SWI with DTI and MRSI for improved diagnosis and prognosis.

References:

1. Haacke EM, Xu Y, Cheng YC, et al. Susceptibility weighted imaging (SWI). Magn Reson Med 2004;52:612–18.
2.Tong KA, Ashwal S, Holshouser BA, et al. Hemorrhagic shearing lesions in children and adolescents with posttraumatic diffuse axonal injury: improved detection and initial results.Radiology 2003;227:332–39.
3.Babikian T, Freier MC, Tong KA, et al. Susceptibility weighted imaging: neuropsychologic outcome and pediatric head injury. Pediatr Neurol 2005;33:184–94.
4.Zafonte, R.D., N.R. Mann, S.R. Millis, K.L. Black, D.L. Wood, and F. Hammond, Posttraumatic amnesia: its relation to functional outcome. Arch Phys Med Rehabil, 1997. **78**(10): p. 1103-6.