Evaluation of pediatric diffuse axonal injury using susceptibility weighted imaging (SWI) and MR spectroscopy.

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Synopsis: Diffuse axonal injury (DAI) remains a difficult diagnosis in the initial period, particularly in the pediatric population. A new 3D susceptibility weighted imaging (SWI) technique dramatically improves detection of small parenchymal hemorrhages suggestive of shearing injury. Using SWI, a significant inverse correlation between hemorrhage extent and Glasgow Coma Scale (GCS) is definitively shown. There is also a significant difference between mean values in dichotomized GCS groups. In addition, MRS abnormalities are greater in voxels with microscopic hemorrhage, suggesting that areas of DAI are associated with neuronal loss or dysfunction. This study shows improved delineation of DAI with SWI and MRS.

Introduction: Diffuse axonal injury (DAI) is a major complication of traumatic brain injury (TBI), although frequently underdiagnosed by conventional imaging. The purpose of this study was to evaluate the ability of a new high-resolution susceptibility weighted imaging (SWI) sequence (Ref. 1) to assess brain injury by detecting parenchymal hemorrhage suggestive of diffuse axonal injury. We previously presented preliminary data in a small group of 7 pediatric patients (Ref. 2) that showed that SWI detected significantly more hemorrhages than conventional GRE imaging, particularly lesions of small size. We present further data from a larger group of 20 patients to determine the correlation of hemorrhage detected on SWI with assessment of initial injury graded by initial Glasgow Coma Scale (GCS). MRS abnormalities in areas of hemorrhage were also evaluated.

Methods: Twenty patients (aged 3-18 years) were imaged on a 1.5 T MRI scanner within 2 weeks of traumatic brain injury. In addition to a standard MR protocol that included conventional gradient echo (GRE) imaging, a new SWI technique was added consisting of a strongly susceptibility-weighted, low-bandwidth (78 Hz/pixel) 3D-FLASH sequence (TR/TE = 57/40 ms, FA = 20°) first-order flow compensated in all 3 orthogonal directions. Thirty two partitions of 2 mm were acquired using a rectangular FOV (5/8 of 256 mm) and a matrix size of 160 x 512, resulting in a voxel size of 1 x 0.5 x 2 mm³. Post-processing of the images was performed to enhance the signal loss due to microscopic hemorrhage. Parenchymal hemorrhagic lesions demonstrated by the SWI method were analyzed using a computer software program (Image Pro Plus, Media Cybernetics Inc.) which could count and calculate the area of each lesion. The volume of each lesion was determined by multiplying the area by the effective slice thickness of the image. Extent of hemorrhage (number or volume) was compared to initial Glasgow Coma Scale (GCS) score by two methods. The relationship was first evaluated using non-parametric analysis by Spearman’s rank correlation. The GCS groups were then dichotomized into those with mild/moderate injury (GCS > 8) or those with severe injury (GCS < 8). The mean number or volume of hemorrhagic lesions in each group were then compared using student’s t-test. Similarly, the correlation coefficient between GCS and the volume of hemorrhagic lesions for each patient was -0.68 (p=0.001). When patients were dichotomized into GCS groups, there were significant differences between hemorrhage extent for each group. The mean number of hemorrhagic lesions for the severely injured (135 ± 18) was significantly higher than those with mild/moderate injury (3277 ± 1512 mm³) (p=0.01). The mean volume of hemorrhages was also significantly different between patients with severe injury (38 ± 18) and those with mild/moderate injury (38 ± 18) (p=0.01). Similarly, the mean volume of hemorrhage was also significantly different between patients with severe injury (38 ± 18) and those with mild/moderate injury (38 ± 18) (p=0.01). The mean volume of hemorrhage for each patient was calculated.

Results: Using Spearman rank analysis, the correlation coefficient between GCS and number of hemorrhagic lesions (Fig. 1) for each patient was -0.69 (p = 0.001). Similarly, the correlation coefficient between GCS and the volume of hemorrhagic lesions for each patient was -0.68 (p=0.001). When patients were dichotomized into GCS groups, there were significant differences between hemorrhage extent for each group. The mean number of hemorrhagic lesions for the severely injured (135 ± 18) was significantly higher than those with mild/moderate injury (38 ± 18), as shown in Fig. 2 (p=0.001, one-tailed student’s t-test). Similarly, the mean volume of hemorrhage for each patient was calculated.

Discussion: This study shows a definitive strong inverse correlation between the extent of parenchymal hemorrhagic lesions detected by SWI and initial GCS, which has not been shown using conventional imaging. MRS abnormalities are also greater in areas with microscopic hemorrhage identified with SWI. Up until recently, imaging has only been able to detect a small fraction of injuries associated with DAI, which is usually only visible at the microscopic level. Newer techniques such as diffusion tensor imaging and MR spectroscopy have been able to demonstrate subtle injuries in normal-appearing brain. However, these techniques are not routinely available and require extensive post-processing. The SWI method is a modification of standard gradient echo imaging that can potentially be performed on any MR scanner to determine the correlation of hemorrhage detected on SWI with assessment of initial injury graded by initial Glasgow Coma Scale (GCS). MRS abnormalities in areas of hemorrhage were also evaluated.

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