Quantitative diffusion tensor imaging evidence of brain damage in professional boxers

L. Zhang1, L. D. Ravdin1, N. R. Relkin1, R. D. Zimmerman1, A. M. Ulug1
1Weill Medical College of Cornell University, New York, NY, United States

Synopsis
Chronic Traumatic brain injury is a common neurological abnormality found in professional boxers. Routine MRI is usually not diagnostic. Recent studies suggested that diffusion weighted imaging may be useful in diagnosing traumatic brain injury by quantifying the microstructural diffusion changes. In this work, we investigated the average brain diffusion coefficient in professional boxers and compared it with that of normal controls and patients with normal pressure hydrocephalus, a syndrome associated brain dysfunction.

Methods
Data from 24 professional male boxers (age range 21-53 year) and 14 normal male volunteers (age range 23-45years) from a previous study [1] were analyzed together with 29 patients with normal pressure hydrocephalus (NPH) [2, 3]. The MR imaging was performed on a 1.5T clinical MR scanner with a quadrature head coil: a) axial T1WI: TR/TE 500/min; axial T2WI: TR/TE 4000/102; FLAIR: TR/TE/TI 10000/162/2200, matrix size 256x192; b) DWI: TR/TE 10500/min, matrix 128x128, slice thickness 5 mm, FOV 220 mm. Diffusion was measured in three orthogonal directions with b value of 1000s/mm². A set of images (So) were obtained with b=0. An orientation-independent diffusion image related to trace of diffusion tensor is obtained as: DWItrace = (1/b) log (So/DWItrace). A computer C program was used to calculate the diffusion distribution histograms by distributing the pixels into 250 bins with a bin width of 0.02x10-5 cm²/s. This histogram was fitted to a triple Gaussian curve using commercial software. This curve (C1e-

σ

(10

σ

3/2) represents a three-compartment model: 1) brain tissue compartment, 2) brain tissue mixed with CSF, 3) the high diffusion compartment of CSF. The mean of the brain tissue distribution is recognized as a mean diffusion constant for the whole brain (BDav).

Results
Both BDav and σ were significantly higher in the boxers as compared to normal controls (p<0.0001and p<0.01, respectively). Boxers have wider diffusion distribution widths with the tissue peak shifting to higher diffusion value. NPH patients have the highest BDav (p<0.001) followed by normals and controls (Figure 1). The plot of BDav versus σ (Figure 2) shows that the diffusion results of professional boxers are in between that of normal controls and NPH patients. Since dementia is the expected symptom of NPH, the increase of diffusion values of boxers may be a preclinical sign for brain damage.

Discussion
This work suggests that quantitative diffusion tensor imaging can show early microstructural changes in the brains of boxers. Increased BDav and σ may represent preclinical signs of traumatic brain injury and brain dysfunction even when the routine MRI findings are non-specific [4-9]. By comparing the BDav and σ, we found that diffusion characteristics of boxers are between that of normal and NPH patients. The quantitative diffusion tensor imaging may prove useful in detecting early brain injury.

Acknowledgement
We thank the New York State Athletic Commission for their support and assistance with subject recruitment. Supported in part by grants from AFAR, NICHD (1R03-HD39796-01), NINDS (K08-NS02016) and NCRR-GCRC (M01RR00047).

References
[8] Bigler ED. J Head Trauma Rehabil 2001; 16(2): 1-21

![Figure 1. Normalized diffusion distributions from a normal control, a boxer and an NPH patient. The measured BDav and σ of the normal control are also shown.](Image)

![Figure 2. BDav versus σ. The diffusion values of boxers clustered in between the normal and the NPH group.](Image)