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Identification of Fiber Degeneration and Organized Gliosis in Stroke Patients by Diffusion Tensor MRI

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INTRODUCTION

Diffusion Imaging is the most effective non-invasive technique for detecting hyperacute stroke (1, 2). Changes in apparent diffusion coefficient (ADC) (2) and more recently the mean ADC (3) have been demonstrated to be useful in assessing acute stroke patients. However, changes of diffusion anisotropy in stroke have not been the focus of previous studies. Since it is sensitive to tissue microstructure, we hypothesized that it could yield useful information about the progression of acute stroke.

METHODS

We use high-resolution Diffusion Tensor MRI to provide quantitative measures of both diffusion isotropy (e.g., the Trace of the diffusion tensor, D) and the degree of diffusion anisotropy (4). Only recently has the clinical feasibility of high-quality, high-resolution *in vivo* DT-MRI been demonstrated (5), as long acquisition times and high sensitivity to motion artifacts had precluded its use for a meaningful radiological assessment in human brain.

To date, ten primarily chronic stroke patients, between 38 and 85 years old, were scanned in a 1.5-Tesla whole-body imaging system, equipped with 22 mT/m MA gradients. Images were acquired using a new interleaved EPI spin-echo diffusion-weighted sequence with navigator echo correction of motion artifacts. Imaging parameters were: minimum TR=5s (cardiac gated to three slices per heart beat, 15-18 slices), interleaves = 8, TE = 80ms, FOV = 240mm, res=128x128, slice thickness = 3mm. Maximum b-matrix were on the order of 1100 sec/mm². For each slice we obtained 31 axial DWIs of human brain in approximately 30 minutes.

Diffusion gradients were applied in 6 noncollinear directions with two gradients applied simultaneously to augment the attenuation of the measured echoes. After images were reconstructed, a diffusion tensor was estimated in each voxel (4) (6). From it we calculated the sum of its diagonal elements, Trace(D), and a new rotationally invariant anisotropy index, used below (7), which is independent of orientation in the tissue. Bright voxels indicate high diffusion anisotropy, and usually correspond to regions of white matter fibers. Dark voxels indicate low anisotropy, which is observed in the ventricles and regions containing grey matter. The brightest voxels contain the most highly ordered white matter fiber tracts.

RESULTS AND DISCUSSION

Figure 1 shows a 74 yr. old patient with a history of multiple white matter infarcts. The Figure shows two axial slices of Trace(D) (left), and the anisotropy index (right). The Trace images show a hyperintense region in the left hemisphere (rt side on images) showing the fluid-filled lacunar infarct in the centrum semiovale. The corresponding anisotropy map (top rt) shows low anisotropy in the lacuna itself, but a ring of highly anisotropic tissue around it. Although the anisotropy index is a scalar, MR-DTI also provides fiber tract direction in each voxel (4). Our data show that the orientation of this anisotropic tissue was not consistent with the expected

orientation of the white matter fiber tracts in this region of the brain, but, is consistent with what has been previously observed histopathologically as a region of gliosis extending several centimeters from the necrotic core of the infarct (8).

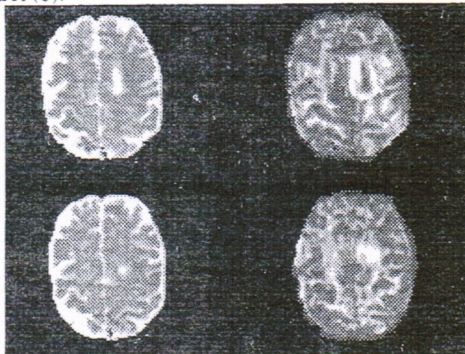
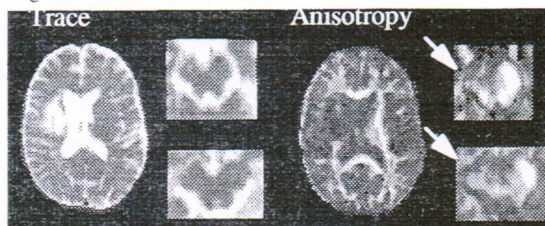


Figure 2 shows a 43 yr. old male with coagulopathy and an old infarct in the MCA territory of the right hemisphere (left on image). The infarct is evident both in the Trace image below as a region of hyperintensity, and in the anisotropy index image as a region of hypointensity. Particularly notable is the reduction in anisotropy in the internal capsule. The insets to the right of each image show two magnified images of the cerebral peduncles, which were not in the vascular territory affected by the infarct. Although the Trace images are almost normal in the right peduncles, the corresponding Anisotropy Index images (arrows) show complete loss of anisotropy consistent with Wallerian degeneration of the fibers (9).



CONCLUDING REMARKS

These preliminary experiments show that a quantitative diffusion anisotropy measure (derived from the diffusion tensor) could complement the mean ADC in the assessment of stroke. New high-resolution DWI techniques make it possible to obtain quantitative measurements of the mean diffusivity and anisotropy index in about 30 minutes.

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