Chapter 17
Differences in Analysis Methods of the Human Uncinate Fasciculus Using Diffusion Tensor MRI

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ABSTRACT

The human uncinate fasciculus is an important cortico-cortical white matter pathway that directly connects the frontal and temporal lobes, but its exact functional role is not yet known. Using diffusion tensor Magnetic Resonance Imaging (MRI), the uncinate fasciculus can be extracted and its volume calculated. DTI metrics such as fractional anisotropy for the uncinate fasciculus can also be analyzed, but there are currently three different methods for this analysis. DTI reports on the uncinate fasciculus are conducted using region of interest, voxel-based, and fiber tracking deterministic approaches. Due to these differences in analysis methods, prior studies report conflicting levels of uncinate asymmetry measured with diffusion anisotropy. Here, the authors briefly introduce these three different methods for measuring uncinate asymmetry values and compare the results. This result can lead to a better understanding of the role of the uncinate fasciculus in future behavioral and clinical studies.

INTRODUCTION AND BACKGROUND

The uncinate fasciculus is a small hook-shaped white matter bundle that connects the inferior frontal gyrus and the inferior surface of the frontal lobe with the anterior portions of the temporal lobe (Figure 1). (Kier et al., 2004). The average length of the uncinate fasciculus is 45 mm and the volume in adults is 1425.9±138.6 mm^3 (Khader et al., 2009). The exact function of the uncinate fasciculus is not resolved, although it is traditionally considered to be part of the limbic system.

DOI: 10.4018/978-1-4666-2113-8.ch017

The uncinate fasciculus on the left side shows greater fractional anisotropy (FA; a measure of microstructural integrity) than on the right, and this asymmetry has been argued to possibly link to the left hemispheric specialization for language (Rodrigo et al., 2007). The uncinate fasciculus has been used as a marker of tissue integrity in healthy and diseased populations (Lebel et al., 2008). Abnormalities within the fiber bundles of the uncinate fasciculus are associated with social anxiety (Phan et al., 2009), Alzheimer's disease (Yasmin et al., 2008), bipolar disorder (McIntosh et al., 2008) and depression in elderly people (Taylor et al., 2007). The greater FA of the left than the right uncinate fasciculus is not the case in people with schizophrenia (Kubicki et al., 2002 and Park et al., 2004).

For measuring the human uncinate fasciculus in vivo, diffusion MRI techniques have been used. Diffusion MRI is a magnetic resonance imaging (MRI) method that produces in vivo images of biological tissues weighted with the local microstructural characteristics of water diffusion, and it is capable of showing the connections between brain regions (Hagmann et al., 2006). There are two different types of diffusion MRI applications—diffusion weighted MRI and diffusion tensor MRI.

In diffusion weighted imaging (DWI), each image voxel (three dimensional pixel) has an image intensity that reflects a single measurement of the rate of water diffusion at that location. This measurement is more sensitive to early changes after a stroke than more traditional MRI measurements such as T1 or T2 relaxation rates. DWI is most applicable when the tissue of interest is dominated by isotropic water movement e.g., grey matter in the cerebral cortex and major brain nuclei—where the diffusion rate appears to be the same when measured along any axis.

Diffusion tensor imaging (DTI) is important when a tissue—such as the neural axons of white matter in the brain or muscle fibers in the heart—has an internal fibrous structure analogous to the anisotropy of crystals. Water will then diffuse more rapidly in the direction aligned with the internal structure, but more slowly if it moves perpendicular to the preferred direction. This also means that the measured rate of diffusion will differ depending on the direction from which an observer is viewing.

More extended DTI scans derive neural tract directional information using 3D or multidimensional vector algorithms based on six or more gradient directions, sufficient to compute the diffusion tensor. The diffusion model is a rather

Figure 1. Principal systems of association fibers in the cerebrum (uncinate fasciculus visible at lower left)