Chapter 26

Diffusion Tensor Imaging for Dementia

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ABSTRACT

Magnetic resonance MR tractography based on diffusion tensor imaging (DTI) was first introduced to the medical imaging community a decade ago. Since then, it has been successfully applied to a number of neurological conditions. It has been most commonly applied to the pre-operative planning of brain tumors. The other areas with active research additionally include stroke, multiple sclerosis and dementia, providing valuable information that would not be available through other imaging techniques. Tractography was first introduced with the deterministic streamline technique and has evolved to use more sophisticated probabilistic approaches. In this chapter, the authors will describe the clinical application of this tractographic technique to patients with dementia.

I. INTRODUCTION

Diffusion-tensor imaging (DTI)-based tractography is one of the most remarkable advances in the field of neuroimaging in the past decade. This method offers in vivo localization of neuronal fiber tracts, which was not previously possible. As a clinical tool, this technique primarily targets intracranial space-occupying lesions, i.e., brain tumors and vascular malformations (Mori, 1999; Witwer, 2002; Wiegell, 2000; Nimsky, 2006; Yamada, 2003; Yamada, 2004). Further, DTI has been shown to be robust by many reports.

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II. BASICS OF DTI AND TRACTOGRAPHY

Water-diffusion anisotropy (directionality) in the white matter of the brain is defined on the basis of axonal alignment (Wiegell, 2000). Water preferentially diffuses in a direction parallel to the axon’s longitudinal axis but is relatively restricted in the perpendicular axis. This phenomenon can be represented mathematically by the so-called diffusion ellipsoid, or tensor (Figure 1).

The tensor has three eigenvalues. The long one pointing along the axonal direction is \( \lambda_1 \), and the two small axes have lengths \( \lambda_2 \) and \( \lambda_3 \) (Figure 2). The diffusivity along the principal axis \( \lambda_1 \) is also called longitudinal, axial, or parallel diffusivity.

The tensors of cerebral white matter can be reconstructed to track three-dimensional macroscopic fiber orientation in the brain. The translation of the longest axis of the tensor (\( v_1 \)) into neural trajectories can be achieved by various algorithms (Figure 3 and Figure 4).

III. LIMITATIONS OF TRACTOGRAPHY

Perhaps the most important limitation of tractography is that it has not yet been fully validated.
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