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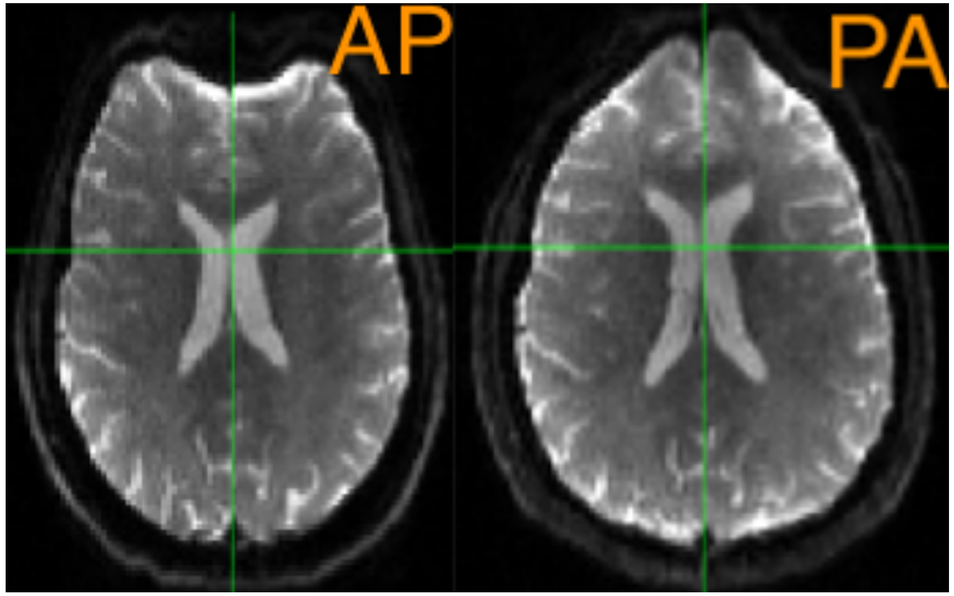

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NeuroImage 20 (2003) 870–888

NeuroImage

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How to correct susceptibility distortions in spin-echo echo-planar images: application to diffusion tensor imaging

Jesper L.R. Andersson,[a,*] Stefan Skare,[a] and John Ashburner[b]

[a] *Karolinska MR Research Centre, Stockholm, Sweden*
[b] *Wellcome Department of Imaging Neuroscience, London, UK*

Received 18 October 2002; revised 28 May 2003; accepted 29 May 2003

Abstract

Diffusion tensor imaging is often performed by acquiring a series of diffusion-weighted spin-echo echo-planar images with different direction diffusion gradients. A problem of echo-planar images is the geometrical distortions that obtain near junctions between tissues of differing magnetic susceptibility. This results in distorted diffusion-tensor maps. To resolve this we suggest acquiring two images for each diffusion gradient; one with bottom-up and one with top-down traversal of *k*-space in the phase-encode direction. This achieves the simultaneous goals of providing information on the underlying displacement field and intensity maps with adequate spatial sampling density even in distorted areas. The resulting DT maps exhibit considerably higher geometric fidelity, as assessed by comparison to an image volume acquired using a conventional 3D MR technique.

Introduction

A number of techniques to assess differences in gross anatomy between healthy and diseased subjects based on neuroimaging have recently been proposed (e.g., Ashburner et al., 1998; Ashburner and Friston, 2000, Good et al., 2001) and applied (e.g., Wright et al., 1995; Gaser et al., 1999; May et al., 1999; Maguire et al., 2000). An interesting addition to this arsenal is represented by diffusion tensor imaging (DTI) (Le Bihan et al., 1986; Turner et al., 1990; Basser et al., 1994; Pierpaoli et al., 1996), which may potentially offer information on differences in the hardwiring of corticocortical connections between different groups.

While alternative methods exist (e.g., Gudbjartsson et al., 1996) most DTI is based on spin-echo echo-planar images (EPI) acquired with and without special diffusion

diffusability of water. A well-known problem with EPI is the geometrical and intensity distortions caused by field imperfections in conjunction with the poor bandwidth in the phase-encode direction. These field imperfections are caused by, among other things, eddy-current-induced global gradients (Jezzard et al., 1998) and susceptibility induced local gradients (Jezzard and Balaban, 1995). We have in previous work dealt with the first of these (Andersson and Skare, 2002) and in the present paper we will address the latter.

We further an idea proposed by Bowtell et al. (1994) which entails collecting two echo-planar images, once traversing *k*-space bottom-up and once top-down. This results in two images with identical magnitude distortions in opposing directions. These two images, together with a model for the image formation process of spin-echo EPI, allow us to estimate the underlying magnetic field map and undis-

METHODS GALORE

- TOPUP is widely used
- Physics based, no real error except a few simplifications