FACT, PROBABILITY MAPS AND GIBBS TRACKING FOR PREOPERATIVE FIBER TRACKING IN EPILEPSY SURGERY

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Introduction

For pre-surgical fiber tracking the FACT algorithm [1] is implemented in the most commercially available navigation systems for neurosurgical operations, and has been shown to be reliable for glioma and cavernoma resection [2, 3]. Problems arise, when a strong bending of the fibers is present as in the optic radiation, which leads to an underestimation of the Meyer loop [4]. Other problems are fiber crossings which lead to a stop of the tracking algorithm. Other techniques as probabilistic fiber tracking [5, 6] and Gibbs tracking [7] are less susceptible to these limitations. The first aim of this work was to compare FACT algorithm, probability maps and Gibbs tracking in their practical relevance for the neurosurgeon. The second aim was to use at least manual work as possible.

Patients and Methods

Ten patients (5 males, 5 females, mean 22.2 years) received pre-operative fiber tracking because of a difficult functional anatomy of their lesions. Two patients had a focal cortical dysplasia, one a schizenecephaly with a dysplastic hemisphere (Figure 1), two a tumour, two an arteriovenous malformation (Figure 2), one a cavernoma, two a hippocampal sclerosis. In 5 cases the corticospinal tract (CST), and in 5 cases the optic radiation (OR) was tracked. DTI was performed at a 3T scanner by a diffusion-sensitive Spin-Echo EPI sequence with 61 diffusion encoding gradient directions. Voxel size was 2^3 mm^3. A high resolution T1w data set with a voxel size of 1^3 mm^3 was acquired, and taken for normalisation and co-registration. The calculation of the diffusion tensor, and the evaluation by the FACT algorithm, probability maps and Gibbs tracking were performed by in-house software [6 - 9].
Seed points were either taken from a voxel based atlas (WFU pick atlas) or derived from fMRI and handled by spm8. Only for anterior and posterior hemipons no atlas or fMRI data were available. There, seed points were created manually according to Kamali et al. 2009 [10].

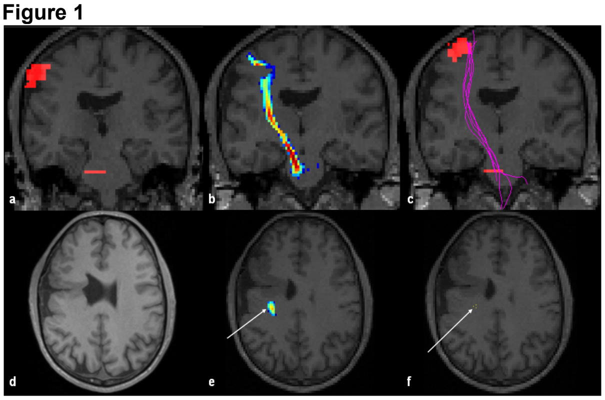
Results

Probability maps *and* Gibbs tracking were successful for all intended fiber structures on the healthy *and* the pathologic side. The FACT algorithm only successfully tracked the corticospinal tract in 3/5 cases on the pathologic side, and in 4/5 cases on the healthy side, the somatosensory fiber system (SSF) in 1/1 cases on both sides, and the optic radiation in 2/5 cases on the pathologic and the healthy side. For examples see Figures 1 - 2. The atlas-based selection of seed points prevented from the introduction of any subjective bias into the tracking procedure. The inspection of the resliced anatomical labels showed some imperfections, but those were negligible.

Discussion

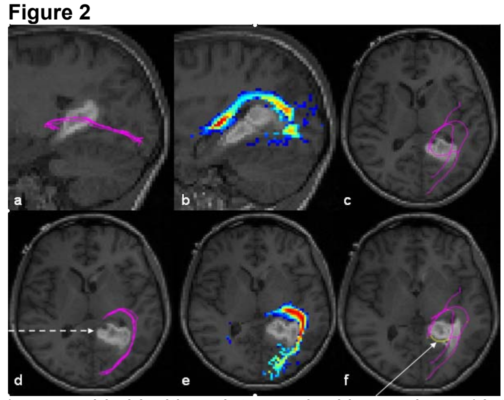
According to the clinical outcome of the patients, the identification of the CST, SSF and OR was reliable by probability maps and Gibbs tracking, even though in some cases a resection had to be performed without any security distance (*e.g.* cases of Figures 1 and 2). Probability maps show the fiber bundle within a larger extent than Gibbs tracking, which is a general finding in all investigated cases, see Figure 1. Technically the question arises, whether probability maps are able to track through any kind of directed tissue and may show false positive fibers. All tracking methods, however, were tracking outside of the mesio-occipital and mesio-temporal haemorrhage of the case in Figure 2 even without application of the brain mask indicating at least certain specificity. The developed advanced methods (probability maps, Gibbs tracking), however, hold a number of internal parameters, which can affect the obtained fiber results.

Figure 1



28-year old man with schizencephaly and a dysplastic hemisphere on the right side.
a, d: FACT; b, e: probability maps; c, f: Gibbs tracking.
The FACT algorithm was not able to track the CST on the pathologic side. Probability maps and Gibbs tracking found the CST. During operation the CST could be preserved.

Figure 2



15-year old girl with an intracerebral hemorrhage (dotted arrow) attributed to an arteriovenous malformation.
a, d: FACT; b,e: probability maps; c,f: Gibbs tracking.
All methods obtained the optic radiation. The fibers crossing through the bleeding in c (←) lies below the image level and outside of the bleeding, the fiber to the insula is attributed to a loop.

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