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Diffusion tensor imaging – Arcuate fasciculus and the importance for the neurosurgeon

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ABSTRACT

Objective: Tumors in eloquent areas of the brain like Broca or Wernicke might have disastrous consequences for patients. We intended to visualize the arcuate fasciculus (AF) and to demonstrate his relation with the corticospinal tract and the visual pathway using diffusion tensor imaging (DTI).
Methods: We depicted between 2012 and 2014 the AF in 71 patients. Men and women of all ages were included. Eleven patients had postoperative controls also. We used a 3DT1-sequence for the navigation. Furthermore T2- and DTI-sequences were performed. The FOV was 200 × 200 mm^2, slice thickness 2 mm, and an acquisition matrix of 96 × 96 yielding nearly isotropic voxels of 2 × 2 × 2 mm. 3-Tesla-MRI was carried out strictly axial using 32 gradient directions and one *b*0-image. We used Echo-Planar-Imaging (EPI) and ASSET parallel imaging with an acceleration factor of 2. *b*-Value was 800 s/mm^2. Additional scanning time was less than 9 min.
Results: AF was portrayed in 63 patients bilaterally. In one glioblastoma patient it was impossible to visualize the left AF and in seven other patients we could not portray the right one. The lesions affected AF by disrupting or displacing the fibers.
Conclusions: DTI might be a useful tool to portray AF. It is time-saving and can be used to preserve morbidity in patients with lesions in eloquent brain areas. It might give deeper insights of the white matter and the reorganization of AF-fibers postoperatively.

1. Introduction

The removal of cerebral lesions is a special challenge for every neurosurgeon. When the lesion is situated next to eloquent cerebral areas the risk of harming patient's autonomy becomes higher. White matter tracts (WMT) bordering these lesions are under extreme risk of being affected by tumors or by surgeons during operation. One of these WMTs is the AF which was already described in 1822 by Burdach as a bundle of fibers surrounding the sylvian fissure [1]. DTI is the only technique up to date that enables physicians to visualize WMT *in vivo* in healthy and non-healthy patients [2,3]. We intended primarily to depict AF in patients who had to undergo a surgical procedure of the brain. Furthermore we depicted AF in patient where surgery was not considered at first but could eventually become and option in the days to come. Finally, AF was depicted in patients where the lesion was far away from it also. The reason was to have a better understanding on how different lesions affect AF depending on their location. Another question was to know whether far away lesions affect the AF at all. In some patients we portrayed AF after surgery too. The reorganization of the fibers after surgery is another important issue, above all when the tract is damaged, be it by the tumor or by surgery. The relation of AF with other WMTs like the corticospinal tract and the visual pathway is another important issue which needs to be considered before and during surgery. Tumors do not make any difference between WMTs when they invade the cerebral white matter. However it is important for neurosurgeons to make this difference and to have knowledge about these tracts and their relations. Patients presenting with troubles of speech may have other symptoms like motoric deficits or troubles with their sight too. Our hypothesis was therefore that the visual pathway and the corticospinal tract should be located in the vicinity of the AF. We wanted to know where AF was located in relation to these tracts aiming neurosurgical accuracy while reducing surgical complications.

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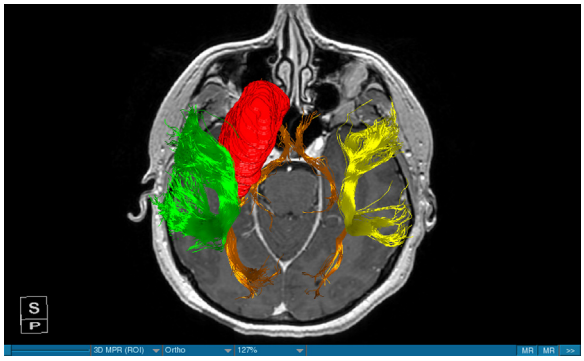

Fig. 1. Capsula externa bleeding left side 5.6 cm long and 1.9 cm wide; blood: red; AF left: green; AF right: yellow; visual pathway: gold.

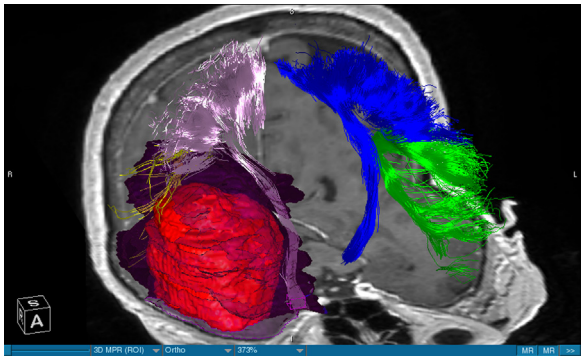

Fig. 2. Glioblastoma temporal on the right side 6 cm long, 4.2 cm wide and 5.3 cm high; AF left: green; AF right: yellow; corticospinal tract left: blue; corticospinal tract right: rose bright; edema: purple; tumor: red.

2. Materials and methods

We have been performing DTI on 71 patients from March 2012 to May 2014. Men, women and children of all age were included. There were 38 men and 33 women. The mean age was 53 years. 28 patients presented with low-grade glioma or glioblastoma, 8 patients had meningioma, 8 patients had metastasis and 3 others suffered from lymphoma. We performed DTI in 2 patients with cerebral hemorrhage and in 2 others with an abscess (Figs. 1–3). We included in our study 6 deep brain stimulations and 7 patients with arterioveinous malformations. 7 patients had other different pathologies. DTI was performed before and after surgery on 11 patients on a 3-Tesla-MRI General Electric Signa HDxt. For the navigation we used a 3DT1-, a T2- and DTI-sequences. The FOV was $200 \times 200\,mm^2$, slice thickness 2 mm, and an acquisition matrix of 96×96 yielding nearly isotropic voxels of $2 \times 2 \times 2$ mm. The low

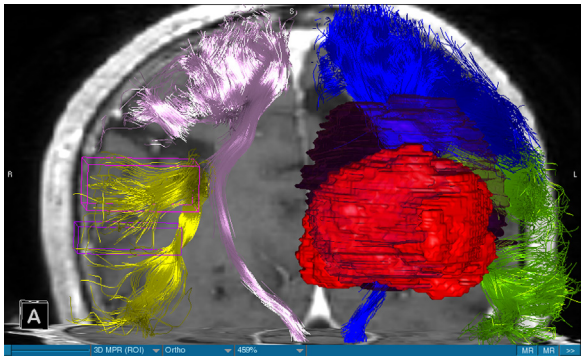

Fig. 4. Glioblastoma opercular region left 5 cm long, 5 cm wide and 4 cm high before surgery; AF left: green; AF right: yellow; corticospinal tract left: blue; corticospinal tract right rose bright; edema: purple; tumor: red.

matrix was used in order to improve the signal. MRI was carried out strictly axial using 32 gradient directions and one *b*0-image. We used Echo-Planar-Imaging (EPI) and ASSET (array spatial sensitivity encoding technique) parallel imaging with an acceleration factor of 2. *b*-Value was $800\,s/mm^2$. Additional scanning time was less than 9 min. DTI-data were processed on an FDA approved surgical navigation system program (StealthViz, Medtronic Inc., USA). The software uses a deterministic straightforward fiber tracking approach known as fiber assignment by continuous tracking (FACT). This is based on the propagation of lines between regions of interest (ROI). ROIs are defined by the physician. We used two ROIs to depict AF. ROI-diameter varied between 1 and 2 cm. ROIs were placed manually using anatomical landmarks in the axial, coronal and sagittal images with the help of an expert in neuroradiology. One of them was set in the frontal inferior gyrus and the other one in the posterior-superior gyrus of temporal lobe.

When these regions were invaded by tumors or edema then we placed our ROI next to them always including a part of the lesion within the ROI. The parameters for tractography were a maximum angle of 60°, FA start value of 0.10 and ADC (apparent diffusion coefficient) stop value of $0.20\,mm^2/s$ which were based on personal experience.

3. Results

AF was visualized in 63 patients on both sides. The left AF could not be portrayed in one glioblastoma patient. In six other patients it was not possible to portray the right AF due to lesions in that area, surrounding edema or both. In one patient there seemed to be no right AF. We identified 33 out of 71 patients as patients at risk. These were patients with a lesion bordering AF or patients who already presented aphasia due to the lesion (Figs. 4 and 5). The lesion and

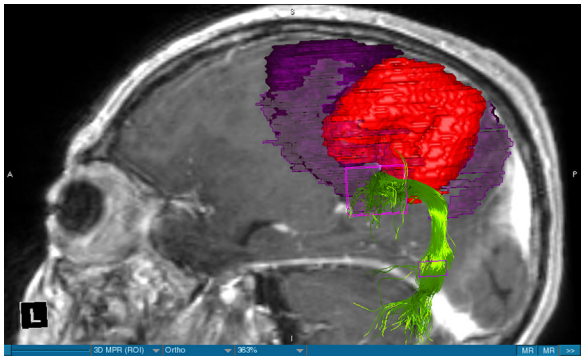

Fig. 3. Abscess right side 5.9 cm long, 3.3 cm wide and 4.7 cm high; AF left: green; AF right: not-portrayable; edema: purple; abscess: red.

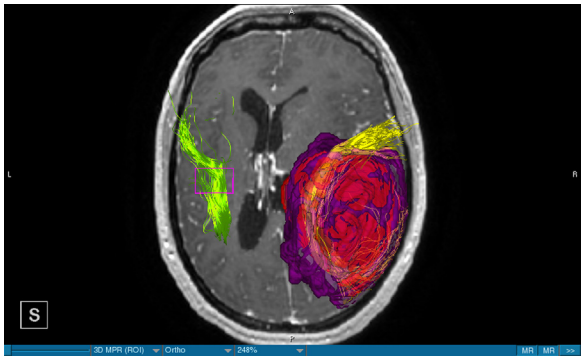

Fig. 5. Glioblastoma temporoparietal right 5.1 cm long, 6 cm wide and 6.8 cm high; AF left: green; AF right: yellow; edema: purple; tumor: red.