"Imaging the Short-Term Memory by fMRI and Fiber Tracking for the Study of Effects of Irradiation in Brain Tumor Patients. A Feasibility Study"

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ABSTRACT

Purpose/Objective(s): To measure brain function by fMRI and fiber tracking (DTI), in order to indicate whether fMRI/DTI can visualize changes in brain function following radiation treatment. Materials/Methods: Five patients irradiated for a brain tumor were included. An MRI (3.0 T, Siemens Allegra head scanner) with high resolution anatomical images and 3D spin echo, rapid dynamic imaging for fMRI and DTI were performed. The working memory was tested by the N-BACK test reflecting neuro-cognitive functions. The fMRI data were analyzed using an automated computerized brain mapping technique (Brainvoyager QX). Among the active areas of working memory those closest to the tumor were selected and the activity of cortical areas around them evaluated. The activation maps and fiber tracts were fused to the diagnostic scans according to the transformations computed with the registration process. Tractography was operated on the diffusion tensor images to locate fibers next to the fMRI activati...
Purpose:
- Proof-of-principle study
- To develop objective quantitative measures of brain function using fMRI and fiber tracking (DTI)
- To indicate whether fMRI/DTI can visualize changes in brain function following radiation treatment

Patients and Methods:
- 5 patients with primary brain tumour irradiated within the last 2-5 years (3 male/2 female, age: mean 55.6 years (30-64 yrs), handedness: all right sides) (See Table)
- Tumours located supratentorially and frontally
- A 3.0 T MRI Siemens Allegra head scanner was used.
  - Imaging protocol consisted of a localizer, high resolution anatomical images T1 weighted (MPRAGE) and T2 weighted (3D spin echo), 12 and 80 directions
  - DTI and an fMRI which was done using fast dynamic imaging (EPI) during a neuro-cognitive task.
- fMRI task: N-BACK test
  - Reflects neuro-cognitive functions which are located frontally (working memory including (visuo-)tactial and language testing).
- fMRI data analyzed with automated computerized brain mapping technique (Brainvoyager QX). Among the specifically active areas of the working memory network those closest to the tumour were selected and the activity of cortical areas around them evaluated (VOI) (Fig. 1).
- DTI: Tractography operated on diffusion tensor images to locate fibers next to the tumor using 3D Slicer (Fig. 1).
- The diagnostic scan (before radiotherapy) was registered to the study images. The activation maps and fiber tracts were fused to the diagnostic scans and to the dose map corresponding to the dose given during treatment.

Results:
- fMRI: the working-memory function could be demonstrated within the irradiated area and around the tumor.
- Out of 5 scanned patients, only 2 were able to perform the working-memory test with a minimum accuracy of 80%.
  - 3 patients irradiated to a high dose (60 Gy) could either not perform the test (patient 1 and 2), or performed badly (pat. 5).
  - fMRI activation spots could be found within the irradiated area and around the tumor (activation volumes represented as small yellow and orange volumes) (Fig. 2).
- DTI: Evaluation of fiber tracking only possible in a descriptive manner.
  - DTI analysis showed that the symmetry of the fibers was disrupted around the tumor.
  - Fibers (in green and blue, Fig. 2) are shown around the tumor and around the functional areas of the memory test as well as the corresponding contra-lateral “normal” brain area.
  - No real differences observed beside for patient 6, where only few fibers in the resected area can be demonstrated (small image below).

Many unexpected difficulties needed to be overcome in order to fuse all different datasets (functional information, radiotherapy dose, volumes) and distorted data due to a too large head (not the whole brain could be scanned).

Conclusions:
- Feasibility demonstrated that it is possible to integrate functional information based on activation of a neuro-cognitive task using fMRI and DTI in the planning of radiotherapy.
- Methods of quantification of DTI need to be defined.
- This is a first step to develop objective and quantitative measures of brain function using combined fMRI and DTI in order to understand the effects of irradiation on functionally important areas and minimize them.
- Future studies need to be conducted to show memory imaging as a valid tool to evaluate function for brain tumor patients and influence of irradiation and by comparison with a control group.