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Short Communication

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Subcortical Stimulation of Fascicles Under ioUS Control with Incorporation of Landmarks

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Introduction

nTMS is a powerful tool to map the cortex and underlying 20mm or so, but few if any fascicle is located at this depth. Cortical mapping is primordial to determine the entry zone, but then starts the hazardous tissue: it has been demonstrated that the most permanent neurological deficits are induced by subcortical damage, vascular or not.

Methods

In current subcortical stimulation-mapping, the exposed white matter is stimulated, either by a dedicated probe or by CUSA-tip: so, the tissue can only be evaluated on eloquence during the resection proper, not in advance. A major drawback in classical subcortical "mapping" is the possible discordance between the site of stimulation and the expected task result. When a white matter tract is encountered, neither the exact location, nor the stimulation threshold nor the response to the task is known in advance. In fact, it is not a real mapping but rather a local testing. So "mapping" in the depth is diving in an unknown territory; either a step-by-step procedure can be initiated, in which each stimulation is followed by resection or not, and each resection by nearby stimulation: at each level appropriated tasks have to be proposed, and an error in choice can be fatal for inducing deficit. An option is to stimulate subcortically at the tip of an electrode, directed towards a MRI-DTI visualized fascicle. starting from the entry point of the chosen trajectory. When the progression of the needle is visualized under ioUS, sulci and vessels can be avoided. Puncture of intrinsic brain tumors (gliomas, metastasis, e.a.) (Figure 1) can give information about anatomical, functional and histological data from the start of the operation. Electrical stimulation at the tip of the puncture needle (as is done for DBS) indicates function or absence of measurable function at the punctured site: if function is present, biopsy or resection obviously cannot be performed, and the site can be registered in the navigation (Figure 1).

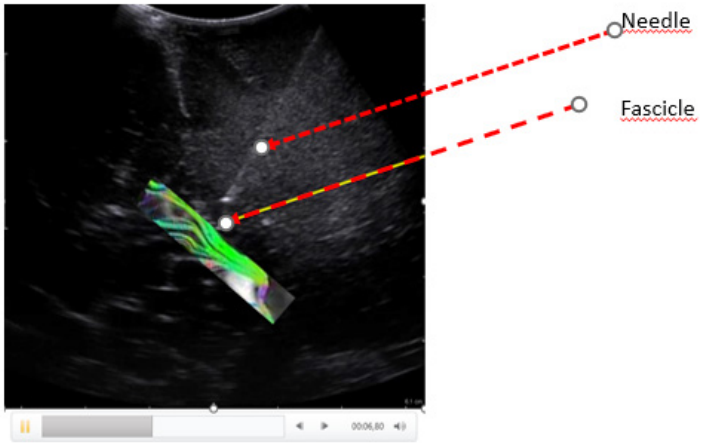


Figure 1: Introduction of Stimulation Needle with projection of underlying fascicle on navigation merge.

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The anatomical tumor border is visible on US [1], the functional border is evaluable with stimulation [2]: the resection should be stopped before the functional limit. This combines the probability of the localization of the fascicle with the real time punction, while one or several tasks can be tested during the stimulation at the tip. The anatomical border being visible real time under US, the functional border, i.e. the limit of resection, can be determined by positive or negative stimulation, resp. evoking a motor or other response or inhibition of a cognitive function, e.g. speaking (Figure 2).



Figure 2: Introduction of Stimulation Needle under pre-planned trajectory.

The precise location of the anatomical and functional border can be defined with registration of coordinates before any brain shift; besides the location, the stimulation parameters and threshold are known, as well as the optimal task to attribute to the site [3]. The location being determined, a US-visible dye can be injected as landmark. The substance should be visible at Ultrasound, colored to be seen during the resection, and should not stick to the CUSA nor the bipolar forceps. It should be ideal to have 2 different dyes, one for the anatomical and one for the functional border. When this is applied at different angles and different depths, a 3D-scaffold is realized, that can be used as reference frame during the resection proper. A real 3D map with anatomical and functional limits is provided. Obviously, the Ultrasound probe has to be fixed firmly to the patient's skull (Figure 3). Rotation over 360° should be possible to stimulate all around (Figure 4). The puncture trajectory can be predetermined by the lateral clamp provided with the probe, or with a dedicated custom made mini-stereotaxic needle guide (Figure 3,4,5) [4].

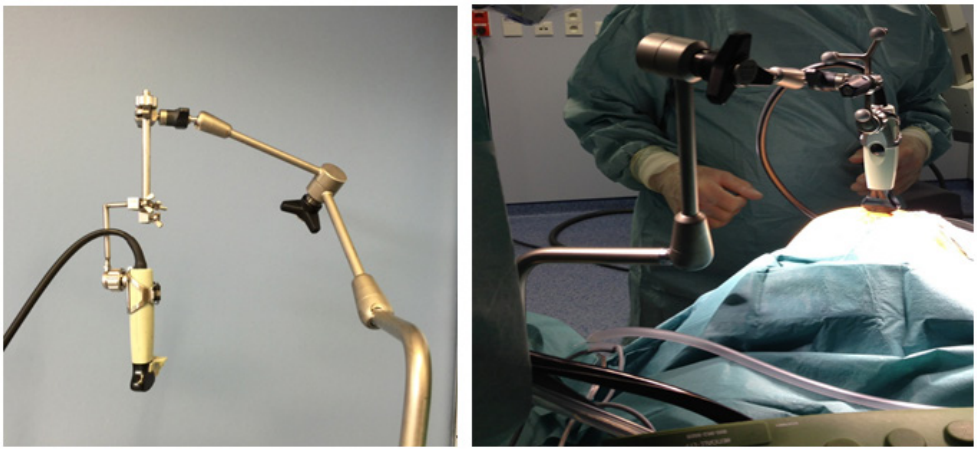


Figure 3: FIXATION OF US PROBE excentric rotation.

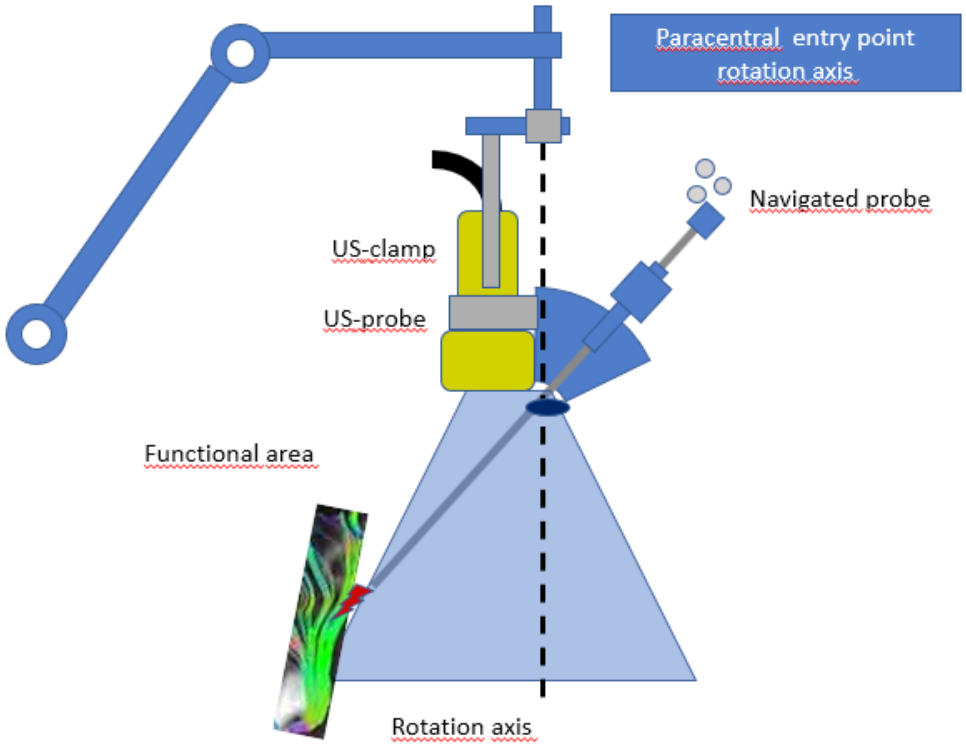


Figure 4: Paracentral entry point rotation axis.



Figure 5: Prototype of mini-stereotaxic needle guide fixed to BK-Brain lab clamp.

The position of the patient being usually with the vertex towards the surgeon, and the trajectory to the zenith, the Ultrasound probe has to be positioned in the same direction as the trajectory, parallel to the entry point of the needle (Figure 6). When the US probe is navigated, a simultaneous image is provided from the Ultrasound and from the MRI-image with fascicle visualization, in the same plane- both can be merged (Figure 6,7) [5].

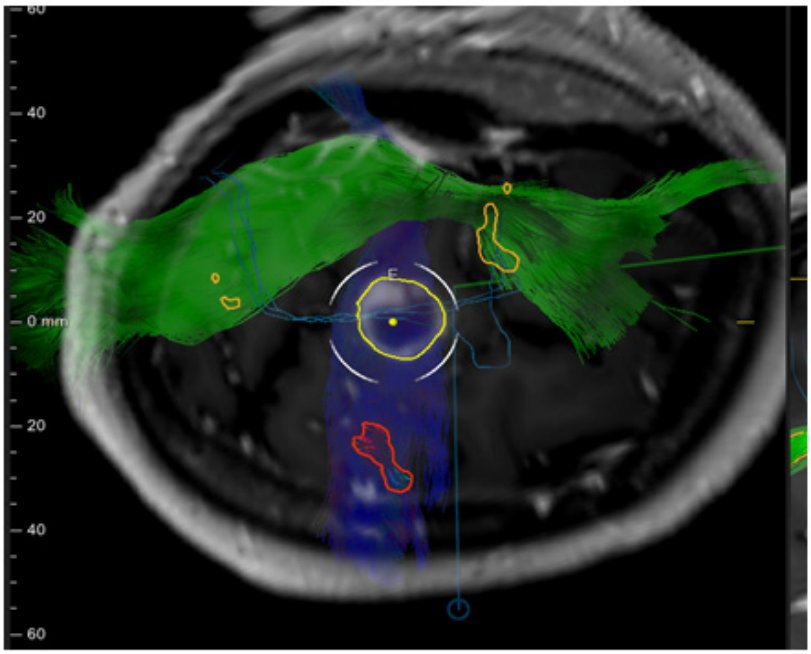


Figure 6: Puncture in any trajectory possible.

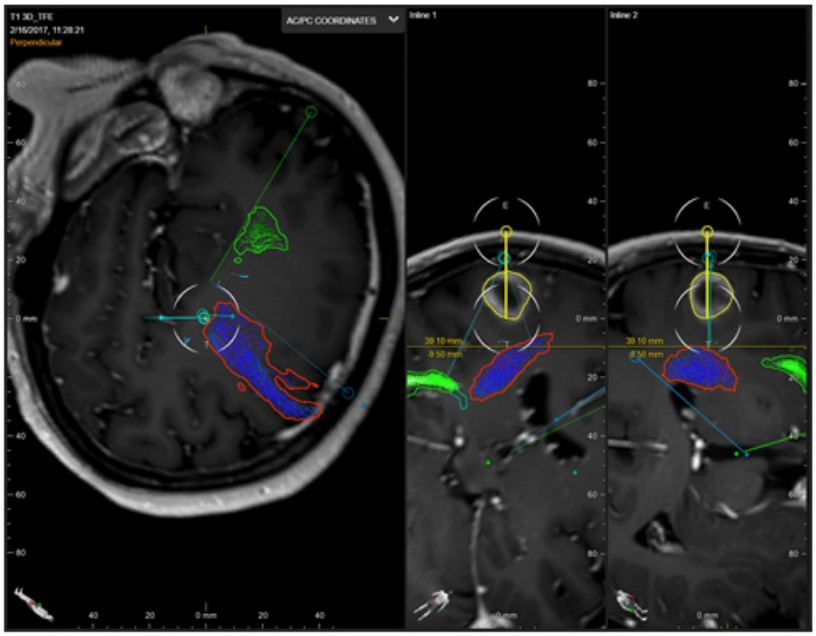


Figure 7: Trajectory visualized with US-navigation.

Moreover, there is the possibility to perform biopsies at e.g. very positive PET-scan sites, to differentiate the tumor grade in function of the location, before any shift. Impedance measurements also could be valuable. A major advantage is the depth cartography at any angle and depth, without hemorrhagic risk, and without damaging deep structures. If it could occur, complications as hemmorrhagy could be detected immediately.

Results

This technique has been applied on 5 patients, without side effects nor complications. A drawback could be the duration of the supplementary mapping; however, having performed the 3D-US-scan, introduction of a stimulation needle under real time US control is very fast, regarding the anatomical reference, indicated by the navigation and verified by the ioUS, and the functional reference, visualized by the superimposed Fiber Tract image on navigation. Moreover, knowing in advance the depth of functional fascicle, the task to be presented, and the stimulation parameters, time is gained at that stage of the operation. Any neurosurgical center having the facilities of intraoperative ultrasound and neuronavigation can perform this procedure. Technical improvement should be the availability of a dedicated needle, yielding as well tip stimulation, possibility of biopsy and injection of a marker at the tip.

Conclusion

A novel concept is presented, with possibility of puncture of tumor and its periphery under real time Ultrasound visualization, with electrical stimulation at the tip. This yields functional evaluation at the tumoral borders, localized serial biopsies, and injection of landmarks at specific spots as guide for further resection.

Acknowledgments

None.

Conflict of Interest

None.

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