Case: Motor Cortex Stimulating Implants

Navigated Brain Stimulation (NBS) for motor cortex stimulating implant localization in patients with stroke

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Background

Despite rehabilitation, permanent motor deficits are common in patients who have suffered a stroke. Combining invasive electric stimulation of the motor cortex with rehabilitation measures has produced promising results in both animals and in early clinical trials (1). In a Phase II trial of 24 patients, clinically significant improvement in upper extremity Fugl-Meyr scores was observed in 67% of patients receiving combined motor cortex stimulation and rehabilitation, compared to 25% of the patients receiving rehabilitation only (2). However, in a pivotal Phase III trial, no significant difference in motor improvement was found between the treatment groups.

Given the promising Phase II trial results, the failure of the Phase III trial has been considered surprising. In a recent analysis, it was recognized that in the failed trial only 16% of patients showed evoked potentials of the affected limb when intraoperatively stimulated, compared to 42% of patients in the Phase II trial (1), suggesting that either patient selection or localization of the stimulating implants may have been suboptimal. In support of this critique, the subset of implanted patients in the Phase III trial, who showed evoked potentials, demonstrated significantly greater improvement score than the patients in the rehabilitation-only group (1). Since the presence of functioning descending motor pathways is an important factor contributing to the prognosis of motor recovery after stroke, pre-surgical determination of the viability of the motor pathways could provide an important tool for patient selection and, potentially, also for planning implant localization.

Navigated Brain Stimulation (NBS) is a non-invasive technique for electrocortical stimulation. Instead of generating an electric field from electrodes placed on the exposed cortex, as in intraoperative direct electrocortical stimulation (DCS), with NBS the electric field (E-field) is induced intracranially by triggering a transcranial magnetic stimulation (TMS) coil placed externally to the head.

In NBS mapping, the patient's MRI dataset is used to link the location, as well as orientation of the TMS-generated stimulating E-field, to the individual patient's cortical anatomy. Using stereotactic navigation techniques, movement of the TMS coil guides the calculated E-field location through the intracranial structures. The simultaneous measurement of motor evoked potentials (MEPs) by electromyography (EMG) is used to identify and verify the motor representation areas in the cortex, in the same manner as with DCS. DICOM-export of motor response maps permit direct integration of functional mapping data into other DICOM-compatible software applications, allowing NBS mapping results to be viewed during intervention planning, for example in a neuronavigator.

In clinical studies in brain tumor surgery, the NBS System (Nexstim Oy, Helsinki, Finland) localized the motor cortex in all patients to the same gyrus as intraoperative DCS. According to the operating neurosurgeons, the results of preoperative mapping of the motor cortex with NBS mapping are as accurate as DCS (3, 4).

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Aim

NBS motor mapping identifies the cortical locations of the motor representation areas as well as allows determination of the stimulating E-field direction which gives rise to maximal motor responses (MEP). We therefore examined whether NBS mapping results can be successfully used for patient selection in chronic stroke, as well as the pre-surgical planning of the location and orientation of the motor cortex stimulating electrodes.

Figure 1: The NBS System used to map the motor cortical areas. At the beginning of a stimulation session the NBS System enables fast alignment of the patient's head to the individual MR-images (top left). On the stimulation planning screen (left screen), the location of the stimulation target, the locations providing responses and the stimulating E-field orientation are visualized in a 3D rendering of the brain. The motor response screen (right screen) displays 6-channel EMG and the triggered EMG responses in real time.

Patient case

A 63-year-old female, who had suffered a right-sided stroke 7 years earlier, was studied. Before stimulating by cortical electrode implantation, the patient had undergone intensive conventional rehabilitation. However, despite rehabilitation, she exhibited no muscle movement of functional relevance in the hand muscles of the lesioned side. An NBS mapping examination was performed to determine the presence of viable descending motor pathways, the cortical location giving rise to largest MEPs and the direction of the stimulating E-field giving rise to the largest responses. The results of the examination were confirmed by repeating the NBS mapping examination on a separate occasion.

A 3D T1 MRI dataset with 1x1x1mm voxels was obtained**.** After loading the MRI dataset to the NBS System, the patient was prepared for the cortical mapping session. EMG surface electrodes were placed over the muscles corresponding to the critical hand motor areas in the cortex (m. Abductor Pollicis Brevis (APB), m.

First Dorsal Interosseous (FDI) and m. Extensor Carpi Ulnaris (ECU)). NBS mapping was initiated by localizing the cortical representation area of the thenar muscle (m.APB) and determining its motor threshold (MT). Mapping of the hand motor cortical areas was performed with the stimulation intensity adjusted for the lesioned side to 110%, of m.APB MT. If motor responses were not obtained using single TMS pulses at 100% stimulator intensity, then a facilitating paired pulse stimulation paradigm was used.

The data file of the mapping session was retrieved from the NBS System for post-processing. The cortical location giving rise to the largest responses for the m.APB and the corresponding orientation of the stimulating E-field were recorded (see Figure 2). For use in the neuronavigator and planning the implant surgery, the results were exported in DICOM format and as screenshots (see Figure 3).

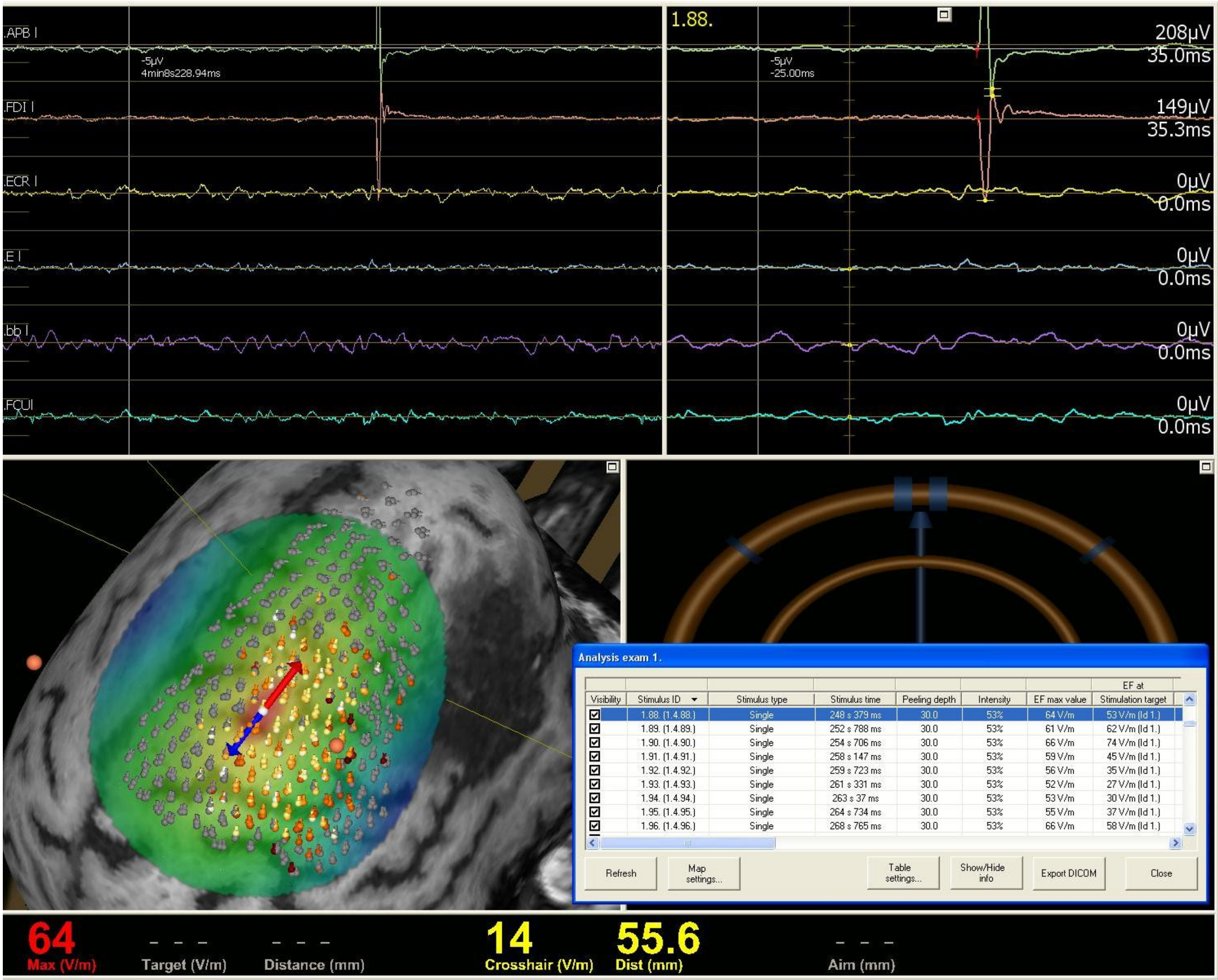

Figure 2: The NBS System screen displaying with windows displaying EMG monitoring, location targeting and a heat map of responses in a 3D rendering (bottom left window). All the stimulated locations giving rise to motor responses are shown in the heat map, color-coded according to the magnitude of the response (white > yellow > red, grey = no response to stimulation). The optimal stimulus location, the cortical location giving rise to the largest responses for the m.APB muscle, is shown by the white marker in the 3D rendering; the red and blue arrows indicate the orientation of the stimulating E-field. The corresponding stimulus-synchronized EMG response for the optimal stimulus location is displayed in the top right window.

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During surgery, motor cortex stimulating electrodes (Resume, Medtronic Inc, USA) were implanted with the centre of the electrodes placed over the cortical location which evoked the largest motor responses during NBS mapping. Similarly, the orientation of the implanted electrodes was based on the optimal E-field orientation determined during NBS mapping. To ensure that the correct location and orientation of the implant had been achieved, the stimulating electrodes were used to evoke motor responses in the affected limb.

Figure 3: Surgical placement of cortical implant electrodes with the help of the NBS mapping results using an image guidance system (VectorVision, Brainlab AG, Feldkirchen, Germany).

Results

After implantation, the patient received conventional rehabilitation combined with invasive cortical stimulation provided through the implant. After 2 months the patient showed clinically significant improvement in hand motor function. The patient was, for example, capable of grabbing objects, a task she had been unable to perform before implant surgery.

Conclusion

Based on our experience with this patient, and other similar cases, NBS motor mapping in patients with stroke is a clinically practical concept. NBS mapping facilitates patient selection for motor cortex stimulating electrode implantation and enables placement of the electrodes in the optimal location and orientation.

References:

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