Reference articles for Nexstim Navigated Brain Stimulation in neurosurgery

Nexstim Navigated Brain Stimulation has been studied in altogether 21 original articles including 359 patients. These include 12 articles including 231 patients on motor mapping in tumor surgery, 5 articles including 27 patients on motor mapping in epilepsy surgery, 2 article including 21 patients on language mapping, and 2 articles including 80 patients on using NBS results as seeding points for diffusion tensor imaging. In addition, 2 method articles and 1 review have been published, as well as conference abstracts, white papers and clinical statements.

Articles on motor mapping in tumor patients


Level of evidence IIa

Description: Controlled trial in 20 patients undergoing surgery for rolandic brain tumors comparing clinical accuracy of non-invasive preoperative navigated transcranial magnetic stimulation to intraoperative direct cortical stimulation. Shows that both methods localize the primary motor cortex to the same gyrus. Authors conclude that nTMS is a reliable tool for preoperative mapping of motor function.


Level of evidence IIa

Description: Controlled trial in 11 patients undergoing surgery for central region tumors evaluating the reliability of non-invasive preoperative navigated transcranial magnetic stimulation (nTMS) compared with fMRI and intraoperative direct cortical stimulation. Shows that nTMS is more accurate than fMRI when direct cortical stimulation is used a golden standard. Authors conclude that nTMS anticipates information usually only enabled by DCS and therefore allows surgical planning in eloquent cortex surgery.


Level of evidence IIa

Description: Controlled trial in 26 patients undergoing surgery for brain tumors comparing clinical accuracy of non-invasive preoperative navigated transcranial magnetic stimulation to intraoperative direct cortical stimulation as well as fMRI. Validates accuracy of NBS for motor mapping with mean distance between NBS and DCS hotspots of 4.4 mm and reports NBS to agree more closely with DCS than fMRI. In addition, shows positive impact of NBS results on surgical planning.

Level of evidence IIa

Description: Clinical trial in 73 patients with brain tumors assessing the influence of pre-operative NBS motor mapping on subsequent surgical planning. NBS confirmed the expected anatomy in 22% of cases, added knowledge that was not used in 23%, added awareness of high-risk areas in 27%, modified the approach in 16%, changed the planned extent of resection in 8%, and changed the surgical indication in 3%. nTMS had an objective benefit on the surgical planning in one-fourth of the cases and a subjective benefit in an additional half of the cases. It had an impact on the surgery itself in just over half the cases.


Level of evidence IIa

Description: Controlled trial in 24 patients undergoing surgery for brain tumors comparing clinical accuracy of non-invasive preoperative navigated transcranial magnetic stimulation to intraoperative direct cortical stimulation. Validates accuracy of NBS for motor mapping with mean distance between NBS and DCS hotspots of 2 mm and reports NBS to agree more closely with DCS than MEG.


Level of evidence IIa


Level of evidence IIa


Level of evidence V


Comparative study in 8 patients. NBS is superior to fMRI in motor mapping.


NBS allows evaluating cortical reorganization after brain tumor surgery. It may contribute to the understanding of neurofunctional dynamics, thus influencing therapeutic strategy.

**Case report – successful mapping in a young child with a brain tumor**


**Case report of a patient with brain tumor in whom NBS mapping resulted in recovery of function in paretic arm.**

Neurosurgeons at the Charité University Hospital, Berlin. Signed clinical statement of the safety and clinical benefits of NBS motor mapping for planning brain tumor surgery (available in Nexstim website).

**Articles on motor mapping in epilepsy patients**


The authors compared the nTMS motor cortical representation maps of hand and arm muscles with the results of invasive electrical cortical stimulation (ECS) in 13 patients with focal epilepsy. The 3D distance between the average nTMS site and average ECS electrode location was 11±4 mm for the hand and 16±7 mm for arm muscle representation areas. In all patients the representation areas defined with nTMS and ECS were located on the same gyrus, also in patients with abundant interictal epileptic activity on the motor gyrus.


**Level of evidence III**

**Description:** Prospective study in 10 consecutive patients undergoing brain surgery due to intractable epilepsy originating from loci near motor cortex. Shows that nTMS can be safely and successfully be performed in this patient population and that the obtained diagnostic information was clinically essential or beneficial in 6 of the 10 patients.


**Level of evidence V**

**Description:** Describes 2 patients undergoing subdural grid implantation and subsequent surgery for intractable epilepsy. Shows that in both patients non-invasive preoperative nTMS accurately identified cortical motor representation areas as verified by electrocortical stimulation through the implanted grid as well as through outcome of surgery.

Level of evidence V

Description: Presurgical nTMS evaluation was performed on an 8-year-old boy with left-sided intractable focal epilepsy, somatosensory auras and epilepsia partialis continua, to identify the pathological hyperexcitability zone indirectly. In the affected hemisphere motor evoked potentials could be elicited over a large area of the cortex even after the stimulation strength was reduced by at least 44%. Latency stratification in the affected hemisphere differentiated a motor from a sensory region of interest. Stimulation over the sensory region induced a sensory aura. The zone was concordant with the MRI epileptogenic lesion.


2 patients undergoing epilepsy surgery (age 9 and 19) demonstrated unexpected motor cortex plasticity by NBS as well as MEG+fMRI

Articles on language mapping


Level of evidence IIa

A good overall correlation between repetitive nTMS and DCS was observed, particularly with regard to negatively mapped regions. Non-invasive inhibition mapping with nTMS is evolving as a valuable tool for preoperative mapping of language areas.


Level of evidence V

Authors describe the successful use of the NEXSPEECH-NBS speech mapping paradigm in four healthy subjects. Speech responses were obtained in all subjects and the mapping was well tolerated.


Level of evidence V

Neurosurgeons at the Charité University Hospital, Berlin, and at the TU München. Signed clinical statement on safety and clinical benefits of NBS speech mapping for planning brain tumor surgery (available in Nexstim website).

Articles on DTI


Level of evidence IIa

**Level of evidence III**

DTI-tracking was performed both using NBS motor mapping results as seed sites and without the information in 30 patients with brain tumors to visualize white matter motor tracts. Tracts obtained with the two methods were compared to each other. Utilization of NBS results as seed sites resulted in more user-independent tractography and more specific tract structure.

**Articles on motor cortex implant localization**


**Level of evidence V**

Authors describe successful use of NBS motor mapping to identify the optimal location for implantation of a motor cortex stimulating electrode for enhanced motor rehabilitation in a patient with chronic stroke and non-existent pre-operative hand function.

**Articles on radiosurgery planning**


**Level of evidence V**

Authors describe the workflow of successful integration of NBS motor mapping data to Brainlab iPlan radiotherapy planning software.


**Level of evidence V**

Authors describe a case where NBS motor mapping results were successfully integrated into the Elekta GammaPlan stereotactic radiosurgery planning software and used to optimize dose planning in a patient with therapy target close to the motor cortex.

**Articles on NBS methodology**


Method paper. Open avenues for speech mapping future development.