Epidural stimulation of the motor cortex for neuropathic pain: future directions

Reithmeier T., Pinsker M., Piroth T., Trippel M. Prokop T., Nikkhah G.
Department of Stereotactic and Functional Neurosurgery, University of Freiburg

Objective:
Motor cortex stimulation (MCS) has recently been demonstrated to be an effective therapeutic option for patients with intolerable neuropathic pain. However long term improvement of pain control is still unsatisfactory and around 25% of patients do not respond to MCS. Therefore we retrospectively analyzed our experience with MCS and - based on these findings - developed future approaches for optimizing this therapy.

Patients and methods:
Four patients with intractable unilateral neuropathic pain (average visual analog scale (VAS) score: 8) secondary to brachial plexus lesions (2 patients), thalamic stroke (1 patient) or brainstem stroke (1 patient) were selected for MCS. The motor cortex was anatomically located in stereotactic technique based on preoperative MRI and a 4-contact electrode (Medtronic Resume 2) was placed epidurally on the motor cortex via a 6mm burr hole. Correct placement of the electrode was confirmed by intraoperative cortical stimulation. Postoperatively the therapeutic effect was tested via an external stimulator and in patients with a positive effect a permanent neurostimulator was implanted (Medtronic Itra III or Synergy). Patients were postoperatively followed-up for a period up to two years and improvement of pain was documented using the VAS scoring system.

Results:
One patient did not report improvement of the pain by external stimulation and was excluded from long-term MCS. Three patients reported a significant positive effect of the external stimulation and underwent implantation of a neurostimulator. During the follow-up period adjusting of the stimulation parameters was necessary in one patient. All of the implanted patients reported a significant improvement of the pain (average VAS score: 4) that persisted during the follow-up period.

Discussion:
The pathophysiological concept of MCS for treatment of neuropathic pain is based on two fundamental principles. Correct identification of that part of the functional motor cortex corresponding to the painful part of the body and application of a current to up-regulate motor cortex excitability. However functional reorganization of the motor cortex has been observed in patients after spinal cord injury or cerebral infarction and as a consequence the anatomically identified precentral gyrus might not represent the functional motor cortex. Therefore generating an individualized somatotopic map of the motor cortex by high resoluted functional-MRI and integrating these data into a frameless, neuro-navigation-based stereotactic system could be helpful for exact electrode placement.

The next step in therapy is to determine the optimal stimulation parameters. Various stimulation regimes exist and up to date no standardization has been achieved, which might lead to a long lasting postoperative trial phase. The development of a computer based stimulation system that virtually visualizes the distribution of the applied current in the brain could support the determination of the optimal stimulating parameters for adequate pain control. Moreover side effects due to inadequate stimulating parameters could be prevented and the hospital stay of the patient reduced.

As the wearing-off effect of MCS is still not fully understood, follow-up evaluation with f-MRI would be desirable to verify ongoing cortical reorganization events triggered by the continuous electrical stimulation or the underlying disease, that might reallocate the optimal stimulation target. Additionally an electrode with the ability to simultaneously stimulate the motor cortex and deduce an electrocorticogram could provide scientists with online information about the electrophysiological effects of continuous motor cortex stimulation.

Conclusion:
In three of four patients MCS induced a significant improvement of pain control during the follow-up period. Virtual imagination of changes in the spatial distribution of the current flow characteristics in relation to different stimulation parameters and improved methods for placement of the epidural strip electrode by functional MRI and frameless stereotactic techniques could improve MCS-therapy for neuropathic pain in the future. The development of a multifunctional strip electrode could be an important tool to investigate the electrophysiological mechanisms of cortical reorganization.
