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MOTOR CORTEX STIMULATOR IMPLANTATION GUIDED BY COMBINATION OF FRAMELESS NAVIGATION AND INTRAOPERATIVE NEUROPHYSIOLOGY

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Abstract: *Introduction*: Motor cortex stimulation (MCS) is perhaps the most promising and least invasive modality for management of the central deafferentation pain syndromes. Described more than a decade ago for the treatment of thalamic and trigeminal pain syndromes, this non-destructive procedure is gradually becoming widely accepted.
Methods: Recently, we used a combination of intraoperative computer-guided navigation and intraoperative electrophysiological monitoring for motor cortex localization in 3 patients with medically intractable pain following cerebral infarction or previous surgery.
Results: The motor cortex was identified using functional MRI on 3-Tesla scanner. Imaging data were used for intraoperative frameless computer-aided navigation. Motor cortex position was verified with epidural recording of somatosensory evoked potentials. Pain relief was obtained with bipolar stimulation below the motor threshold.
Conclusion: Combination of functional MRI, image-guided computer navigation, and intraoperative electrophysiological testing allows one to precisely localize motor cortex and subsequently achieve excellent pain relief in patients with medically intractable central pain. MCS may be an option for patients with chronic pain syndromes due to strokes, destructive surgical procedures and other deafferentative processes

Introduction

Initially described more than 10 years ago [1], chronic stimulation of the motor cortex in patients with medically intractable neuropathic and central pain has become a widely accepted procedure with multiple reports recently appearing in the literature from more than dozen of clinical centers [2-10]. It has been noted in several publications that the long-term success of this non-destructive approach greatly depends on accuracy of localization of the motor cortex [2], making correct localization of the motor cortex extremely important during the procedure.

Eventually, an approach was described that utilizes computer-assisted neuronavigation based on anatomical and physiological data [2, 7-10]. Since functional magnetic resonance imaging (fMRI) and frameless intraoperative image-guidance are now widely available, we decided to present our technique of combining the frameless navigation and intraoperative neurophysiology for motor cortex stimulator implantation.

Description of technique

Recently, we used a combination of intraoperative computer-guided navigation and intraoperative electrophysiological monitoring for localization of the motor cortex in 3 patients with medically intractable pain following cerebral infarctions (n=2) or facial deafferentation pain after surgery for treatment of trigeminal neuralgia (n=1). The patients did not respond to various means of medical management including a trial of intrathecal opioids. They were, therefore, considered for motor cortex stimulation procedure and had a formal neuropsychological testing that we perform routinely in all patients undergoing pain-relieving surgical interventions.

During the pre-operative workup, it became obvious that the patient's anatomical MRI does not clearly identify the position of motor cortex; therefore we decided to use fMRI for its localization. In one patient, however, due to severe discomfort and persistent uncontrolled movements, acquisition of fMRI became problematic. A paradigm was developed to localize the motor cortex under general anesthesia by subtracting the area of activation that occurs during tactile stimulation of the hand from similar activation that takes place when the hand is passively moved in the wrist joint. The location of the motor cortex obtained with this method was then reconstructed with CBYON image-guidance system (CBYON Inc., Mountain View, CA). The fMRI acquisition was done in the morning of surgery with the patient having fiducial markers attached to the skin of the frontal and parietal regions. The information was then processed and prepared for intraoperative navigation.

In the operating room, a small (about 4 cm in diameter) round craniotomy was performed over the area of the motor cortex that was located earlier. The position of the motor cortex and the central sulcus was then further verified by an epidural recording of the somatosensory evoked potentials using a 16-contact (4x4) standard electrode-recording grid (Ad-Tech Instrument Corp., Racine, WI). Reversal of the N20 peak polarity indicated location of the Rolandic sulcus. The quadripolar electrode (Resume, Medtronic Inc., Minneapolis, MN) was then positioned over the motor cortex and sutured to the dura before the replacement of the bone flap. We did not incise the outer layer of the dura as was suggested by some authors to minimize stimulation-induced headaches that may arise from direct dural irritation.

During the subsequent 5-day-long inpatient trial, pain relief was obtained with bipolar stimulation at a voltage of about 60% of the motor stimulation threshold. There were no stimulation-induced paresthesias; pain relief from the stimulation was almost immediate and lasted for few minutes after the stimulation was stopped. Once the trial was completed, the electrode was internalized, and the ITREL 3 (Medtronic) generator was implanted under general anesthesia. The patients were reprogrammed during the post-operative period to achieve optimal pain relief.

Results:

The patients that underwent MCS implant with this technique experienced 80% pain relief during the post-operative period (according to their own estimate). The pain intensity decreased from 8-9/10 before the surgery to 3-5/10 during the inpatient trial, 5-6/10 after internalization, 2-3/10 one month and nine months later. Neither patient required strong analgesics. At the same time, MCS significantly reduced intensity of involuntary movements in contralateral arm in one patient

Discussion:

The motor cortex stimulation is gradually becoming an accepted way to treat medically intractable pain that develops in patients with cerebral infarctions and trigeminal neuropathies [1-10]. Practicality of this straightforward, albeit not completely understood, procedure is somewhat limited by our ability to localize the motor cortex on the side opposite to the patient's pain. Multiple approaches have been suggested to accomplish this task, including anatomical localization of the brain surface, three-dimensional surface rendering using the computed tomography and magnetic resonance imaging, functional imaging with fMRI and positron emission tomography, and electrophysiological approach with intraoperative recording of somatosensory evoked potentials and determination of the polarity reversal of the N20 peak. Recently, frameless intraoperative image-guided navigation has been suggested for motor cortex localization in patients undergoing stimulation procedure [6-8]. Although the idea of using pure imaging-based motor cortex localization has been brought up, the need in intraoperative physiological confirmation remains generally accepted [11].

Using combination of functional MRI, image-guided computer navigation, and intraoperative electrophysiological testing, we were able to precisely localize the primary motor cortex and subsequently achieve excellent pain relief in patients with medically intractable pain. In our opinion, MCS may be an option for patients with chronic pain syndromes due to strokes, destructive surgical procedures and other deafferentative processes.

References:

1. Tsubokawa T, Katayama Y, Yamamoto T, Hirayama T, Koyama S. Chronic motor cortex stimulation for the treatment of central pain. Acta Neurochir (Wien) 1991; Suppl 52: 137-139

2. Nguyen JP, Lafaucheur JP, Deck P, Uchiyama T, Carpentier A, Fontaine D, Brugieres P, Pollin B, Feve A, Rostaing S, Cesaro P, Keravel Y. Chronic motor cortex stimulation in the treatment of central and neuropathic pain. Correlations between clinical, electrophysiological and anatomical data. Pain 1999; 245-251

3. Meyerson BA, Lindblom U, Linderoth B, Lind G, Herregodts P. Motor cortex stimulation as treatment of trigeminal neuropathic pain. Acta Neurochir (Wien) 1993; Suppl 58: 150-153

4. Garcia-Larrea L, Peyron R, Mertens P, Gregoire MC, Lavenne F, Le Bars D, Convers P, Mauguiere F, Sindou M, Laurent B. Electrical stimulation of motor cortex for pain control: a combined PET-scan and electrophysiological study. Pain 1999; 83: 259-273

5. Carroll D, Joint C, Maartens N, Schlugman D, Stein J, Aziz T. Motor cortex stimulation for chronic neuropathic pain: a preliminary study of 10 cases. Pain 2000; 84: 431-437

6. Rainov NG, Heidecke V. Motor cortex stimulation for neuropathic facial pain. Neurol Res 2003; 25: 157-161

7. Mogilner AY, Rezai AR. Epidural motor cortex stimulation with functional imaging guidance. Neurosurg Focus 2001; 11(3): article 4, 1-4

8. Roux FE, Ibarrola D, Lazorthes Y, Berry I. Chronic motor cortex stimulation for phantom limb pain: a functional magnetic resonance imaging study: technical case report. Neurosurgery 2001; 48: 681-688

9. Pirotte B, Voordecker P, Joffroy F, Massager N, Wikler D, Baleriaux D, Levivier M, Brotchi J. The Zeiss-MKM system for frameless image-guided approach in epidural motor cortex stimulation for central neuropathic pain. Neurosurg Focus 2001; 11(3): article 3, 1-6

10. Son BC, Kim MC, Moon DE, Kang JK. Motor cortex stimulation in a patient with intractable complex regional pain syndrome Type II with hemibody involvement. J Neurosurg 2003; 98: 175-179

11. Roux FE, Ibarrola D, Tremoulet M, Lazorthes Y, Henry P, Sol JC, Berry I. Methodological and technical issues for integrating functional magnetic resonance imaging data in a neuronavigational system. Neurosurgery 2001; 49: 1145-1157

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