Spinal cord stimulation for consciousness disorder

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Spinal cord stimulation (SCS) has been explored as a potential treatment for various disorders, including those related to consciousness disorder, which include conditions like persistent vegetative state, minimally conscious state, and coma. The idea behind using spinal cord stimulation for these conditions is to modulate the neural circuits involved in wakefulness, sensory processing, and consciousness, potentially leading to improvements in cognitive function and awareness.

The mechanisms through which spinal cord stimulation might work for consciousness disorders are not entirely clear, but some possible pathways include:

1. **Neurostimulation Effects**: SCS involves the implantation of a device that delivers electrical impulses to the spinal cord. This can modulate neural activity, potentially influencing sensory and motor pathways that are involved in consciousness.

2. **Activation of Sensory Inputs**: The theory is that spinal cord stimulation may activate sensory pathways that could help to “reboot” brain activity or help individuals in a minimally conscious or vegetative state regain some level of awareness by stimulating the brainstem or higher cortical areas.

3. **Improved Connectivity**: By stimulating the spinal cord, SCS could help improve connectivity between the spinal cord and the brain, facilitating communication between these regions that might be impaired in individuals with DoC.

4. **Clinical Studies**: Some small-scale studies and case reports have suggested that spinal cord stimulation could potentially help improve levels of awareness in patients with DoC, particularly in those who have not responded to other treatments. However, the evidence is still limited, and more rigorous, large-scale clinical trials are needed to fully understand its potential and efficacy.

5. **Other Uses**: Aside from consciousness disorders, spinal cord stimulation has been primarily used for chronic pain management and certain motor disorders like Parkinson's disease. In DoC, its use would represent an innovative application in neurostimulation, still in the early stages of exploration.

While the concept holds promise, it is still considered experimental, and decisions to use SCS in patients with consciousness disorders are typically made on a case-by-case basis, with careful consideration of the patient's condition, the potential risks, and available alternatives.

Cervical spinal cord stimulation for minimally conscious state treatment

Cervical spinal cord stimulation for minimally conscious state treatment.

Systematic Reviews

Adhering to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic literature review, the PubMed, Scopus, and Web of Science databases were queried to identify articles published between 1990 and 2023 in which neuromodulation was used, usually in conjunction with pharmacologic intervention, to treat or reverse DoC in humans and animals. Records were excluded if DoC (eg, unresponsive wakefulness syndrome, minimally conscious state, etc) were not the primary clinical target.

Results: A total of 69 studies (58 human, 11 animal) met the inclusion criteria for the systematic review, resulting in over 1000 patients and 150 animals studied. Most human studies investigated deep brain stimulation (n = 15), usually of the central thalamus, and transcranial magnetic stimulation (n = 18). Transcranial direct-current stimulation (n = 15) and spinal cord stimulation (n = 6) of the dorsal column also were represented. A few studies investigated low-intensity focused ultrasound (n = 2) and median nerve stimulation (n = 2). Animal studies included primate and murine models, with nine studies involving deep brain stimulation, one using ultrasound, and one using transcranial magnetic stimulation.

Discussion: While clinical outcomes were mixed and possibly confounded by natural recovery or pharmacologic interventions, deep brain stimulation appeared to facilitate greater improvements in DoC than other modalities. However, repetitive transcranial magnetic stimulation also demonstrated clinical potential with much lower invasiveness [1)].

Prospective cohort studies

A study employed resting-state functional MRI (rs-fMRI) and the amplitude of low-frequency fluctuation (ALFF) to investigate differential brain activity in patients with DoC following spinal cord stimulation (SCS) therapy. It also assessed the predictive value of rs-fMRI and ALFF in determining the consciousness levels at 3 months post-therapy.

They analyzed rs-fMRI data from 31 patients with traumatic brain injury (TBI) and 22 with non-traumatic brain injury (non-TBI) diagnosed with DoC. ALFF was measured before SCS therapy, and clinical outcomes were assessed 3 months later using the Coma Recovery Scale-Revised.

Patients with TBI showed increased ALFF in the thalamus and anterior cingulate cortex, whereas the

middle occipital lobe showed decreased ALFF. In the non-TBI group, a higher ALFF was noted in the precuneus, with a reduced ALFF in the occipital and temporal lobes. Patients with improved consciousness post-SCS exhibited distinct ALFF patterns compared with those with unchanged consciousness, particularly in the posterior cingulate and occipital regions.

Applying ALFF in rs-fMRI may be a predictive tool for post-treatment outcomes in patients with DoC of varying etiologies. Differential ALFF in specific brain regions could indicate the likelihood of improvement in consciousness following SCS therapy.

Clinical trial registration: https://www.chictr.org.cn/, Identifier ChiCTR2300069756 [2)]

This study contributes significantly to understanding differential brain activity in DoC patients, highlighting the potential of rs-fMRI and ALFF as predictive tools for consciousness recovery. However, the limitations regarding sample size, follow-up duration, and methodological concerns suggest that further research is needed to validate these findings and explore the long-term implications of brain activity monitoring in this patient population. Overall, while promising, the findings should be interpreted cautiously, and future studies with larger, more diverse cohorts and extended follow-up periods are warranted.

A study aims to explore the electrophysiological and behavioral evidence of consciousness recovery in DOC patients after spinal cord stimulation (SCS) and to investigate the role of scalp EEG as a guide for preoperative assessment related to the surgery.

For the 27 recruited patients, the CRS-R (Coma Recovery Scale-Revised) assessment and event-related potential (ERP) P300 evaluation were completed before the surgery. At 3 months post-surgery, all 27 patients underwent the same assessments as preoperatively, and at 6 months post-surgery, the same evaluations were repeated for the 15 patients who could still be followed up. Between May 2023 and November 2023, resting-state EEG was collected from 13 patients using a 19-channel setup, with additional resting-state EEG recordings taken at 3 months and 6 months after the surgery. The EEG data were processed using EEGLAB to obtain P300-related metrics and EEG power spectrum. Changes in the CRS-R scale, ERP, and EEG power spectrum before and after the surgery were compared.

The Behavioral Scale (CRS-R) showed significant improvement at 3 months and 6 months post-surgery compared to preoperative assessments, with statistical significance ($p < 0.001$). The resting-state EEG power in the 5-9 Hz frequency band demonstrated statistically significant improvements at the P3 and O1 electrodes; however, this statistical result do not survive FDR correction. In the 9-13 Hz and 20-35 Hz frequency bands, the power spectrum showed statistically significant improvements across most electrodes of the brain, and these results survived FDR correction ($p < 0.05$). The mean amplitude, peak, and latency of P300 at the Pz electrode showed significant improvements at 3 months and 6 months post-surgery compared to preoperative values, with statistical significance ($p < 0.05$).

The study shows that SCS can effectively improve the consciousness states of patients with DOC. After surgery, there were positive changes in the EEG power spectrum of the patients, transitioning from type “B” to better types “C” and “D.” The average amplitude, peak, and latency of P300 also demonstrated significant improvements postoperatively. They believe that the “ABCD” model and ERP assessment applied during the preoperative evaluation can effectively enhance the success rate of SCS surgery in promoting awakening [3)].

The study provides valuable preliminary evidence supporting the use of spinal cord stimulation as a treatment for disorders of consciousness, with promising findings in both behavioral and electrophysiological assessments. However, the study's small sample size, lack of a control group, and limited scope of EEG analysis reduce the strength of its conclusions. Future studies with larger sample sizes, longer follow-up periods, and control groups would help validate the effectiveness of SCS and its potential as a therapeutic intervention for DOC patients. Additionally, a deeper exploration of the electrophysiological mechanisms behind consciousness recovery and potential adverse effects would contribute to a more comprehensive understanding of this treatment.

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Dutta RR, Abdolmanafi S, Rabizadeh A, Baghbaninogourani R, Mansooridara S, Lopez A, Akbari Y, Paff M. Neuromodulation and Disorders of Consciousness: Systematic Review and Pathophysiology. Neuromodulation. 2024 Oct 17:S1094-7159(24)00708-6. doi: 10.1016/j.neurom.2024.09.003. Epub ahead of print. PMID: 39425733.
2)
Qin X, Chen X, Yao L, Lu F, Liang Z, He J, Guo X, Li X. Differential brain activity in patients with disorders of consciousness: a 3-month rs-fMRI study using amplitude of low-frequency fluctuation. Front Neurol. 2024 Dec 13;15:1477596. doi: 10.3389/fneur.2024.1477596. PMID: 39734630; PMCID: PMC11673223.
3)
Sun J, Yan J, Zhao L, Wei X, Qiu C, Dong W, Luo B, Zhang W. Spinal Cord Stimulation for Prolonged Disorders of Consciousness: A Study on Scalp Electroencephalography. CNS Neurosci Ther. 2024 Dec;30(12):e70180. doi: 10.1111/cns.70180. PMID: 39736021.