Ultrasound neuromodulation for treatment-resistant depression: A case for deep brain stimulation

openaccessgovernment.org/article/ultrasound-neuromodulation-for-treatment-resistant-depression-a-case-for-deep-brain-stimulation/189774

17 March 2025

Tiago Costa from Delft University of Technology discusses why ultrasound neuromodulation has significant potential to transform the treatment of depression

Major Depressive Disorder (MDD), commonly referred to as depression, is a prevalent mental health condition affecting millions worldwide. Characterized by persistent sadness, loss of interest, and a range of emotional and physical symptoms, depression significantly impairs an individual's quality of life. While various treatment options exist, including psychotherapy and medication, a substantial portion of individuals with depression do not respond adequately to these conventional approaches. This subset of patients, classified as having Treatment-Resistant Depression (TRD), presents a significant challenge in mental healthcare.

Deep Brain Stimulation (DBS)

For individuals with TRD, Deep Brain Stimulation (DBS) has emerged as a potential therapeutic avenue. DBS involves the implantation of electrodes in specific brain regions, delivering continuous electrical stimulation to modulate neural activity. While DBS has shown promise in treating various neurological conditions, including Parkinson's disease and epilepsy, its application in depression is still under investigation. However, DBS is not without limitations. It is an invasive procedure requiring surgery, and the implanted electrodes are fixed in place, limiting the flexibility to target multiple brain regions or adjust stimulation parameters over time. This inflexibility poses a challenge for treating depression, as the neural networks involved in mood regulation are complex and distributed, and the optimal stimulation targets may vary across individuals and over the course of treatment.

In this context, ultrasound neuromodulation has emerged as a promising alternative for deep brain stimulation in depression.

Ultrasound neuromodulation

Ultrasound neuromodulation utilizes focused beams of acoustic energy to non-invasively stimulate or inhibit specific neural circuits. Unlike DBS, which requires surgery and implanted electrodes, ultrasound neuromodulation can be delivered externally, eliminating the risks associated with invasive procedures. Moreover, ultrasound neuromodulation offers greater flexibility in targeting
and adjusting stimulation parameters. The focused ultrasound beams can be steered electronically, allowing for precise targeting of multiple brain regions without the need for

additional surgery. This capability is particularly advantageous for treating depression, as it enables clinicians to target different nodes within the complex neural networks involved in mood regulation, potentially tailoring the treatment to the individual needs of each patient. Furthermore, the stimulation parameters, such as frequency, intensity, and pulse duration, can be adjusted remotely and non-invasively, allowing for real-time optimization of treatment based on patient response. This adaptability is crucial for treating depression, as the optimal stimulation parameters may vary across individuals and over the course of treatment.

Preclinical and clinical studies for ultrasound neuromodulation

The potential of ultrasound neuromodulation for treating depression is supported by preclinical and clinical studies. Preclinical studies have demonstrated the ability of ultrasound to modulate neural activity in brain regions implicated in depression, such as the prefrontal cortex and the subcallosal cingulate cortex. Clinical studies, although still limited in number, have shown encouraging results, with some patients experiencing significant reductions in depressive symptoms following ultrasound neuromodulation. For example, a recent case study published in the journal Brain Stimulation reported the successful treatment of a patient with severe treatment-resistant depression using ultrasound neuromodulation. (1) The study involved a 46-year-old male patient with a long history of depression who had not responded to various treatment modalities, including psychotherapy, medication, and electroconvulsive therapy. The patient underwent a single session of ultrasound neuromodulation targeting the right-lateralized ventral capsule/ventral striatum and anterior limb of the internal capsule. The ultrasound stimulation was delivered using a transcranial-focused ultrasound system with a 500kHz transducer and a 25Hz pulse repetition frequency. The treatment session lasted 300 seconds (five minutes). The patient's mood and anxiety levels were assessed before and after the stimulation using visual analog scales (VAS, which is a psychometric response scale used to measure subjective experiences, such as pain, mood, or anxiety, where individuals mark a point on a continuous line representing the intensity of their feeling. The results of the study showed that the patient experienced a significant reduction in depressive symptoms immediately following the ultrasound stimulation. The patient's VAS scores for depression decreased from 70 before stimulation to 30 after stimulation, indicating a substantial improvement in mood. Additionally, the patient reported a decrease in anxiety levels, with VAS scores for anxiety decreasing from 60 to 20. These improvements in mood and anxiety were maintained for at least 24 hours after the stimulation, suggesting a durable therapeutic effect. The patient did not report any adverse effects associated with the ultrasound neuromodulation. This case study provides compelling evidence for the potential of ultrasound neuromodulation as a non-invasive and effective treatment option for individuals with TRD. The study's findings suggest that ultrasound neuromodulation can induce rapid and sustained improvements in mood and anxiety in patients who have not responded to conventional treatments.

Further research

While further research is needed to fully elucidate the mechanisms of action and optimize treatment protocols, ultrasound neuromodulation holds significant promise for revolutionizing the treatment of depression. Its non-invasive nature, combined with its flexibility in targeting and adjusting stimulation parameters, makes it an attractive alternative to invasive procedures like DBS. As the technology continues to advance, ultrasound neuromodulation has the potential to transform the lives of millions suffering from depression.

References

1. Riis et al. Journal of Medical Case Reports (2023) 17:449. https://doi.org/10.1186/s13256-023-04194-4

Contributor Details

Stakeholder Details

Sorry, no contributor(s) found.

- Article Categories
- Health

- Article Tags
- Depression
- Medical Technology
- Mental Health

- Publication Tags
- OAG 046 – April 2025

- Stakeholder Tags
- SH - Delft University of Technology