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Case Report

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Non-invasive vestibular neuromodulation for chronic insomnia following hypoxic-ischemic brain injury: A case report

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Abstract

Sleep dysregulation occurs frequently after brain injury, although its management can be difficult, particularly when cognitive deficits limit behavioral interventions and medications may contribute to cognitive impairment. In this report, we present a 29-year-old male veteran with chronic severe insomnia and highly disruptive parasomnias persisting 11 years after hypoxic-ischemic brain injury (HIBI) following cardiac arrest. His symptoms were refractory to sleep hygiene interventions, multiple pharmacological regimens, and alternative therapies. He was initiated on nightly non-invasive electrical vestibular system stimulation (VSS). At one, seven, and 13-month follow-up, his caregiver reported marked improvement in nighttime sleep, resolution of parasomnias, and improved daytime cognitive engagement. His Insomnia Severity Index score improved from 25 (severe clinical insomnia) to 4 (no clinically significant insomnia), without adverse effects. In conclusion, this case suggests that VSS may represent a promising non-pharmacological treatment option for refractory insomnia after HIBI and warrants further prospective study in brain injury populations.

Keywords: Anoxic brain injury, rehabilitation, sleep dysregulation, vestibular system stimulation, wearable device.

Sleep disturbances are common after brain injuries, affecting up to 50% of patients at one year post-injury, with nearly half reporting insomnia.[1] Sleep has a key role in cognitive function, and sleep disruption is associated with deficits in attention, memory, and executive function.[2] Although primary chronic insomnia (without an underlying brain injury) has been extensively studied in the literature, management of insomnia after brain injury, particularly hypoxic-ischemic brain injury (HIBI), has been minimally investigated.[1] Given the potential cognitive impacts of sleep medications after brain injury, non-pharmacological interventions remain of great interest for this patient population. In this article, we report a case showing a notable improvement in chronic insomnia after HIBI using a recently available non-invasive neuromodulation modality, electrical vestibular system stimulation (VSS).

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CASE REPORT

A 29-year-old male veteran sustained HIBI after a cardiac arrest during basic training drills 11 years ago. He has been followed in a brain injury clinic for the past six years. His neurological deficits included expressive and receptive aphasia, short- and long-term memory deficits, mood instability, cognitive deficits affecting problem solving and initiation, and sleep-wake cycle dysregulation. Prior to his injury, he met all developmental milestones, had no prior use of tobacco, alcohol, or illicit substances, and had no history of psychiatric or sleep issues, according to report from his guardian (mother) and medical records. Due to his complex needs, he requires 24-h caregiver supervision, primarily provided by his mother. Due to impaired insight and memory deficits, he was still at risk for wandering and elopement, requiring continuous supervision and resulting in limited nighttime rest for his guardians. A particularly challenging concern for his caregivers was his sleep dysregulation, including insomnia, parasomnias, and decreased daytime wakefulness. Insomnia was first noted in medical notes one month after his injury, and at eight months after his injury was noted to have "variable sleep with daytime somnolence". Upon initial evaluation at his current Veterans Affairs Medical Center brain injury clinic, his caregiver reported continued inconsistent sleep and daytime somnolence. This concern persisted throughout several follow-up clinic visits. Notably, he woke frequently throughout the night and was observed performing tasks such as brushing his teeth, taking a bath, and attempting to use the toilet, raising safety concerns given his cognitive deficits. He experienced episodes of impaired nocturnal toileting, and although he retained daytime bowel continence, his profound nocturnal somnolence and cognitive impairment prevented him from appropriately cleaning himself after defecation, resulting in fecal contamination. He required naps during the day, limiting daytime engagement and participation in therapy sessions.

Evaluation of other potential causes of sleep dysregulation was performed, including sleep clinic evaluation and endocrinological labs. Polysomnography indicated no signs of obstructive sleep apnea, though delayed sleep phase was noted. Pituitary screening showed normal levels of thyroid-stimulating hormone, insulin-like growth factor-1, adrenocorticotropic hormone, follicle-stimulating hormone, luteinizing hormone, prolactin, and testosterone. He was also evaluated by neuropsychology and was noted to have impairment in his visuospatial skills. However, he did not have cerebral visual impairment. Sleep hygiene measures and nighttime stimulus-control strategies were implemented with initial improvement of insomnia, though with continued frequent nocturnal awakenings. Cognitive behavioral therapy for insomnia (CBT-I) was not implemented, as cognitive deficits limited participation.

Medications were trialed for sleep dysregulation without notable improvements. Melatonin and trazodone were trialed, leading to excessive daytime somnolence and decreased attention noted by his caregiver. Neurostimulants were trialed for daytime wakefulness and attention, including amantadine, modafinil, and methylphenidate. Duloxetine was trialed for anxiety, and divalproex was trialed for mood stabilization. Although positive cognitive effects were seen with methylphenidate, none of these medication trials improved nighttime sleep. His caregiver additionally sought alternative treatment approaches, including hyperbaric oxygen therapy and acupuncture, which did not yield improvement in the patient's sleep.

Given the refractory nature of his insomnia, the patient was trialed on a non-invasive VSS device (Modius Sleep, Neurovalens, UK), which is designed for use in the home setting and was recently made available and received United States Food and Drug Administration (FDA) clearance (K230826) for the treatment of chronic insomnia. The efficacy and safety of the VSS device were previously assessed in a multisite, double-blind, randomized, sham-controlled trial involving adults with chronic insomnia, which demonstrated that repeated 30-min daily sessions administered over four weeks significantly reduced insomnia severity.[3]

The device was worn on the head and administered low-level electrical pulses to the vestibular system via two self-adhesive

Figure 1. Representative photo of the non-invasive electrical vestibular nerve stimulation device. Image provided by the manufacturer and reproduced with permission from Neurovalens. ©2024 Neurovalens.

electrode pads placed on the skin behind the ears (Figure 1). The patient's caregiver was instructed to administer the device nightly according to the manufacturer's instructions, consisting of a 30-min session performed 1 to 2 h before bedtime. At one-month follow-up, his caregiver reported notable improvements in sleep, stating that the patient was able to sleep throughout the night with resolution of parasomnias including attempts to toilet or bathe at night. His prior episodes of impaired nocturnal toileting and associated fecal contamination were completely resolved. It was reported that he was able to tolerate changes in environment, such as with travel, no longer developing severe sleep dysregulation. His caregiver reported improvements in sleep within one to two weeks of using the device, and no missed treatment nights were reported. Due to these initial positive results, the caregiver opted for the patient to continue using the device for an additional 12 months. At seven-month follow-up, his insomnia severity was assessed using the Insomnia Severity Index (ISI) questionnaire to assess the severity of insomnia symptoms, completed by the patient's caregiver. The ISI is a standardized, validated questionnaire that assesses the nature, severity, and impact of insomnia. ISI scoring is interpreted as 0-7 (no clinically significant insomnia), 8-14 (subthreshold insomnia), 15-21 (moderate clinical insomnia), and 22-28 (severe clinical insomnia), with a 6-point reduction typically representing a clinically meaningful improvement.[4,5] The patient's score decreased from 25 (severe clinical insomnia) to 4 (no clinically significant insomnia) after starting nightly VSS, indicating a clinically meaningful improvement. The patient's caregiver also noted improvement in cognition, with improved initiation during activities and engagement with his environment. This included appropriately saluting at a funeral, remembering to pick up trash without cues, and opening the front door to sign for package deliveries, each of which had not occurred since his brain injury. At the 13-month follow-up, his caregiver reported continued improvement of sleep, improved mood and cognition, and that the patient no longer needed to take methylphenidate. The patient tolerated VSS usage well without noted adverse effects.

A written informed consent was obtained from the patient for publication of this case report.

DISCUSSION

Management of sleep disturbances after brain injury can be challenging, with a complex network of sleep-related brain structures that may be impacted. Mechanisms of insomnia after HIBI have not been established, although traumatic brain injury (TBI) literature proposes theories of hormonal dysregulation and disruption of the hypothalamus, brain stem, and reticular activating system.[6] Furthermore, there has been recent interest in the role of the neurovestibular system in promoting sleep, as neuronal projections exist between the vestibular nuclei and the hypothalamus and locus coeruleus (key brain structures for sleep-wake regulation).[7] Therefore, the vestibular system may represent an important therapeutic target for sleep dysfunction. Recent studies have demonstrated efficacy of non-invasive VSS in patients with moderate-to-severe chronic primary insomnia, improving ISI scores with nightly VSS usage.[3,8] However, these studies excluded patients with severe head injuries and, thus, VSS has not been

described for patients with chronic insomnia after HIBI.

Non-pharmacological approaches for sleep dysfunction have been studied in patients with an acquired brain injury, with findings suggesting that CBT-I can improve insomnia and sleep quality.[9] However, such interventions have not been well studied in patients with HIBI, and may be particularly challenging for individuals with severe cognitive deficits. Pharmacological management with hypnotics in patients with brain injuries increases the risk of cognitive impairment or daytime somnolence.[10]

In conclusion, this case describes a marked response to nightly non-invasive VSS in a patient with chronic insomnia after HIBI with continued effects at one, seven, and 13 months of usage. Resolution of parasomnias improved a key safety risk and reduced nighttime caregiver burden. Subjective cognitive improvements were also reported by the patient's caregiver, although no formal neuropsychiatric testing was performed to assess for changes. Although subjective improvements were reported at 13 months of device usage, formal insomnia severity assessment was only performed at seven months of nightly VSS usage. Currently, Veterans Affairs facilities provide this device as a covered benefit for veterans with qualifying diagnoses. Outside the Veterans Affairs, the device is not yet broadly available; however, future access is expected through insurance reimbursement, Health Savings Account (HSA) or Flexible Spending Account (FSA) funds, or self-pay options. Non-pharmacological approaches to insomnia management, such as VSS, may be particularly favorable, since cognitive impairment and daytime arousal concerns are common after severe brain injury. The notable response in this case warrants further prospective study in the brain injury patient population including HIBI.

Declaration of Conflicting Interests

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Author Contributions

J.P.C., D.D.M..: Idea/concept; D.D.M.: Control/supervision; M.T., J.P.C., D.D.M.: Data collection and/or processing; J.P.C.: Analysis and/or interpretation, literature review; M.T., J.P.C..: Writing the article; M.T., J.P.C., D.D.M.: Critical review.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

AI Disclosure

The authors declare that artificial intelligence (AI) tools were not used, or were used solely for language editing, and had no role in data analysis, interpretation, or the formulation of conclusions. All scientific content, data interpretation, and conclusions are the sole responsibility of the authors. The authors further confirm that AI tools were not used to generate, fabricate, or 'hallucinate' references, and that all references have been carefully verified for accuracy.

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