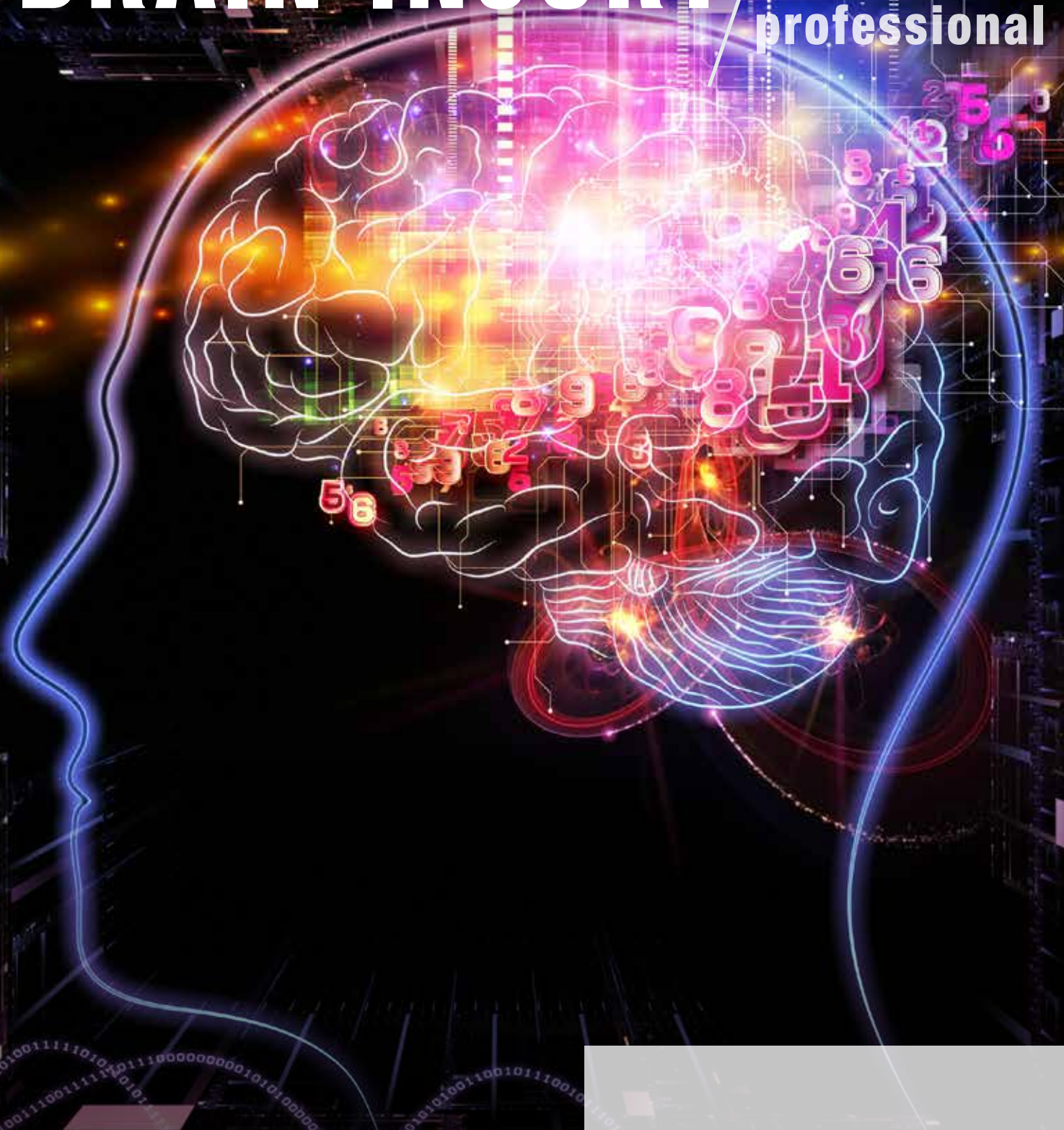


BRAIN INJURY

vol. 21 issue 4

professional



Neuromodulation



Recovery from a neurologic injury can be uncertain.



Trust our nationally renowned rehabilitation experts and specialized care to guide the way.

Your patient just had a stroke, spinal cord injury, or traumatic brain injury. What happens next is critical to their recovery. Finding the best choice for rehabilitation—where specialized, multidisciplinary experts guide their care with state-of-the-art techniques, innovative research, and advanced technology—will make all the difference in their tomorrows.

At Casa Colina Hospital and Centers for Healthcare, we have been providing a comprehensive continuum of rehabilitative care for nearly a century. We use proven pathways and the latest evidence-based science to help each patient in their recovery.

Our Continuum of Care

- Inpatient rehabilitation, medical-surgical and ICU beds, surgical suites
- Residential rehabilitation beds and day treatment program
- Outpatient rehabilitation centers
- Long-term residential facilities
- Physician specialty clinics
- Diagnostic imaging and lab
- Audiology services
- Research Institute
- Support groups, wellness, and fitness programs
- Outdoor Adventures & Wheelchair Sports program

To learn more, call 909/596-7733, ext. 3900 or visit casacolina.org.



Accredited Specialty Programs:
Brain Injury
Spinal Cord Injury
Stroke



255 East Bonita Avenue
Pomona, California



BRAIN INJURY

professional

vol. 21 issue 4

departments

- 5 Editor in Chief Message
- 7 Guest Editor's Message
- 30 Books You May Have Missed

features

- 8 Noninvasive Brain Stimulation for Disorders of Consciousness (DoC) After TBI: Is it really safe?
David Ripley, MD, MS
- 14 Neuromodulatory Interventions in Patients with Disorders of Consciousness after Severe Brain Injury: What is the State of the Evidence?
Patricia Grady-Dominguez, PhD • Lauren Teague
Jennifer Weaver, PhD, OTR/L
- 18 Non-Invasive Brain Stimulation for Cognitive Rehabilitation - A Brief Overview
André Lindsey, PhD, CCC-SLP • Monica T. Ly, PhD
Karen Lê, PhD, CCC-SLP
- 22 Precision Transcranial Magnetic Stimulation (TMS) for Co-occurring Mild Traumatic Brain Injury and Alcohol Use Disorder: A Roundtable Discussion with Clinical End Users
Amy A. Herrold, PhD • Alma Ramic, MD • Brian Gomoll, MD
Sonia Bobra, MD • Amy Kemp, PhD
- 24 Interviews with Research Participants about Transcranial Magnetic Stimulation Experiences: Voices from the Field
Amy Kemp, PhD • Kelly Krese, DPT • Ibuola Kale, MS
Amy Herrold, PhD
- 28 PM&R Clinical Adoption of Transcranial Magnetic Stimulation (TMS) in Traumatic Brain Injury (TBI) Rehabilitation
Ana Durand-Sanchez, MD

Brain Injury Professional is a membership benefit of the North American Brain Injury Society and the International Brain Injury Association



NORTH AMERICAN BRAIN INJURY SOCIETY

CHAIRMAN Mariusz Ziejewski, PhD
VICE CHAIR Debra Braunling-McMorrow, PhD
IMMEDIATE PAST CHAIR Ronald C. Savage, EdD
TREASURER Bruce H. Stern, Esq.
SECRETARY Brian Greenwald, MD
FAMILY LIAISON Skye MacQueen
EXECUTIVE DIRECTOR/ADMINISTRATION Margaret J. Roberts
EXECUTIVE DIRECTOR/OPERATIONS J. Charles Haynes, JD
MARKETING MANAGER Megan Bell-Johnston

BRAIN INJURY PROFESSIONAL

PUBLISHER J. Charles Haynes, JD
CO-EDITOR IN CHIEF Beth Slomine, PhD - USA
CO-EDITOR IN CHIEF Nathan Zasler, MD - USA
ASSOCIATE EDITOR Juan Arango-Lasprilla, PhD - Spain
TECHNOLOGY EDITOR Stephen K. Trapp, PhD - USA
EDITOR EMERITUS Debra Braunling-McMorrow, PhD - USA
EDITOR EMERITUS Ronald C. Savage, EdD - USA
DESIGN AND LAYOUT Kristin Odom
ADVERTISING SALES Megan Bell-Johnston

EDITORIAL ADVISORY BOARD

Nada Andelic, MD - Norway
Philippe Azouvi, MD, PhD - France
Mark Bayley, MD - Canada
Lucia Braga, PhD - Brazil
Ross Bullock, MD, PhD - USA
Fofi Constantinidou, PhD, CCC-SLP, CBIS - USA
Gordana Devecerski, MD, PhD - Serbia
Sung Ho Jang, MD - Republic of Korea
Cindy Ivanhoe, MD - USA
Inga Koerte, MD, PhD - USA
Brad Kurowski, MD, MS - USA
Jianan Li, MD, PhD - China
Christine MacDonell, FACRM - USA
Calixto Machado, MD, PhD - Cuba
Barbara O'Connell, OTR, MBA - Ireland
Lisandro Olmos, MD - Argentina
Caroline Schnakers, PhD - USA
Lynne Turner-Stokes, MD - England
Olli Tenovuuo, MD, PhD - Finland
Asha Vas, PhD, OTR - USA
Walter Videtta, MD - Argentina
Thomas Watanabe, MD - USA
Alan Weintraub, MD - USA
Sabahat Wasti, MD - Abu Dhabi, UAE
Gavin Williams, PhD, FACP - Australia
Hal Wortzel, MD - USA
Mariusz Ziejewski, PhD - USA

EDITORIAL INQUIRIES

Managing Editor
Brain Injury Professional
PO Box 131401, Houston, TX 77219-1401
Tel 713.526.6900 Email: mbell@hdiipub.com
Website: www.nabis.org

ADVERTISING INQUIRIES

Megan Bell-Johnston
Brain Injury Professional
HDI Publishers
PO Box 131401, Houston, TX 77219-1401
Tel 713.526.6900 Email: mbell@internationalbrain.org

NATIONAL OFFICE

North American Brain Injury Society
PO Box 1804, Alexandria, VA 22313
Tel 703.960.6500 / Fax 703.960.6603
Website: www.nabis.org
ISSN 2375-5210

Brain Injury Professional is a quarterly publication published jointly by the North American Brain Injury Society and HDI Publishers. © 2025 NABIS/HDI Publishers. All rights reserved. No part of this publication may be reproduced in whole or in part in any way without the written permission from the publisher. For reprint requests, please contact, Managing Editor, Brain Injury Professional, PO Box 131401, Houston, TX 77219-1400, Tel 713.526.6900, Fax 713.526.7787, e-mail mbell@hdiipub.com.

ACCREDITATION MATTERS

Highlight the quality services that you provide for people with acquired brain injury.

You have quality practices in place to ensure optimal outcomes.

Accreditation is the next step in growing your organization by demonstrating your person-centred focus, and your commitment to continuous quality improvement.

CARF is a leading independent, nonprofit accreditor of health and human services that accredits nearly 1,000 brain injury programs in the United States, Europe, the Middle East, New Zealand, and Canada. Our accreditation covers the continuum of services offered to individuals with ABI in a variety of treatment settings.

About CARF:

- Accredits programs internationally
- Reviews business and clinical practices
- Guides person-centred, evidence-based practices
- Establishes quality performance improvement systems
- Hosts training and education on standards

Benefits of CARF accreditation:

- Service excellence
- Business improvement
- Funding access
- Competitive differentiation
- Risk management
- Positive visibility
- Accountability
- Peer networking



Snap the QR code or visit
[www.carf.org/
Programs/Medical](http://www.carf.org/Programs/Medical)
for program descriptions.



Terrence Carolan
Managing Director,
Medical Rehabilitation

**NEW in 2024
Concussion
Management
Standards**

To provide your
input, contact
tcarolan@carf.org

To learn more about CARF and how accreditation can help your organization. Call or email us today!

(888) 281-6531

med@carf.org

carf INTERNATIONAL

www.carf.org

from the editor



Nathan D. Zasler, MD,
DABPM&R, FAAPM&R, FACRM,
BIM-C, CBIST

Editor Bio

Nathan Zasler, MD, is an internationally respected physician specialist in acquired brain injury (ABI) care and rehabilitation. He is CEO and Medical Director of the Concussion Care Centre of Virginia, an outpatient neurorehabilitation practice, as well as, the Medical Director of Tree of Life, a living assistance and transitional neurorehabilitation program for persons with acquired brain injury in Richmond, Virginia. He is board certified in Physical Medicine and Rehabilitation and fellowship trained in brain injury, as well as, Brain Injury Medicine certified.

Dr. Zasler is an Affiliate Professor of PM&R at VCU in Richmond, Virginia, as well as, a Visiting Professor of PM&R at the University of Virginia, Charlottesville, Virginia.

Dr. Zasler has lectured and written extensively on neurorehabilitation issues in ABI. He is active in national and international organizations dealing with acquired brain injury and neurodisability, serving in numerous consultant and board member roles.

I was very excited when Dr. Theresa Bender Pape agreed to edit this issue of *BIP* on the topic of neuromodulation given the significant advances in the field as it applies to treating various conditions in persons with traumatic brain injury. This issue of *BIP* features six articles on a variety of different neuromodulation topics as well as a number of sidebars providing additional updated information on related neuromodulation topics and are recurring section entitled “books you may have missed”.

The first article entitled “Non-invasive brain stimulation for disorders of consciousness after TBI: Is it really safe?” was authored by Dr. David Ripley and is an excellent overview not only of the technique’s safety but also a very well-done historical overview of neurostimulation technology. The article focuses on rTMS and TES (tDCS and tACS).

The second article by Dr. Grady-Dominguez and colleagues on “Neuromodulatory interventions in patients with disorders of consciousness after severe brain injury: What is the state of the evidence?” provides a nice overview of transcranial direct-current stimulation, repetitive transcranial magnetic stimulation near infrared laser therapy and focused shockwaves. The take-home message is that we are early on in terms of understanding how these techniques might alter recovery from DOC with the understanding that none are currently approved by the FDA in this context.

The next article by Dr. Andre Lindsey and colleagues entitled “Non-invasive brain stimulation for cognitive rehabilitation: A brief overview” provides some enticing early data showing the potential benefit of neuromodulation interventions in the context of their impact on arousal and awareness secondary to targeting the prefrontal cortex. Clearly, this area of neuromodulation use is in its infancy but warrant further study.

Dr. Amy Herrold and colleagues contributed a paper entitled “Precision transcranial magnetic stimulation for co-occurring mild traumatic brain injury and alcohol use disorder: Around table discussion with clinical end-users”. This paper provides a stimulating and dynamic discussion regarding the potential use of personalized TMS using an integrated care model in the treatment of substance use disorders in persons with mTBI.

Dr. Kemp and colleagues contributed a paper entitled “Interviews with research participants transcranial magnetic stimulation experiences: Voices from the field”. This article provides a unique perspective of research participants with histories of TBI involved in TMS studies. It provides unique perspective on how personalized interactions between patients’ receiving TMS and their healthcare providers potentially enhances the therapeutic alliance and optimizes meaningful outcomes.

The last article by Dr. Ana Durand-Sanchez entitled “PM&R clinical adoption of transcranial magnetic stimulation in traumatic brain injury rehabilitation” explores the essential elements of integration of TMS clinical practice into the field of TBI neurorehabilitation. For those interested in developing such a practice, this overview provides the critical elements required to initiate and conduct such a program on an ongoing basis.

Readers should be sure to review the excellent sidebar features in this issue as well as peruse new books and the “books you may have missed” section. I am sure readers will enjoy this “stimulating” issue on the diverse topics provided relating to neuromodulation and TBI.

Raising the bar for *inpatient* and *day* rehabilitation services




Children's Healthcare of Atlanta is Commission on Accreditation of Rehabilitation Facilities (CARF)-accredited for pediatric rehabilitation services.

We offer:

- An expansive Inpatient Rehabilitation Program
 - A spinal cord system of care, brain injury and pediatric specialty programs that have received CARF specialty recognition
 - A team of brain injury board-certified pediatric physiatrists
 - Comprehensive care for young patients from birth to age 21
 - Therapy seven days a week
 - 28 private patient rooms
- A Day Rehabilitation Program to assist patients during recovery
- Technology-assisted therapy through our Center for Advanced Technology and Robotic Rehabilitation
- A full-service hospital with emergency services



Learn more or make a referral:

 **404-785-2274**

 **choa.org/rehab**



Children'sSM
Healthcare of Atlanta

from the guest editor



Theresa L. Bender Pape,
Dr.PH, MA, SLP/L

Editor Bio

Theresa L. Bender Pape, Dr.PH, MA, SLP/L, is a Research Professor at Northwestern University's Feinberg School of Medicine in the Department of Physical Medicine and Rehabilitation where she contributes her expertise in neuroplasticity and neuroscience. With a clinical background in Speech-Language Pathology, she specializes in traumatic brain injury (TBI) and disorders of consciousness (DoC) and focuses on developing therapies to enhance daily function. A leading investigator in groundbreaking studies, including the use of transcranial magnetic stimulation (TMS) with TBI, she is recognized for advancing personalized medicine in neurorehabilitation. Dr. Pape is dedicated to bridging the gap between the laboratory and the clinic.

It is my pleasure to present this special issue of *Brain Injury Professional* dedicated to the rapidly evolving field of neuromodulation where targeted signals (e.g., electrical) are delivered to specific brain areas or brain systems to enhance or suppress nervous system activity. This issue brings together a collection of insightful articles delving into rehabilitation applications of non-invasive brain stimulation (NIBS) techniques, with an emphasis on disorders of consciousness (DoC) and mild Traumatic Brain Injury (mTBI).

As our understanding of recovery trajectories after brain injury evolves, so does our knowledge of how neuromodulation can contribute to recovery. Neuromodulation holds promise for facilitating the recovery of somatosensory and higher-order cognitive functions by engaging plasticity mechanisms that help the brain reorganize and form new neural connections. This is crucial for the estimated 56,000 people in the U.S. living with disorders of consciousness (DoC).¹ Previously, those who remained in DoC for 12 or more months were believed to have a low chance of further recovery. However, studies since Katz et al. (2009)² have shown that many can progress to higher functional levels even after remaining in DoC for 5 to 10 years. Despite this, neurostimulant medications remain the primary approach to DoC rehabilitation.³ As growing evidence shows that this population could benefit from NIBS, the feature article addresses the historical evolution of NIBS relative to the concerns of adverse events for this vulnerable group of patients. It is followed by a critical summary of literature shedding light on the efficacy of neuromodulatory treatments in DoC. Together, these articles underscore the need to update clinical practice guidelines to include NIBS recommendations for individuals with DoC.

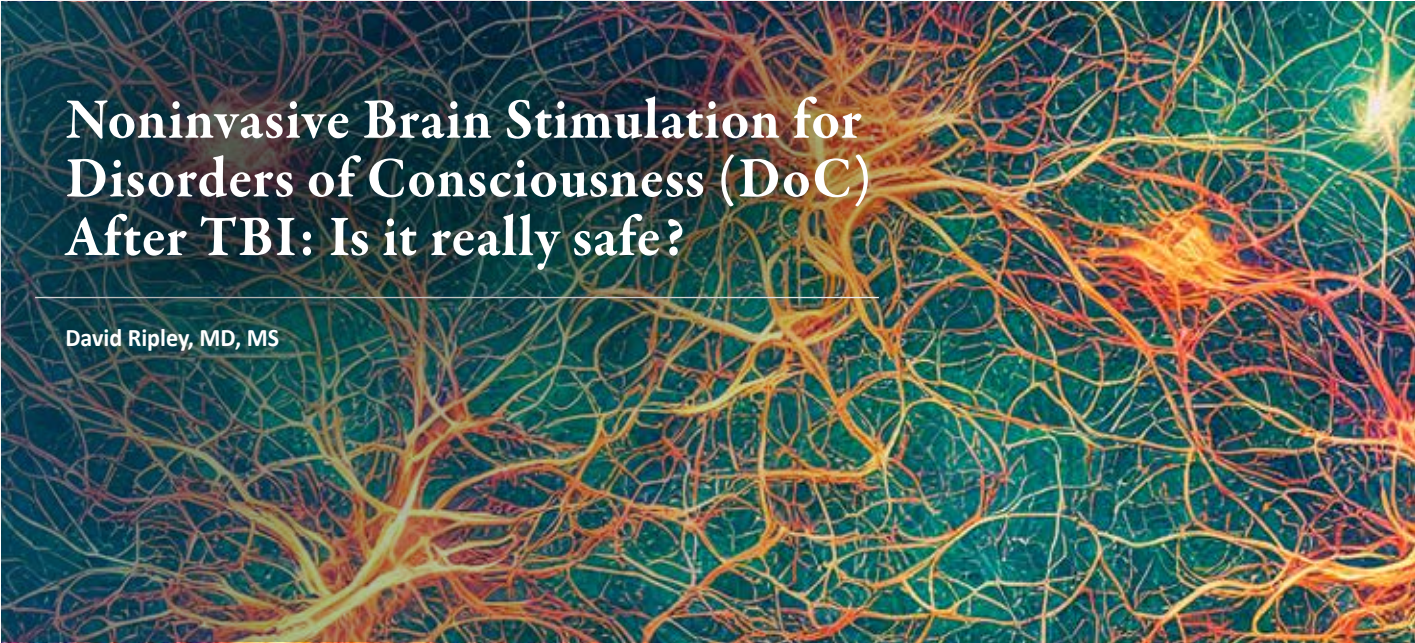
Rehabilitation treatments improving function in daily life after mild traumatic brain injury (mTBI) are notably scarce, despite evidence showing that 15% to 30% of individuals with mTBI experience long-term cognitive, emotional, and physical symptoms.⁴ Current rehabilitation approaches primarily focus on symptom management without addressing the underlying neural dysfunctions. This treatment gap is partly due to the subtle and diffuse nature of mTBI-related brain pathology, which complicates the identification of specific neural systems to target. Cognitive rehabilitation strategies offer some benefits but often fall short in improving daily functioning, especially when mTBI co-occurs with conditions like post-traumatic stress disorder, substance use disorders, anxiety, and depression. The third article in this issue provides a concise overview of how non-invasive brain stimulation (NIBS) can play a crucial role in cognitive rehabilitation for patients with mTBI, helping them regain cognitive and functional capabilities needed for successful functioning in the community.

Personal perspectives of NIBS as rehabilitation interventions are crucial for advancing use of NIBS in clinical practice, and the final set of articles in this issue captures these valuable insights. One article captures the lived experiences of patients who have undergone TMS, offering a unique view of how these treatments have impacted their lives. This is complemented by a roundtable discussion among clinical practitioners exploring the potential of precision TMS as a targeted therapeutic tool for complex co-occurring conditions. Another article delves into the practical aspects of integrating TMS into clinical settings, highlighting both the opportunities and challenges faced by practitioners in physical medicine and rehabilitation.

Collectively, the articles emphasize the transformative potential of neuromodulation as a component of rehabilitation to enable recovery of skills valued by individuals with acquired brain injuries. I hope this issue sparks thoughtful discussion, encourages further research, and ultimately leads to better patient outcomes.

References

1. Beaumont JG, Kenealy PM. Incidence and prevalence of the vegetative and minimally conscious states. *Neuropsychol Rehabil.* 2005;15(3-4):184-189.
2. Katz DI, et al Natural history of recovery from brain injury after prolonged disorders of consciousness: outcome of patients admitted to inpatient rehabilitation with 1-4 year follow-up. *Prog Brain Res.* 2009;177:73-88.
3. Giacino, JT et al, Practice Guideline Update Recommendations Summary: Disorders of Consciousness: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology; the American Congress of Rehabilitation Medicine; and the National Institute on Disability, Independent Living, and Rehabilitation Research, *Neurology* 91, no. 10 (2018): 450-460.
4. Haarbauer-Krupa, J et al, Epidemiology of Chronic Effects of Traumatic Brain Injury. *J Neurotrauma.* 2021 Dec;38(23):3235-3247.



Noninvasive Brain Stimulation for Disorders of Consciousness (DoC) After TBI: Is it really safe?

David Ripley, MD, MS

Introduction

As emergency life-saving medical treatments have improved, there has been a steady increase in people surviving with several studies showing that many people remaining for years in states of DoC will evolve to higher states of functioning even 5 to 10 years after injury. While there are few treatments available to enhance the recovery of consciousness, growing evidence shows that this population has the potential to benefit from noninvasive brain stimulation (NIBS).

NIBS is Not a New Phenomenon: History of Electricity as a Medical Treatment

The potential for NIBS to facilitate recovery from states of DoC offers great promise, but many clinicians remain concerned about the potential for adverse effects using NIBS despite the historical use of electricity to treat medical conditions that actually dates to ancient times (Figure 1). In ancient Greece, torpedo fish were applied to patient's heads to relieve headaches¹. This use predated the invention of the battery by several centuries, and it was not really understood that electricity was the underlying cause of the effect. In 1743, Kruger suggested that electricity might be helpful for people with movement problems^{2,3}. This led to a plethora of interventions with electricity, as well as numerous public demonstrations, which, while entertaining, probably had little to no therapeutic effect. The public's perception of electricity as a "cure-all" for many conditions rode the wave of popular opinion for many years, and lack of regulatory mechanisms in medicine at the time allowed this to propagate. In the late 1700's, Benjamin Franklin published a work that outlined that electricity was the cause of these effects⁴. His own research into the use of electricity in various conditions generally failed to demonstrate efficacy. In 1802 Dr. T Gale published a handbook intended for use by the general public to support the use of electricity to cure many conditions and gave instructions on how to build an electrotherapy device for use at home, arguably the first instance of a durable medical equipment electrical medical device for home use².

Early users of electricity in medicine demonstrated little concern for safety.

Dr. Gale was an exception to this, explaining regret that electricity had been used before its nature was truly understood. He felt that many of the earlier failures in the use of electricity as a cure were due to improper application of electricity, and that many of the earlier "treatments" were too strong. In reading his text, this is somewhat ironic, given his explanation of the force which we now know to be incorrect.

The use of electricity for treatment of medical conditions received a backlash in the late 1800's with the public's awareness of the use of electroconvulsive therapy without anesthesia for individuals with mental health disorders and epilepsy. Despite the efficacy of many of these treatments, much of the stigma of this period remains today, with the lay public maintaining a generally negative perception of electroconvulsive therapy despite safer, more modern approaches.

In the last several decades, the use of electricity in the treatment of medical conditions has seen an explosion with wide-ranging uses, from surgery for electrocautery to applications for wound care. Many advances have also been seen in the field of neurological rehabilitation, where electrical impulses have been used to treat everything from mental health disorders, paralysis, pain, seizures, swallowing dysfunction, and movement disorders. In the 1960's, Bindman et al⁵ demonstrated that application of direct current on the cortex could modify neuronal excitability, and that this effect could persist hours after completion of the stimulation. This was followed by the discovery that sufficient current to induce this effect could be delivered transcranially. Unfortunately, this finding lay dormant for many years.

History of the NIBS Development

The first device developed specifically to induce neuromodulation using electrical impulses was functional electric stimulation (FES). Clinical studies suggested that FES could be utilized to improve neurological functioning following central nervous system injury⁶. Around the same time, similar devices were modified to induce an electrical impulse to provide pain relief, called transcutaneous electrical nerve stimulation (TENS) devices. These gained widespread support and continue to be used today.

History of Neurostimulation Technology

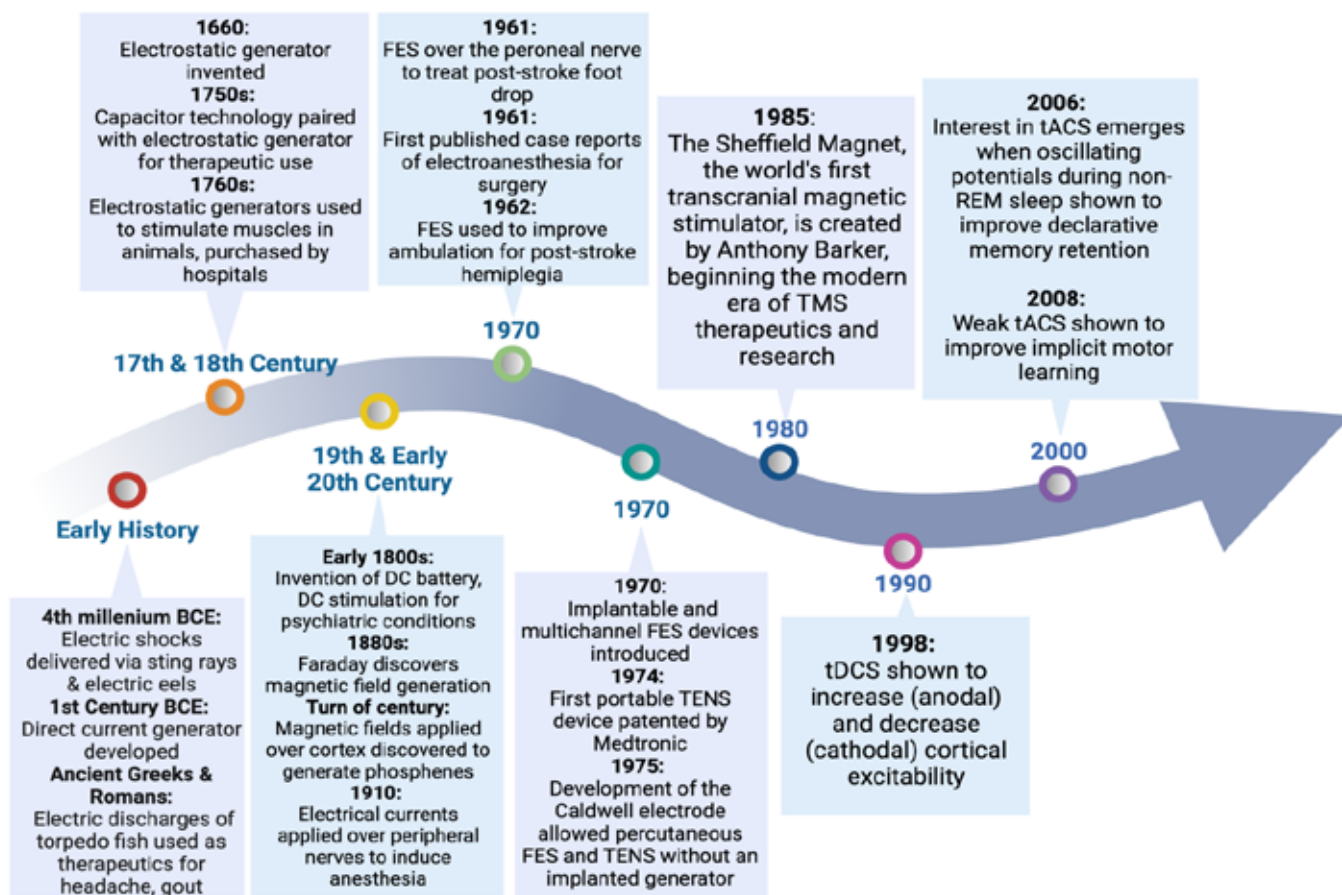


Figure 1. The History of Neurostimulation Technology. Reprinted with permission From Bender Pape, TL, Barrington NM, Webber EK. Exogenous Induction of Neuroplasticity: Non-Invasive Neurostimulation. In Grafman J (ed.) Encyclopedia of the Human Brain, 2nd edition, pages 730-757. Elsevier, 2024, London

Repetitive Transcranial Magnetic Stimulation (rTMS)

In 1985, the Sheffield Magnet was introduced by Anthony Barker, beginning the current era of noninvasive brain stimulation. Barker leveraged Faraday's effect, by delivering a strong directional magnetic field to induce an electrical current on the surface of the brain. It was later determined that pulses or trains of magnetic stimuli delivered in precise amplitudes and frequencies could alter excitability of the targeted cortical tissue⁶. Numerous clinical applications have subsequently been created, from cortical functional mapping to treatment of neurological and psychological disorders. The physiological basis for rTMS-mediated neuromodulation is theorized to be long term potentiation resulting in neuroplasticity.

Transcranial Electrical Stimulation (TES)

There are two types of transcranial electrical stimulation in use today, transcranial direct current stimulation (tDCS) and transcranial alternating current stimulation (tACS). tDCS was rediscovered as a tool to promote neuroplasticity just prior to the turn of the 21st century. Priori et al⁷, and Nitsche and Paulus^{8,9} revealed that anodal

tDCS delivered to the cortex of healthy brain tissue results in a shift of the resting membrane potential towards depolarization, whereas cathodal tDCS shifts towards hyperpolarization. Short stimulation periods have not been found to meaningfully change the polarization potential for longer than the stimulation period, but longer duration of stimulation can induce excitability changes that last far beyond the stimulation period. This has been found to be true for stimulation of motor, visual and somatosensory cortices¹⁰. Connectional effects of tDCS have also been demonstrated. This led to the development of multiple devices to provide direct current stimulation, many of which have been commercialized. More recently, transcranial alternating current stimulation (tACS) has received interest as an alternative clinical intervention¹¹. While some anecdotal evidence suggests that tACS may be better tolerated than tDCS, the current lack of literature in this area makes true comparisons difficult. The debate of which technique is more advantageous may become reminiscent of the war between Tesla and Edison for the type of current utilized in our power grids!¹².

TES and Home Use

TES has the benefits of low cost and portability. This has led to development of devices for home use.

Table 1 – Safety recommendations for intertrain intervals for 10 trains at <20 Hz. Modified from Rossi S, Hallett M, Rossini PM, Pascual-Leone A; Safety of TMS Consensus Group. Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. Clin Neurophysiol. 2009

Inter-train Interval (ms)	Stimulus intensity (% of Motor Threshold)			
	100%	105%	110%	120%
5000	Safe	Safe	Safe	Insufficient data
1000	Unsafe	Unsafe	Unsafe	Unsafe
250	Unsafe	Unsafe	Unsafe	Unsafe

For many, this has raised the issue of safety, ethical, and legal concerns with potential “misuse or overuse.” As would be expected with use of a home medical device, there is very little evidence of the safety of TES with home use. Jwa¹³ indicated that approximately one half of survey respondents reported mild transient symptoms, during the use of home tDCS. In an online forum of home users, no serious adverse events have been reported. However, the potential of these devices to be improperly used, especially in vulnerable populations, have led many clinicians and ethicists to express concern about unmonitored home use of TES, until efficacy and safety data is clearer¹⁴. However, if further support and evidence for safety is provided, the convenience of providing in-home neuromodulation treatments could be extremely beneficial in a population where transport to and from a clinical setting is complicated by immobility. Current technology has the potential to make this intervention even safer, by limiting current levels, program duration, and by including internal safety checks on impedance.

NIBS Guidelines

rTMS

The first guidelines for safe use of rTMS were published by Wasserman et al based on a conference held at the National Institutes of Health in 1996 and were published in 1998¹⁵. Following the publication of these guidelines, reports of the use of rTMS dramatically increased, so in 2008 another consensus conference was held to update the safety guidelines.¹⁶, and a third update from a conference in 2018¹⁷. Following this latest update, there were no significant changes to as the 2008 recommended guidelines have proven safe for the prevention of seizures.

Summaries of the safety and stimulation parameter recommendations are presented in Tables 1 and 2.

Conventional rTMS should be limited to the stimulation intensities of 90% to 130% of motor threshold for the standard figure 8 coil. Other safety guidelines are as follows:

1. Physiological monitoring of every subject undergoing rTMS is desirable when stimulation parameters exceed the guidelines.
2. Visual monitoring of subjects is mandatory to observe for muscle twitching.
3. Neuropsychological monitoring is strongly recommended when cumulative daily sessions of rTMS are administered.
4. rTMS should be performed in an appropriate clinical setting.
5. rTMS should be done under the supervision of a responsible physician.
6. Special precautions must be taken for rTMS provided in neuroimaging centers with MRI.
7. rTMS should be performed by personnel who are adequately trained.
8. Currently the only absolute contraindication for TMS/rTMS is the presence of metallic hardware in close contact to the discharging coil (such as cochlear implants or an internal pulse generator or medication pumps).
9. Hearing protection should be provided.
10. Patients with the following situations should be avoided: persons with epilepsy; vascular, traumatic, tumoral infections, or metabolic lesions of the brain, and administration of medications that lower the seizure threshold, sleep deprivation, alcoholism.
11. Conditions of uncertain or increased risk include: implanted brain electrodes, pregnancy, severe or recent heart disease.

Table 2 - Recommended stimulation parameters for rTMS. Modified from Rossi S, Hallett M, Rossini PM, Pascual-Leone A; Safety of TMS Consensus Group. Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. Clin Neurophysiol. 2009

Frequency (Hz)	100%		110%		120%		130%	
	Duration	Pulses	Duration	Pulses	Duration	Pulses	Duration	Pulses
1	>270	>270	>270	>270	>180	>180	50	50
5	10	50	10	50	10	50	10	50
10	5	50	5	50	3.2	32	2.2	22
20	1.5	30	1.2	24	0.8	16	0.4	8
25	1.0	25	0.7	17	0.3	7	0.2	5

TES Guidelines

Indications for use of tDCS with empirical support were published by a European group¹⁸ followed by an international review with publication of an “updated” set of guidelines in 2017, including discussion of ethical and regulatory issues¹⁹. The initial guidelines were limited by the lack of available study evidence to support Level A (definite efficacy) for any indication. For level B (probable efficacy), guidelines were proposed as follows:

1. Anodal tDCS of the left primary motor cortex in **fibromyalgia**
2. Anodal tDCS of the left dorsolateral prefrontal cortex in **major depression**.
3. Anodal tDCS of the right DLPFC in **addiction/craving**.

Level C recommendations (possible efficacy) was proposed for

1. Anodal tDCS of left M1 in chronic lower limb **neuropathic pain secondary to spinal cord lesion**.

Conversely, level B evidence for absence of clinical effects for

1. Anodal tDCS of the left temporal cortex in **tinnitus**.
2. Anodal tDCS of the left DLPFC in **drug resistant major depression**.

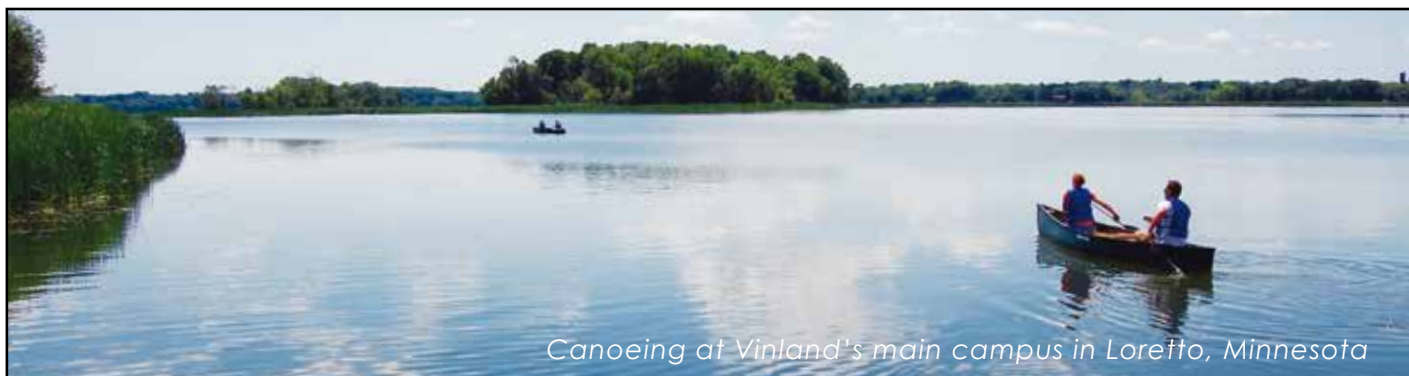
The published guidelines from Antal et al (2017) suggested that safety considerations for tDCS must include parameters of the application, including the intensity, repetition timing, and duration of stimulation. tDCS effects depend on complex interactions between the targeted tissue area and its surroundings, pathology of the tissue, genetic factors, and even medication effects. While changing intensity of stimulation may change the efficacy of treatment, it may also change the direction of excitability of the nerve tissue targeted, potentially leading to the opposite of the intended effect.

In addition, as intensity increases, the induced electrical effect spreads to deeper areas of the brain and can affect neural networks other than the intended targets. By maintaining treatment within set parameters, unintentional consequences can be avoided. Generally, by using low intensity stimulation combined with approved indications and standard montage applications, tDCS is felt to be extremely safe. Low intensity TES is defined as intensities <4 mA, a total stimulation duration of up to 60 min per day and using electrode sizes between 1 cm² and 100 cm², delivering 7.2 coulombs of charge to apply frequencies between 0 and 10,000 Hz²⁰.

Adverse Events for NIBS

rTMS

The main reported risks of rTMS are heating of tissue, magnetic energy affecting implanted ferromagnetic material, induced voltages in implanted wires causing tissue injury or device malfunction or damage, or various side effects including seizures, transient hypomania, headaches, transient hearing changes, transient cognitive/neurocognitive changes, burns from scalp electrodes. Although rare, seizures are reported to occur in healthy subjects during and after rTMS sessions. Prior publications suggest that TMS delivered within recommended guidelines to low-risk individuals caused fewer than 1 seizure per 60,000 sessions²¹. rTMS-related seizures in general populations typically occur during or within a few minutes of stopping rTMS, and within the first few sessions of rTMS. Given that seizures have been reported to occur in healthy subjects makes this risk more of a concern when applying these interventions to individuals with Traumatic Brain Injury (TBI), as these individuals are already at increased risk for seizures compared to the healthy population.



Canoeing at Vinland's main campus in Loretto, Minnesota

drug & alcohol treatment for adults with disabilities



Vinland Center provides drug and alcohol treatment for adults with cognitive disabilities, including traumatic brain injury, fetal alcohol spectrum disorder and learning disabilities. We make all possible accommodations for cognitive deficits and individual learning styles.

Located in Loretto, Minnesota — just 20 miles west of Minneapolis.

(763)479-3555 • VinlandCenter.org

The risk of seizures is as high as 20% following TBI^{22,23,24}, and seizure risk progressively increases with severity of injury. Because of the increased clinical likelihood of seizures in persons incurring severe TBI, many clinicians would be concerned about an intervention that may further increase seizure risk.

TES

The reported risks tDCS or tACS include tingling, itching, burning, transient skin redness, fatigue, headache, nausea, insomnia, pain at electrode site, skin burns, mood changes, irritability. More serious adverse events included mania/hypomania. There has been one report of a seizure in a 4-year-old boy with history of seizures controlled with antiepileptic medications who had a seizure 4 hours after a tDCS session²⁵. It is unclear whether the tDCS contributed to the seizure or not. Antal et al¹⁹ found that no serious adverse events, as reported in the literature, occurred in over 18,000 tDCS sessions. When reviewing conventional bipolar tDCS in human clinical trials, no reports of serious adverse events were reported in over 33,200 sessions. Therefore, Antal suggested “there is no solid evidence to suggest that the AE’s in patients or in vulnerable populations are significantly higher and different in magnitude in comparison to healthy subjects” although it was noted that in some studies in specific populations, the reported adverse events (AE) were higher. Concerns have been expressed however regarding the quality of AE reporting in clinical trials of TES.

Studies evaluating the use of tDCS in subjects with implanted intracranial devices have also been shown to be safe. Implanted devices in these subjects include various intracranial EEG electrodes and grids.

This review went on to state that implanted stimulators of the central and peripheral nervous system were deemed to be safe with TMS and as such tDCS with its lower intensities is unlikely to be associated with complications associated with implanted devices.

AE’s for NIBS after DOC

Despite an increase in the use of NIBS in individuals with DOC after TBI, there remains very little data published with respect to the safety of these interventions. Many of the published reports contain little data regarding safety monitoring and adverse events, leaving limited data with which to advance our understanding of the safety of these techniques.

As noted previously, the risk of seizures is as high as 20% following TBI. This risk increases with the severity of injury and associated factors. Given that individuals with DOC following TBI generally represent the most severely injured, it logically stands to reason that these are also the ones at highest risk of having seizures. DOC is often associated with a higher risk of other complications that may further increase this risk.

Additionally, due to the severity of injury, the DOC population often has more altered neuroanatomy even than other individuals with TBI. Widespread areas of cortical injury make occurrence of seizures more likely, as well as targeting areas for application of stimulation more difficult. Skull damage and surgical sequelae may also affect the pathways of electrical currents, making proper application and understanding of electrical stimuli both less accurate and ultimately alter the physiological effects of the treatment.

One other factor that limits our understanding of the risk of the interventions is the lack of placebo-controlled studies in this population. A recent study regarding the relationship between seizures and rTMS delivered to patients in a state of DoC after TBI is the only published study to date reporting a study of rTMS induced seizure risk, and is limited, like many studies in this area, by small sample size²⁶. This study found a low-likelihood that a specific rTMS protocol exacerbates baseline seizure rates but also a strong correlation between occurrence of seizure and the presence of a ventricular shunt. It was noted that hydrocephalus is itself a risk factor for seizures, and placement of a ventricular shunt does not necessarily mitigate this risk²⁷. Although presence of shunts had previously been listed as a potential contraindication for rTMS, this was largely a theoretical risk, as no studies had previously been done.

Summary

Although NIBS interventions do not yet have FDA approval for clinical use in the treatment of DoC after TBI, there is little evidence to suggest that these interventions are unsafe to use in this population, particularly when given within the recommended clinical guidelines. Given the poor prognosis for recovery for individuals with DoC, if efficacy can be clearly demonstrated, it would justify the small risk reported. As tDCS has not been shown to be associated with serious AE’s, the primary concern remains the possibility of inducing a seizure with rTMS. The finding of low likelihood of rTMS exacerbating baseline seizure risk was based on a specific rTMS protocol and the finding of association between seizures and the presence of ventricular shunts suggests that use of rTMS in patients with shunts should be approached with extreme caution.

Limited sample size also limits our knowledge of safety of rTMS interventions, and it is hoped that further research will include more robust safety data to better inform our understanding of the risks. Ultimately, the decision to administer rTMS is left to the individual researcher or clinician. Also, almost all tDCS and rTMS studies are focused on short term outcomes, there needs to be further research on long term outcomes and possible consequences.

It is possible, for example, that seizure threshold is altered for a sustained duration following the rTMS treatments during which time some patients may require aggressive seizure hygiene (e.g., maintaining optimal sleep patterns, minimizing infections) and/or conservative pharmacological management where anti-epileptics are provided with pharmacological neurostimulants²⁸. The potential downside to this, however, is that these medications may also limit the efficacy of the treatment. Clearly, this is an area where more study is needed. Ultimately, we may find in the end that Dr. Galen was correct; electricity applied in the proper controlled protocols may prove safe and efficacious, and use of home electrical stimulation devices may help this unfortunate population on the road to enhanced, meaningful functional outcomes.

References

1. Sarmiento, C.I., San-Juan, D., Prasath, V.B.S., 2016. Letter to the Editor: brief history of transcranial direct current stimulation (tDCS): from electric fishes to microcontrollers. *Psychol. Med.* 46, 3259e3261.
2. Beaudreau SA, Finger S. Medical electricity and madness in the 18th century: the legacies of Benjamin Franklin and Jan Ingenhousz. *Perspect Biol Med.* 2006;49:330–345.
3. Delbourgo J. A most amazing scene of wonders: electricity and enlightenment in early America. Cambridge, Mass: Harvard University Press; 2006.

4. Finger S. Benjamin Franklin, electricity, and the palsies: on the 300th anniversary of his birth. *Neurology*. 2006;66:1559-1563.

5. Bindman, et al. (1964), The action of brief polarizing currents on the cerebral cortex of the rat (1) during current flow and (2) in the production of long-lasting after-effects. *The Journal of Physiology*, 172.

6. Pape TL, et al. Exogenous Induction of Neuroplasticity: Non-Invasive Neurostimulation. In Grafman J (ed.) *In Encyclopedia of Human Brain*, 2nd edition, Jordan Grafman (Editor), Section: Neuroplasticity, A.M. Barrett and Keith McGregor (Section Editors). Elsevier, 2024, London

7. Priori A, et al. 1998. Polarization of the human motor cortex through the scalp. *Neuroreport*, 9, 2257-2260

8. Nitsche MA, Paulus W. 2000. Excitability changes in the human motor cortex by weak transcranial direct current stimulation.pdf. *Journal of Physiology*.

9. Nitsche MA, Paulus W. 2001. Sustained excitability elevations induced by transcranial DC motor cortex stimulation in humans. *Neurology*, 57, 1899-1901

10. Lefaucheur JP, et al. Evidence-based guidelines on the therapeutic use of transcranial direct current stimulation (tDCS). *Clin Neurophysiol*. 2017 Jan;128(1):56-92. doi:10.1016/j.clinph.2016.10.087. Epub 2016 Oct 29.

11. Antal A, et al. Comparatively weak after-effects of transcranial alternating current stimulation (tACS) on cortical excitability in humans. *Brain Stimul*. 2008 Apr;1(2):97-105.

12. Tesla versus Edison: the conflict that gave us alternating current. <https://www.endesa.com/en/the-face/biographies/tesla-edison-war>

13. Jwa A. Early adopters of the magical thinking cap: a study on do-it-yourself (DIY) transcranial direct current stimulation (tDCS) user community. *J Law Biosci*. 2015 Jun 2;2(2):292-335. doi: 10.1093/jlb/lsv017.

14. Wurzman R, et al. An open letter concerning do-it-yourself users of transcranial direct current stimulation. *Ann Neurol*. 2016 Jul;80(1):1-4. doi: 10.1002/ana.24689.

15. Wassermann EM. Risk and safety of repetitive transcranial magnetic stimulation: report and suggested guidelines from the International Workshop on the Safety of Repetitive Transcranial Magnetic Stimulation, June 5-7, 1996. *Electroencephalogr Clin Neurophysiol*. 1998 Jan;108(1):1-16.

16. Rossi S, et al. Safety of TMS Consensus Group. Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. *Clin Neurophysiol*. 2009 Dec;120(12):2008-2039.

17. Rossi S, et al. basis of this article began with a Consensus Statement from the IFCN Workshop on "Present, Future of TMS: Safety, Ethical Guidelines", Siena, October 17-20, 2018, updating through April 2020. Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines. *Clin Neurophysiol*. 2021 Jan;132(1):269-306.

18. Lefaucheur JP, et al. Evidence-based guidelines on the therapeutic use of transcranial direct current stimulation (tDCS). *Clin Neurophysiol*. 2017 Jan;128(1):56-92.

19. Antal A, et al. Low intensity transcranial electric stimulation: Safety, ethical, legal regulatory and application guidelines. *Clin Neurophysiol*. 2017 Sep;128(9):1774-1809. doi: 10.1016/j.clinph.2017.06.001. Epub 2017 Jun 19.

20. Bikson M, et al. Safety of Transcranial Direct Current Stimulation: Evidence Based Update 2016. *Brain Stimul*. 2016 Sep-Oct;9(5):641-661. doi: 10.1016/j.brs.2016.06.004. Epub 2016 Jun 15.

21. Lerner AJ, et al. Seizures from transcranial magnetic stimulation 2012-2016: Results of a survey of active laboratories and clinics. *Clin Neurophysiol*. 2019;130(8):1409-1416.

22. Englander J, et al. Analyzing risk factors for late posttraumatic seizures: a prospective, multicenter investigation. *Arch Phys Med Rehabil*. 2003;84(3):365-373.

23. Ferguson PL, et al. A population-based study of risk of epilepsy after hospitalization for traumatic brain injury. *Epilepsia*. 2010;51(5):891-898.

24. Asikainen I, et al. Early and late posttraumatic seizures in traumatic brain injury rehabilitation patients: brain injury factors causing late seizures and influence of seizures on long-term outcome. *Epilepsia*. 1999;40(5):584-589.

25. Ekici, B., 2015. Transcranial direct current stimulation-induced seizure: analysis of a case. *Clin. EEG Neurosci*. 46, 169.

26. Ripley D Krese K Rosenow J Patil V Schuele S Pacheco M Roth E Kletzel S Livengood S Aaronson A Herrold A Blabas B Bhaumik R Guernon A Burrest Kestner C Walsh E Bhaumik D Bender Pape T (in press) Seizure risk associated with the use of transcranial magnetic stimulation for coma recovery in individuals with disordered consciousness after severe traumatic brain injury, *J Head Trauma Rehabilitation*. (PMID: 39293071).

27. Sato O, et al. Hydrocephalus and epilepsy. *Childs Nerv Syst*. 2001 Jan;17(1-2):76-86.

28. Kletzel SL, et al. Safety Considerations for the Use of Transcranial Magnetic Stimulation as Treatment for Coma Recovery in People with Severe Traumatic Brain Injury. *J Head Trauma Rehabil*. 2020;35(6):430-438.

Author Bios

David Ripley, MD, MS is the Chief Medical Officer of New Summit Rehabilitation and Healthcare. He brings extensive expertise in physical medicine and rehabilitation, with a focus on innovative therapies for brain injury recovery. Throughout his career, Dr. Ripley has been dedicated to advancing the field of neurorehabilitation, integrating evidence-based practices and cutting-edge treatments to improve patient outcomes. At New Summit, he oversees the development and implementation of comprehensive care plans that address the complex needs of individuals with traumatic brain injuries and other neurological conditions. Dr. Ripley is recognized for his commitment to patient-centered care and his leadership in driving excellence in rehabilitation services.

Transcranial Stimulations

Sidebar: Transcranial Magnetic Stimulation (TMS)

Repetitive TMS (rTMS)	
Repeated magnetic pulses are delivered to the brain via magnetic coils intended to facilitate excitatory or inhibitory responses ⁵	
Theta-burst stimulation (TBS)	
A form of rTMS in which faster pulses are delivered	
intermittent Theta-Burst Stimulation (iTBS)	continuous Theta-Burst Stimulation (cTBS)
Patterned magnetic pulses are delivered to increase excitability	Pulses are delivered without pauses to reduce excitability
Single Session Treatment Duration	
rTMS	TBS
30-38 min	3-10 min
Most Common Side Effects	
Headache, Fatigue, Nausea, Dizziness, Pain at stimulation site ⁶	
Less Common Notable Adverse Side Effects	
Seizure	

Sidebar: Transcranial Direct Current Stimulation tDCS

A weak electrical current is delivered to the surface of brain via a minimum of two electrodes with the intent of facilitating excitatory or inhibitory responses	
anodal tDCS	cathodal tDCS
Enhances excitability	Decreases excitability
Single Session Treatment Duration	
5-30 min	
Most Common Side Effects	
Fatigue, Tingling Sensation, Itching at electrode site	
Less Common Notable Adverse Side Effects	
Headache, Nausea, Insomnia, Lesion at electrode site	

Neuromodulatory Interventions in Patients with Disorders of Consciousness after Severe Brain Injury: What is the State of the Evidence?

Patricia Grady-Dominguez, PhD • Lauren Teague • Jennifer Weaver, PhD, OTR/L

Patients with disorders of consciousness (DoC) are characterized by a continuum of clinical states (Table 1)^{1,2} and emerging research suggests that neuromodulatory interventions may lead to improved neurobehavioral function.^{3,4} In the context of brain injury rehabilitation, neuromodulation has been defined as “the alteration of nerve activity through targeted delivery of stimulation provided to modulate dysfunctional as well as functional neural pathways to support neural repair and neural alterations necessary

for sustained recovery of functional skills valued by the patient” (p. 368).⁵ Neuromodulatory interventions may aid in reconfiguring neural networks, improve the structure and function of viable networks after injury, engage dormant networks, and create new neural connections. For patients with DoC, these benefits may contribute to increases in neurobehavioral function including arousal and awareness, subsequently leading to an improved state of consciousness.

Table 1. Characterizing States of Consciousness in DoC, adapted from Giacino et al. and Thibaut et al.^{1,2}

Clinical States	Sleep/Wake Cycles	Motor Function	Auditory Function	Visual Function	Communication
Comatose	Absent	Reflexive and postural responses	None	None	None
Unresponsive Wakefulness Syndrome (UWS)	Present	Withdrawal from painful/noxious stimuli; some non-purposeful movement	Startle, brief orientation to sound	Startle, brief visual fixation	None
Minimally Conscious State Minus (MCS-)	Present	Localized response to painful/noxious stimuli, occasional automatic and/or purposeful movement	Localization to sound, inconsistent response to command	Sustained visual fixation	None
Minimally Conscious State Plus (MCS+)	Present	Localized response to painful/noxious stimuli, occasional automatic and/or purposeful movement	Localization to sound, command following ¹	Sustained visual fixation	Intelligible vocalization and/or gestural communication of yes/no responses regardless of accuracy ¹
Emerged from Minimally Conscious State (eMCS)	Present	Functional object use ²	Localization to sound, command following ²	Sustained visual fixation	Functional communication, confusion is often present ²

¹ For MCS+, only one of either command following, intelligible vocalization, or consistent (even if inaccurate) verbal or gestural yes/no responses must be present.

² For eMCS, either functional object use or functional communication must be present; command following may be present but is not currently required to meet criteria for eMCS.

Table 2. Current Evidence For Neuromodulatory Interventions in DoC.

Interventions	Brief Description	Considerations	Level of Evidence
Sensory Stimulation			
Unimodal Sensory Stimulation	Application of stimuli to the auditory, tactile, visual, gustatory, olfactory, proprioceptive, or vestibular senses.	Low cost and uses readily available materials. Most research has focused on familiar auditory stimuli (e.g., music or storytelling). Only one study demonstrated moderate evidence; this study used familiar voices telling structured stories. Only familiar voices telling structured stories showed moderate evidence; all other modalities had low evidence.	Low to moderate
Multimodal Sensory Stimulation	Application of at least two types of sensory stimulation.	Low cost and uses readily available materials. Interventions including personally relevant stimuli and/or family involvement may be more effective.	Strong
Peripheral Nerve Stimulation			
Median Nerve Stimulation*	Electrical stimulation of the median nerve at the wrist.	Low cost, safe, and generally available in inpatient rehabilitation settings.	Moderate
Non-Invasive Brain Stimulation			
Transcranial Direct Current Stimulation*	Application of low, constant current using scalp electrodes.	Low cost, safe, and sometimes available in inpatient rehabilitation settings. May be more effective for patients in MCS+ or MCS- compared to UWS.	Moderate
Repetitive Transcranial Magnetic Stimulation*	Application of alternating magnetic fields to up- or down-regulate nerve cells in the brain.	High cost and limited availability of rTMS units.	Low
Near Infrared Laser Therapy*	Application of low-level near-infrared laser to the scalp.	High cost and limited availability of near infrared laser units. Safety has not been established. Single study does not adequately describe protocol.	Low

In this article, we draw upon two recent literature reviews to briefly summarize the current evidence and clinical utility of six non-invasive neuromodulatory interventions for patients with DoC (Table 2). Murtaugh and colleagues (2024)⁴ conducted an umbrella review of systematic reviews for allied health interventions (i.e., music, occupational, physical, and speech therapy). To include additional information about emerging stimulation interventions that are less available in clinical practice, we also include evidence from a systematic review conducted by Weaver and colleagues (2022).³ Non-invasive brain stimulation techniques based on medical devices (noted with an ‘*’ in Table 2) are regulated in the United States (US) by the Food and Drug Administration (FDA) and companies marketing these devices are required to comply with regulatory requirements before they can legally sell their devices in the US. US based clinicians considering the purchase of a device should have the company confirm the FDA approval status for use in brain injury rehabilitation.

Sensory Stimulation

Sensory stimulation is provided to individuals with DoC to increase arousal and awareness. Research has largely examined two types of sensory stimulation interventions: unimodal and multimodal (i.e., interventions where more than one of the visual, auditory, tactile, olfactory, gustation, vestibular, and/or proprioception senses are addressed). Protocols typically involve providing 2 to 5 minutes of stimulation several times per day.⁴

Low to moderate evidence supports the use of unimodal sensory stimulation. There is moderate evidence for the use of structured, familiar storytelling and low evidence for the use of unstructured storytelling and music.³ All studies examining unimodal stimulation

have, to date, focused on auditory stimuli including structured and unstructured storytelling, familiar voices, and music (within and outside the context of music therapy). These studies have low methodological quality, limiting the ability to provide evidence for their efficacy. Systematic reviews of music therapy interventions indicate promise for improving arousal and awareness, but current research is largely exploratory.⁴

Strong evidence supports the use of multimodal sensory stimulation to improve neurobehavioral function in patients with DoC.^{3,6} Approaches include a combination of at least two types of sensory stimuli, including storytelling (auditory), familiar music (auditory), footbaths (tactile), massage (tactile), positioning (vestibular/ proprioceptive), and other types of stimulation. Some studies used structured protocols, while others used stimuli tailored to the patient’s preferences. Two studies showed that patients had better recovery in neurobehavioral function when sensory stimulation was delivered by family members compared to delivered by clinical staff.

Clinical Takeaway

Sensory stimulation is a low-technology intervention that can be delivered by clinicians, staff members, and/or family members at the bedside.³ Strong evidence supports the delivery of familiar, multimodal stimuli provided by family members. Moderate to low evidence supports unimodal sensory stimulation. Most research has focused on auditory and tactile sensory stimulation. Significant heterogeneity exists in the research for sensory stimulation protocols – currently, no specific protocol has emerged as superior. Clinicians and family members should consider applying this low-risk intervention to patients with DoC to increase neurobehavioral function.

Median Nerve Stimulation

Peripheral nerve stimulation has been studied as it can increase bilateral cerebral blood flow, directly stimulate the brainstem and cerebral cortex, and enhance the secretion of neurotransmitters in patients with DoC.⁷ Most research has focused on stimulation of the right median nerve at the wrist, a simple, inexpensive, and safe approach to peripheral nerve stimulation.

Emerging research suggests that median nerve stimulation may have a positive impact on improving state of consciousness.⁴ However, as with other interventions, significant heterogeneity in dosing and frequency prevents conclusive evaluation of this intervention. Individual patient responses vary significantly across studies. No research has determined which patients (i.e., UWS or MCS) are most likely to benefit from this intervention.

Clinical Takeaway

Median nerve stimulation, like other non-invasive neuromodulatory interventions, shows some promise for increasing arousal and awareness in patients with DoC. More research is necessary to establish appropriate dosing and determine which patients are most likely to respond to this therapy. Advantages to be considered include that, relative to other interventions, median nerve stimulation is safe and inexpensive.

Non-Invasive Brain Stimulation

Non-invasive brain stimulation can be used to induce electrical currents in the brain via the delivery of electrical stimuli or magnetic pulses. These methods vary in cost and availability to clinicians for use with patients in DoC. Evidence for using these devices to treat patients with DoC is just beginning to emerge, and we include it to highlight potential future clinical applications.

Transcranial Direct Current Stimulation

Transcranial Direct Current Stimulation (tDCS) is a technique that involves delivering low, constant current to the brain using electrodes placed on the scalp. Depending on the parameters applied, it may increase viable synaptic connections (anodal tDCS) or decrease undesirable connections (cathodal tDCS).³ tDCS units are relatively inexpensive, portable, and can be used for multiple patients. This intervention has gained attention in recent years for its potential therapeutic benefits in patients with DoC.

Moderate evidence supports the use of tDCS on the dorsolateral prefrontal cortex. Studies included in the Weaver review ranged in frequency from a single session to 20 sessions over four weeks.³ Patients in the MCS showed gains in neurobehavioral outcomes, suggesting a potential benefit for enhancing neurobehavioral function. Results were mixed for patients with UWS; two studies showed benefits for these patients while two did not. Weaver and colleagues also identified a single study examining tDCS stimulating the primary motor cortex; this study found no benefit from the intervention.³

Repetitive Transcranial Magnetic Stimulation

Repetitive transcranial magnetic stimulation (rTMS) uses alternating magnetic fields to up- or down-regulate nerve cells in the brain.³ rTMS has been applied to many neurological conditions, and

Educational Resources for Persons Caring for Individuals with Disorders of Consciousness

In collaboration with Brainline.org, the Family Education workgroup of the American Congress of Rehabilitation Medicine Brain Injury Special Interest Group Disorders of Consciousness Task Force has created a comprehensive web-based education and resource guide for family caregivers of persons with severe brain injury. All of the resources and website links included on this “Disorders of Consciousness Hub” (www.brainline.org/dchub) have been reviewed and vetted by brain injury experts to ensure accuracy. Informed by consumer input at every stage of development, the DoC hub is easy-to-navigate by caregivers on their own to support education, answering questions, and advocacy about their loved one's needs. This fully customizable resource can also be used by professionals as a tool to aid implementation of best practices for providing individualized education and training to family caregivers.



recent evidence has examined its efficacy in increasing arousal and awareness in patients with DoC. rTMS units are large and more expensive than tDCS devices, limiting their availability for use with this population. While randomized placebo-controlled clinical trials of rTMS are underway, only one low-quality study was identified by Weaver and colleagues, and this report indicated no clinical benefit. While the currently published evidence of clinical efficacy is limited, an in-press article in *Journal of Head Trauma Rehabilitation*,⁸ is a seminal report of rTMS-related seizure risk indicating low likelihood that rTMS elevates baseline seizure risk for the majority of patients with DoC. This evidence and emerging evidence of efficacy from rigorous trials should be considered by researchers studying the clinical benefits of rTMS in isolation and when combined with other interventions provided to patients with DoC.

Near Infrared Laser Therapy and Focused Shockwaves

Near infrared laser therapy may increase the availability of adenosine triphosphate in the brain, leading to improved cellular respiration and oxygenation.³ Focused shockwaves are also thought to produce biologic responses including anti-inflammatory actions and improved cellular function. One small study, included in the Weaver review, compared these two approaches and reported that both groups experienced statistically significant increases in neurobehavioral function. Both approaches require costly, specialized equipment and trained personnel and, at this time, these

approaches are not readily available for use in rehabilitation for patients in DoC. These techniques may improve neurobehavioral function, but the current evidence is low due to the small sample size and lack of control group.

Clinical Takeaway

Evidence supporting clinical use of tDCS, rTMS, near-infrared laser therapy, and focused shockwaves is slowly emerging. tDCS applied to the dorsolateral prefrontal cortex shows moderate evidence for improvements in arousal and awareness in patients in the minimally conscious state. The other approaches currently have limited evidentiary support and are largely unavailable in current clinical settings. Notably, at this time the FDA has not approved clinical use of these devices in the United States to treat patients in DoC. Further research is needed to establish safety, clinical benefits, optimal protocols, understand long-term effects, for patients in both the minimally conscious state and those with unresponsive wakefulness syndrome.

Concluding Remarks

The American Congress of Rehabilitation Medicine and the American Academy of Neurology (ACRM/AAN) published joint clinical practice guidelines for the evaluation and treatment of patients with prolonged DoC.⁹ They noted that existing treatments for DoC generally lack strong evidentiary support, leading to uncertainty in clinical decision-making for these patients. While the neuromodulatory interventions reviewed in this article present some benefits and/or merit further study for enhancing neurobehavioral recovery, there are no clinical practice guidelines for their use. For both existing and emerging treatments, variability in study methodologies and patient responses to treatments pose substantive challenges to providing clinical guidance. Given the paucity of clear guidance, clinicians should engage in transparent communication and shared decision-making with family caregivers while selecting neuromodulatory interventions. Continued research efforts should focus on establishing safety, clinical benefits, optimal protocols, understanding long-term effects, for both existing and emerging treatments for patients in the minimally conscious state and with unresponsive wakefulness syndrome.

References

1. Giacino JT, Ashwal S, Childs N, et al. The minimally conscious state: Definition and diagnostic criteria. *Neurology*. 2002;58(3):349-353. doi:10.1212/WNL.58.3.349
2. Thibaut A, Bodien YG, Laureys S, Giacino JT. Minimally conscious state "plus": diagnostic criteria and relation to functional recovery. *J Neurol*. 2020;267(5):1245-1254. doi:10.1007/s00415-019-09628-y
3. Weaver JA, Watters K, Cogan AM. Interventions facilitating recovery of consciousness following traumatic brain injury: A systematic review. *OTJR: Occupation, Participation and Health*. Published online September 1, 2022:153944922211177. doi:10.1177/1539449222111777
4. Murtaugh B, Morrissey AM, Fager S, Knight HE, Rushing J, Weaver J. Music, occupational, physical, and speech therapy interventions for patients in disorders of consciousness: An umbrella review. Schnakers C, Zasler ND, eds. *NRE*. 2024;54(1):109-127. doi:10.3233/NRE-230149
5. Bender Pape TL, Herrold AA, Guernon A, Aaronson A, Rosenow JM. Neuromodulatory interventions for traumatic brain injury. *Journal of Head Trauma Rehabilitation*. 2020;35(6):365-370. doi:10.1097/HTR.0000000000000643
6. Padilla R, Domina A. Effectiveness of sensory stimulation to improve arousal and alertness of people in a coma or persistent vegetative state after traumatic brain injury: A systematic review. *The American Journal of Occupational Therapy*. 2016;70(3):7003180030p1-7003180030p8. doi:10.5014/ajot.2016.021022
7. Wang P, Cao W, Zhou H, et al. Efficacy of median nerve electrical stimulation on the recovery of patients with consciousness disorders: a systematic review and meta-analysis. *J Int Med Res*. 2022;50(12):030006052211344. doi:10.1177/03000605221134467
8. Ripley D, Krese K, Rosenow J, Patil V, Schuele S, Pacheco M, Roth E, Kletzel S, Livengood S, Aaronson A, Herrold A, Blabas B, Bhaumik R, Guernon A, Burrell, Kestner C, Walsh E, Bhaumik D, Bender Pape T (in press) Seizure risk associated with the use of transcranial magnetic stimulation for coma recovery in individuals with disordered consciousness after severe traumatic brain injury. *J Head Trauma Rehabilitation*. (PMID: 39293071)
9. Giacino JT, Katz DI, Schiff ND, et al. Practice guideline update recommendations summary: Disorders of consciousness: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology; the American Congress of Rehabilitation Medicine; and the National Institute on Disability, Independent Living, and Rehabilitation Research. *Neurology*. 2018;91(10):450-460. doi:10.1212/WNL.00000000000005926

Author Bios

Patricia Grady-Dominguez, PhD, a postdoctoral fellow in the Meaningful Measurement for Rehabilitation Research Lab at Colorado State University, holds a Ph.D. in Occupation and Rehabilitation Science. Her research focuses on improving precision of rehabilitation outcome measures and improving utility of assessment tools for evaluating recovery, particularly for severe traumatic brain injury and pediatrics. With expertise in advanced psychometric models, including Rasch analysis, she has contributed to developing and validating instruments used to measure rehabilitation outcomes ranging from body functions to participation.

Lauren Teague is a Doctor of Occupational Therapy student at Colorado State University. She is originally from Indiana, where she graduated from Purdue University with a Bachelor of Science in Psychological and Brain Sciences. Lauren is a Graduate Research Assistant in the Meaningful Measurement in Rehabilitation Research Lab (METEOR Lab) at Colorado State University. Her research interests include rehabilitation measures, practitioner-caregiver communication, and neurological disorders.

Jennifer Weaver, PhD, OTR/L, is an Assistant Professor in the Department of Occupational Therapy at Colorado State University (CSU), Director of the Meaningful Measurement in Rehabilitation Research Lab, and Director of Implementation Research for the Translational Neurological Lab located at the CSU Spur campus. She has over 10 years of experience as an occupational therapist and was a certified brain injury specialist. She is the project lead on advancing outcome measures and implementing evidence-based measurement practices in rehabilitation for patients with disorders of consciousness.

Resources for the Familiar Auditory Sensory Training Intervention

Familiar Auditory Sensory Training (FAST) is a subcortical and cortical neuromodulation treatment for people with severely impaired attention systems. Repeated exposure to personal linguistic FAST stimuli (FAST-L) in people with disorders of consciousness after traumatic brain injury is known to induce attention system changes and improve attention skills.

To listen to the patient's and caregiver's perspective about the FAST benefits, please go to this URL: <https://news.feinberg.northwestern.edu/2015/01/22/pape-coma-voices/>

For a checklist on how to create the FAST stories as well as articles reporting the evidentiary basis for providing the FAST, please go to this URL or scan the QR code: https://arch.library.northwestern.edu/concern/generic_works/wp988k41f?locale=en





Non-Invasive Brain Stimulation for Cognitive Rehabilitation *A Brief Overview*

André Lindsey, PhD, CCC-SLP • Monica T. Ly, PhD • Karen Lê, PhD, CCC-SLP

Traumatic brain injuries (TBIs) commonly disrupt and impair cognitive processes. Mild TBIs (mTBI) resulting in persisting deficits often co-occur with psychiatric disorders, such as major depressive disorder (MDD) and posttraumatic stress disorder (PTSD), which also entail altered cognitive functioning. Many patients report that the cognitive symptoms resulting from mTBI create challenges that deleteriously impact daily function in their community, work, and school causing detriment to their emotional well-being, interpersonal relationships, and overall quality of life. The negative impact of these cognitive deficits on daily life underscores the need for interventions enabling long-lasting recovery of cognitive skills. Addressing this need is a small but growing body of literature suggesting that neuromodulation via non-invasive brain stimulation (NIBS) techniques has the potential to enhance cognitive rehabilitation, particularly when provided in tandem with other intervention approaches.

Transcranial direct stimulation (tDCS) and transcranial magnetic stimulation (TMS) are types of NIBS techniques that have gained interest and traction in clinical use for their potential to alter neural functioning. While TMS has become widely implemented as an effective treatment for medication-resistant depression,¹ researchers are still examining the utility of TMS as a cognitive enhancement strategy and treatment tool for individuals who are experiencing persistent cognitive deficits (e.g., impaired attention, reduced short- and long-term memory, brain fog).

Neuromodulation

Neuromodulatory treatments, such as TMS and tDCS, offer a potential pathway to engage with and act on processes disrupted (e.g., altered neural signaling) or triggered (e.g., inflammation) as a consequence of mTBI. Individuals recovering from a mTBI are potential candidates for NIBS treatments due to the region of concern (i.e., the brain) and because many symptoms of mTBI are neither alleviated by pharmaceutical interventions,² nor by standard cognitive rehabilitation which can be due to a number of factors including, but not limited to, severity of injury, age, sex,

clinical biomarkers resulting from injury, and co-occurring medical and psychiatric conditions³⁻⁶. NIBS treatments directly engage neural processes with both TMS and tDCS noted to induce long-term potentiation-like processes, during which cells appear more responsive and adaptable to change⁷⁻⁹. A specific type of TMS known as intermittent theta-burst stimulation (iTBS) can, for example, produce cortical excitability lasting up to 60 minutes following stimulation⁹.

Both tDCS and the differing types of TMS typically target the prefrontal cortex (PFC), as it is a neural hub critical to cognitive engagement supporting multiple neural processes including executive functions (e.g., planning, problem solving, cognitive flexibility) through its vast connections with other brain regions and systems¹⁰. More specifically, the most commonly targeted region during tDCS and iTBS treatment is the dorsolateral prefrontal cortex (DLPFC). Prior to commencing treatment, the target region is identified using either EEG (10-20 system), structural MRI, functional MRI, and/or neuro-navigation systems that facilitate accurate localization of brain targets^{11,12}. Both tDCS and TMS interventions can be provided when the individuals are awake and most individuals resume their normal routine within minutes to an hour following treatment. Many studies investigating these treatments require individuals to be monitored for at least 30 minutes following treatment as a safety precaution and it is during this post-neuromodulation period that individuals may also be led through therapeutic cognitive exercises.

Neuromodulation Followed by Cognitive Rehabilitation

Ongoing research is examining whether implementing traditional cognitive rehabilitation interventions during the post-neuromodulation period yields increased therapeutic benefit by leveraging the heightened state of neuroplasticity. It is thought that this sequential approach will support neural restructuring and skill restoration¹³.

The Dorsolateral Prefrontal Cortex (DLPFC)

There is a great deal of heterogeneity in the boundaries of the DLPFC as, across studies, it is defined by function versus physiology. However, gross boundaries and functions are well defined in this image, reprinted with permission from: Friedman, N.P. and T.W. Robbins, The role of prefrontal cortex in cognitive control and executive function. *Neuropsychopharmacology*, 2022. 47(1): p. 72-89. The image from this paper considers the DLPFC medial and superior frontal gyri with an anterior-posterior boundaries at fronto-polar and sensory cortex. The top panel depicts a lateral view, and the bottom panel depicts a medial view. Numbers indicate Brodmann Areas (BA). Note that the commonly described “ventromedial prefrontal cortex” potentially subsumes several BAs: 25, 32, 14, and possibly 11 and 13.



Cognitive rehabilitation has traditionally encompassed behavioral interventions, ranging from formal, skill-level training programs to improve specific cognitive processes (e.g., Attention Process Training) to more functional approaches that incorporate “real-world” activities and contexts (e.g., keeping and updating an appointment calendar, using a daily task list, CogSMART¹⁴). The former approaches are sometimes described as “restorative” interventions and are intended to prompt gains toward preinjury status, whereas the latter are frequently characterized as “compensatory.” The latter approaches often focus on implementing accommodations and supports, learning compensatory strategies, and practicing cognitive strategies in order to address an individual’s specific goals, while maximizing functioning¹³.

Cognitive rehabilitation interventions designed for mTBI patients (e.g., cognitive symptom management and rehabilitation therapy [CogSMART¹⁴]) often include practice with functional memory and

organizational strategies, attention training exercises, education about mTBI recovery, and strategies to address poor sleep and mood symptoms. Cognitive rehabilitation also often includes metacognitive strategy training (MST), which focuses on increasing active self-awareness and promoting independent problem-solving. During MST, individuals learn to identify and acknowledge their strengths and weaknesses, utilize their strengths, and account for their limitations when performing a task.

Pairing non-invasive brain stimulation (NIBS) treatments with cognitive-behavioral interventions provides an opportunity to leverage a neural environment that has been primed for change. By engaging in therapeutic exercises and training, while cells are potentiated, cognitive processes impaired by TBI may be enhanced¹³. Given that any behavioral change involves some alteration of neural activity, both restorative and compensatory interventions may benefit from the use of NIBS.

The Current State of Affairs

The research on NIBS treatments as an adjunct to cognitive rehabilitation is in a nascent stage, and such treatments have not yet been approved by the Food and Drug Administration (FDA) to treat cognitive impairments secondary to mTBI or other neurological conditions, such as stroke. However, TMS is FDA-approved to treat major depressive disorder, obsessive compulsive disorder, and smoking cessation¹⁵. Research examining the use of NIBS interventions to treat cognitive impairments resulting from TBI has produced mixed results. A recent meta-analysis examining both tDCS and rTMS revealed a modest effect of treatment with regard to alleviating symptoms¹⁶. Specific treatment effects were observed for anxiety and headaches (both modest), but not for cognitive deficits. Researchers posit that lack of conclusive findings regarding the use of these treatments with cognitive impairments may be due to small sample sizes, individual differences between research participants, and/or a need to further develop and refine treatment protocols^{13,17,18}. Of additional note, neuromodulation is not suitable for everyone, and many individuals with TBI will not qualify because of the use of supportive medical devices and/or injury related material remnants (e.g., shrapnel). Neuromodulation is contraindicated for individuals who have intracranial metal (e.g., plates), implants (e.g., cochlear implants, pacemakers), or a history of seizure¹⁹.

Conclusion

Non-invasive brain stimulation (NIBS) holds promise as a means of improving cognitive functioning following mTBI, but additional research is needed to clarify candidacy and treatment safety and efficacy across patient and injury characteristics. Future studies should further investigate stimulation of specific brain regions and levels of stimulation most likely to yield the greatest gains. Furthermore, researchers should continue examining the extent to which NIBS can provide additional benefit when paired with cognitive rehabilitation interventions. Recent work investigating NIBS has primarily focused on short-term benefits, but the long-term effects should also be examined. While the emerging findings suggest the potential of NIBS as an important component of cognitive rehabilitation, more research is needed to understand whether these techniques can produce lasting, functional change for individuals with mTBI.

Disclaimer

This work was partially supported by the Rehabilitation Research and Development Service, Office of Research and Development, Veterans Health Administration, U.S. Department of Veterans Affairs (Award 1 IK2 RX003494-01A2) awarded to Karen Lê. The views expressed in this work are those of the authors and do not necessarily reflect the official views, policy, or position of the Department of Veterans Affairs or the U.S. Government.

References

1. Perera T, et al. The Clinical TMS Society Consensus Review and Treatment Recommendations for TMS Therapy for Major Depressive Disorder. *Brain Stimulation*. 2016;9(3):336-346. doi:10.1016/j.brs.2016.03.010
2. Giza CC, Hovda DA. The Neurometabolic Cascade of Concussion. *J Athl Train*. 2001;36(3):228-235.
3. Rabinowitz AR, et al. Prevalence and Predictors of Poor Recovery from Mild Traumatic Brain Injury. *Journal of Neurotrauma*. 2015;32(19):1488-1496. doi:10.1089/neu.2014.3555
4. Ponsford J. Factors contributing to outcome following traumatic brain injury. Wood RLI, ed. *NRE*. 2013;32(4):803-815. doi:10.3233/NRE-130904
5. Sigurdardottir S, Andelic N, Roe C, Schanke AK. Cognitive recovery and predictors of functional outcome 1 year after traumatic brain injury. *J Int Neuropsychol Soc*. 2009;15(5):740-750. doi:10.1017/S1355617709990452
6. Muballe KD, et al. Predictors of recovery in moderate to severe traumatic brain injury. *Journal of Neurosurgery*. 2019;131(5):1648-1657. doi:10.3171/2018.4.JNS172185

7. Frase L, et al. Transcranial direct current stimulation induces long-term potentiation-like plasticity in the human visual cortex. *Transl Psychiatry*. 2021;11(1):17. doi:10.1038/s41398-020-01134-4
8. Agboada D, et al. Induction of long-term potentiation-like plasticity in the primary motor cortex with repeated anodal transcranial direct current stimulation – Better effects with intensified protocols? *Brain Stimulation*. 2020;13(4):987-997. doi:10.1016/j.brs.2020.04.009
9. Wischniewski M, Schutter DJLG. Efficacy and Time Course of Theta Burst Stimulation in Healthy Humans. *Brain Stimulation*. 2015;8(4):685-692. doi:10.1016/j.brs.2015.03.004
10. Menon V, D'Esposito M. The role of PFC networks in cognitive control and executive function. *Neuropsychopharmacol*. 2022;47(1):90-103. doi:10.1038/s41386-021-01152-w
11. Thair H, et al. Transcranial Direct Current Stimulation (tDCS): A Beginner's Guide for Design and Implementation. *Front Neurosci*. 2017;11:641. doi:10.3389/fnins.2017.00641
12. Sack AT, et al. Optimizing Functional Accuracy of TMS in Cognitive Studies: A Comparison of Methods. *Journal of Cognitive Neuroscience*. 2009;21(2):207-221. doi:10.1162/jocn.2009.21126
13. Lindsey A, Ellison RL, Herrold AA, Aaronson AL, Kletzel SL, Stika MM, Guernon A, Bender Pape T. rTMS/iTBS and Cognitive Rehabilitation for Deficits Associated With TBI and PTSD: A Theoretical Framework and Review. *J Neuropsychiatry Clin Neurosci*. 2023 Winter;35(1):28-38. doi:10.1176/appi.neuropsych.21090227. Epub 2022 Jul 25. PMID: 35872613.
14. Twamley EW, et al. CogSMART Compensatory Cognitive Training for Traumatic Brain Injury: Effects Over 1 Year. *Journal of Head Trauma Rehabilitation*. 2015;30(6):391-401. doi:10.1097/HTR.0000000000000076
15. Cotovio G, et al. Regulatory Clearance and Approval of Therapeutic Protocols of Transcranial Magnetic Stimulation for Psychiatric Disorders. *Brain Sciences*. 2023;13(7):1029. doi:10.3390/brainsci13071029
16. Galimberti A, et al. Effectiveness of rTMS and tDCS treatment for chronic TBI symptoms: A systematic review and meta-analysis. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*. 2024;128:110863. doi:10.1016/j.pnpbp.2023.110863
17. Tsai PY, et al. Effect of repetitive transcranial magnetic stimulation on depression and cognition in individuals with traumatic brain injury: a systematic review and meta-analysis. *Sci Rep*. 2021;11(1):16940. doi:10.1038/s41598-021-95838-2
18. Alashram AR, et al. Noninvasive brain stimulation for cognitive rehabilitation following traumatic brain injury: A systematic review. *Applied Neuropsychology: Adult*. 2023;30(6):814-829. doi:10.1080/23279095.2022.2091440
19. Rossi S, et al. Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines. *Clinical Neurophysiology*. 2021;132(1):269-306. doi:10.1016/j.clinph.2020.10.003
20. Matsumoto H, Ugawa Y. Adverse events of tDCS and tACS: A review. *Clinical Neurophysiology Practice*. 2017;2:19-25. doi:10.1016/j.cnp.2016.12.003
21. Poreisz C, et al. Safety aspects of transcranial direct current stimulation concerning healthy subjects and patients. *Brain Research Bulletin*. 2007;72(4-6):208-214. doi:10.1016/j.brainresbull.2007.01.004
22. Hallett M. Transcranial magnetic stimulation and the human brain. *Nature*. 2000;406(6792):147-150. doi:10.1038/35018000
23. Blumberger DM, et al. Effectiveness of theta burst versus high-frequency repetitive transcranial magnetic stimulation in patients with depression (THREE-D): a randomised non-inferiority trial. *The Lancet*. 2018;391(10131):1683-1692. doi:10.1016/S0140-6736(18)30295-2

Author Bios

André Lindsey, PhD, CCC-SLP, is an assistant professor of speech-language pathology at Nevada State University and a research investigator with the Edwards Hines Jr VA Hospital. He earned his PhD in Speech and Hearing Sciences from the University of Connecticut. He studies acquired brain injuries and methods of rehabilitation. His works plays particular attention to the relationship between language, memory, and executive functions.

Monica Ly, PhD, is a neuropsychologist and assistant professor of neurology at the Boston University Chobanian and Avedisian School of Medicine. She earned her degree in clinical psychology from the University of Connecticut and completed specialized training in traumatic brain injury rehabilitation through her internship at the Polytrauma Rehabilitation Center and Transitional Rehabilitation Program at the James A. Haley Veterans Hospital. Her research interests lie at the intersection of head injury, aging, and dementia.

Karen Lê, PhD, CCC-SLP, is a research and clinical speech-language pathologist at the VA Connecticut Healthcare System (VACHS) and Assistant Professor of Neurology at the Yale School of Medicine. She has worked with Veterans with TBI in the VA for more than 10 years and is a Polytrauma Support Clinic Team member at VACHS. She conducts rehabilitation research to develop cognitive-communication interventions for Veterans with TBI and is funded by a VA Rehabilitation Research and Development grant. She is currently a collaborator on the Defense and Veterans Brain Injury/Traumatic Brain Injury Center of Excellence (DVBIC/TBICoE) 15-Year Longitudinal Study. Her research interests include cognitive-communicative disorders in TBI, discourse intervention, and the impact of mental health and neurological comorbidities on cognitive-communicative functioning.

events

2025

March

12 - 15: *35th Annual Meeting*, March 12-15, 2025, Montréal, Québec, Canada. For more information, visit anpaonline.org.

19 - 22: *15th World Congress on Brain Injury*, March 19-22, 2025, the Palais de Congres in Montreal, Canada. For information, please visit braininjurycongress.org.

April

3 - 5: *2025 AOTA Annual Conference and Expo*, April 3 - 5, Philadelphia, PA, USA. For more information, visit aota.org.

May

5 - 6: *15th Annual Traumatic Brain Injury Conference*, May 5 - 6, Boston, MA. For more information, visit tbiconference.com/home.

19 - 22: *ISPRM 2025 - The 19th World Congress of the ISPRM*, May 19 - 22, 2025, Dead Sea, Jordan. For more information, visit www.isprm2025.org.

October

22 - 25: *2025 Annual Assembly*, October 22-25, Salt Lake City, UT, USA. For more information, visit aapmr.org.

27 - 30: *ACRM 102nd Annual Fall Conference & Expo*, Chicago, IL, USA. For more information, visit acrm.org.

2026

April


29 - 2: *6th International Paediatric Brain Injury Society Conference*, April 29 - May 2, Calgary, AB, Canada. For more information, visit ipbis.org/calgary-2026.

October

30 - 2: *ACRM 103rd Annual Fall Conference & Expo*, October 30 - November 2, Washington, DC. For more information, visit acrm.org.



Success Rehabilitation, Inc.




We Put You First
...By improving the lives of individuals with a traumatic brain injury or other neurological impairment through residential and/or outpatient therapies.

5666 Clymer Road • Quakertown PA 18951
215-538-3488 • SuccessRehab.com

STARK & STARK

ATTORNEYS AT LAW

Experience You Can Trust in Brain Injury Law



With over 40 years of experience in the area of head and brain injuries, nationally recognized Stark & Stark attorney **Bruce H. Stern** devotes himself to obtaining the compensation his injured clients deserve and to providing them with personal guidance to coordinate and promote the healing process.

Bruce H. Stern, Esq.
bstern@stark-stark.com

www.Stark-Stark.com • 1-800-53-LEGAL
100 American Metro Blvd., Hamilton, NJ 08619

Precision Transcranial Magnetic Stimulation (TMS) for Co-occurring Mild Traumatic Brain Injury and Alcohol Use Disorder: A Roundtable Discussion with Clinical End Users

Amy A. Herrold, PhD • Alma Ramic, MD
Brian Gomoll, MD • Sonia Bobra, MD
Amy Kemp, PhD



Alcohol use disorder (AUD) is prevalent among U.S. Veterans and often co-occurs with mild traumatic brain injury (mTBI)¹, exacerbating brain impairment and complicating rehabilitation^{2,3}. Evidence supports transcranial magnetic stimulation (TMS) for treating AUD and mTBI individually, but the optimal TMS target sites are still debated, especially for co-occurring mTBI+AUD³. Dr. Amy Herrold, a VA-funded neuroscientist, is working to identify a customized TMS target for mTBI+AUD using neuroimaging. She and Dr. Amy Kemp convened a round-table with experts to discuss precision TMS targeting and clinical applications. The panel included Dr. Alma Ramic, an addiction psychiatrist; Dr. Brian Gomoll, a neuropsychiatrist; and Dr. Sonia Bobra, a neuroradiologist.

Dr. Herrold: How significant is precision in TMS targeting for clinical implementation?

Dr. Gomoll: A majority of TMS is used for depression, and we're still figuring out exactly how important targeting is. Precision is somewhat important overall, but where targeting might be useful is in patients that have potentially different brain anatomy. Maybe people who have different brains - either because of TBI or neurological conditions - that's where targeting could be very important. For research, especially for addictions, I could see it being very important because that's a very particular set of networks in the brain that you're targeting.

Dr. Herrold: Dr. Ramic, given the heterogeneity for substance use disorders (SUD), do you think we might have different targets for different SUD symptoms?

Dr. Ramic: I think it will be a challenge as many patients we treat have severe SUDs and comorbidities for example TBI, post-traumatic stress disorders (PTSD), and depression, which could have altered brain anatomy. It will also be interesting to see if all SUDs will have the same target.

Dr. Herrold: Dr. Gomoll, when you're evaluating folks for TMS for treatment resistant depression, how do you consider active SUDs? Can you speak to the safety considerations, and overlapping comorbidity?

Dr. Gomoll: Safety is the most important thing. Mostly we want to check if any substances / withdrawal increases the risk of treatment. I think a lot of people would feel uncomfortable treating somebody that's actively using a significant amount of alcohol, but in theory, if they keep their use stable or go down gradually, they can be getting TMS for depression.

Dr. Herrold: Would an AUD comorbidity cause you to consider different outcomes?

Dr. Gomoll: It depends a lot on the patient, you must have a personalized approach, and unfortunately, we don't necessarily have data yet for true precision. But it depends on how much we think the substances are contributing directly to the mood and how much we think it's going to affect whether TMS works. Often when people are actively using alcohol or have other comorbidities, we will ask that they start getting those treated before we start TMS.

The area targeted for depression (dorsolateral prefrontal cortex, DLPFC) is a huge area that is transdiagnostically relevant, probably due to a fact that there's top-down control, so there are studies for many conditions. Some patients getting routine TMS for depression might theoretically help for their comorbidities.

Dr. Herrold: I want to pivot to another question that I had for the DLPFC, being a large area of the brain. With clinical TMS, we don't usually use neuronavigation. For my research and for some research studies, neuro-navigation is used to improve precision. I wanted to know your thoughts on how much neuro-navigation matters to you and on its clinical implementation?

Dr. Gomoll: Clinically, it's gone back and forth between measurements / "best guess" and neuronavigation. For research, just to know where you're even targeting, using neuronavigation is essential. I think clinically, it will likely be important in the future, though one problem is implementing it in the community - where not only do you have to have a neuronavigator that people can use, but you'd have to have either an MRI or possibly even an fMRI.

Dr. Herrold: Dr. Bobra, you have guided the TMS treatment and motor threshold sites for our TMS and yoga study for co-occurring mTBI and chronic pain. Can you tell me about your thoughts on utilization of neuronavigation with TMS?

Dr. Sonia Bobra: In my experience, I am yet uncertain what causes most pathologies. The brain is, in my opinion, the most mysterious organ in the body. It connects our bodies to the world and universe around us in ways we are yet to discover and may never fully understand. Ancient practices like yoga and new technology like TMS to treat disorders of the brain are innovative. We use structural MRI to help us target the areas of the brain for TMS, a useful visual tool for preplanning. Although we cannot see the effects of these treatments on structural MRI, I see a fantastic future ahead including fMRI to test blood flow improvements to specific regions of the brain following treatments.

Dr. Herrold: What TMS safety or resource considerations are needed for co-occurring mild TBI and AUD and for clinical implementation of TMS in the future?

Dr. Gomoll: It's important to have people on your team that have some comfort and knowledge with these conditions. For example, some of the tobacco cessation protocols require you to induce cravings. That's different than what we do in depression. Also, TMS always should be considered a tool that's part of a bigger approach to treatment - we've had an active discussion about the ideal model for any intervention and how it would be great if it could be a clubhouse or drop-in center model, where you could be getting cognitive behavioral therapy (CBT) groups, SUD groups, whole health approaches while getting treatment - and have people there who have the expertise required.

Dr. Herrold: What about you, Dr. Ramic?

Dr. Ramic: Many patients with SUDs need additional treatments, especially patients with comorbidities. They might not be interested at first, but if they decide they do want additional treatments during TMS, we are able to offer it. Also, we can potentially investigate two groups of patients; one group not receiving any additional care while engaged in TMS treatment and another group who does, for example get CBT for SUD. Currently, we encourage patients to do comprehensive SUD treatment or at least CBT for SUD, but we want to be able to tell them about TMS effectiveness. In addition, it's fair to ask who the patients are who will benefit the most from TMS. Patients with severe SUD, patients with mild to moderate, patients with comorbidities like TBI and selection of patients; for example, during residential treatments, patients in intensive outpatient programs or patients who are not engaged in treatment at all. The same would apply for comorbidities. I believe this might give us different research outcomes that we can apply in clinical work.

Dr. Herrold: Those are great perspectives. Thank you all for this wonderful discussion on all these different complex topics related to comorbidities and TMS treatment and the future of research and clinical implementation.

Summary

The discussion highlighted the complexities of applying TMS for mTBI and AUD, emphasizing the need for precise targeting amidst diverse brain pathologies and co-occurring SUDs. The panel underscored the importance of an integrated care model to optimize TMS treatment's safety and efficacy, advocating for further research and a personalized approach to address individual patient needs effectively.

References

1. Heltemes KJ, Dougherty AL, MacGregor AJ, Galarneau MR. Alcohol abuse disorders among U.S. service members with mild traumatic brain injury. *Mil Med.* Feb 2011;176(2):147-50.
2. Corrigan JD. Substance abuse as a mediating factor in outcome from traumatic brain injury. *Arch Phys Med Rehabil.* 4/1995 1995;76(4):302-309. Not in File. doi:10.1016/S0003-9993(95)80654-7 [pii]
3. Herrold AA, Kletzel SL, Harton BC, Chambers RA, Jordan N, Pape TL. Transcranial magnetic stimulation: potential treatment for co-occurring alcohol, traumatic brain injury and posttraumatic stress disorders. *Neural Regen Res.* Oct 01 2014;9(19):1712-30. doi:10.4103/1673-5374.143408

Author Bios

Amy A. Herrold, PhD, is a Research Health Scientist at Edward Hines Jr. VA Hospital and an Adjunct Research Associate Professor at Northwestern University Feinberg School of Medicine. A neuroscientist with over 10 years of experience in traumatic brain injury, transcranial magnetic stimulation, and neuroimaging, she also has 20 years of expertise in addiction neuroscience. Dr. Herrold recently co-authored the "Traumatic Brain Injury and Substance Use Disorders" chapter in the 7th edition of the ASAM Principles of Addiction Medicine and contributed to The ASAM Criteria, 4th Edition: Cognitive Impairment.

Alma Ramic, MD, is the Director of Substance Use Disorder Services at Edward Hines Jr., VA Hospital and Assistant Professor at Loyola University Medical School, Department of Psychiatry and Behavioral Neurosciences. Dr. Ramic is an addiction psychiatrist with over 15 years of experience in the substance use disorder treatment field. Dr. Ramic is a vital study physician on Dr. Herrold's research team.

Brian P. Gomoll, MD, is the director of Transcranial Magnetic Stimulation (TMS) and one of the medical directors of the mental health clinic at Edward Hines Jr., VA Hospital, as well as assistant professor at Loyola University of Chicago Stritch School of Medicine. Dr. Gomoll is a neuropsychiatrist with over 10 years of experience in the field with subspecialty certification in Brain Injury Medicine and Behavioral Neurology & Neuropsychiatry. Dr. Gomoll is a vital study physician on TMS research studies at Hines VA.

Sonia Bobra, MD, is a Neuroradiologist at Edward Hines Jr., VA Hospital and Assistant Professor at Loyola University Chicago, Stritch School of Medicine. Dr. Bobra has over 13 years of experience in neuroradiology. Dr. Bobra is a vital study physician on Dr. Herrold's TMS research team.

Amy Kemp, PhD, is an assistant professor in the Department of Speech and Hearing Sciences at Washington State University. She has a clinical background as a speech-language pathologist with 9 years of experience in adult and geriatric populations. Her clinical, teaching, research addresses innovative assessment and treatments for enhancing the quality of life and functional outcomes for individuals who have experienced acquired brain injuries. Dr. Kemp also uses implementation science to develop, adapt, and assess accessible, efficient, and effective rehabilitation protocols for healthcare providers in rural areas.



Interviews with Research Participants about Transcranial Magnetic Stimulation Experiences: Voices from the Field

Amy Kemp, PhD • Kelly Krese, DPT • Ibuola Kale, MS
Amy Herrold, PhD

Introduction

In the rapidly evolving landscape of neurorehabilitation, transcranial magnetic stimulation (TMS) has emerged as a beacon of hope for those experiencing the long-term effects of traumatic brain injury (TBI). This noninvasive treatment has garnered clinical and scientific attention for its potential to significantly improve outcomes after TBI. Despite its promising application, responsiveness to TMS can vary widely depending on the individual's specific condition, the severity of the injury, and the treatment protocol used. This article delves into the lived TMS experience unfolding from observations and conversations with research participants who had been assigned to and were undergoing active treatment study conditions, offering an ethnographic lens on how TMS is experienced by those it aims to impact. We created composite vignettes based on real experiences of three research participants, but real names are not used in the vignettes. These stories reflect the nuanced narratives of hope, challenge, and, in some cases, recovery patients have experienced. As professionals in the field of brain injury, understanding the real-world experiences of patients can enhance empathy and enrich practice and the hopeful translation of TMS into clinical practice.

Ethnographic Narratives

Narrative 1:

Tiana, a woman in her 30s, suffered a TBI from a car accident two years before enrolling in the study. After her TBI, she reported cognitive slowdowns, difficulty concentrating, and persistent headaches, profoundly affecting her professional and personal life.

Tiana's journey with TMS began after traditional rehabilitation methods showed limited success. She found a TMS research study and saw it as a non-invasive option to potentially improve her cognitive function and alleviate symptoms related to her TBI. Initially skeptical, Tiana's desperation for a semblance of her former life overcame her reservations. She hoped TMS could be the key to reclaiming her independence and ability to work.

During her first session, Tiana was tense, and the unfamiliar sound of the machine clicking rhythmically heightened her anxiety. However, her provider was patient and supportive, guiding her through the process with explanations and reassurances. Over time, Tiana began to find the sessions strangely meditative, using rhythmic sounds as the focus for mindfulness exercises her personal psychologist had suggested.

Tiana formed a strong bond with the treatment team, which kept her anxiety associated with TMS at bay and, overall, solidified her comfort with receiving treatment. A pivotal moment occurred halfway through her treatment course when Tiana noticed subtle improvements in her concentration and a decrease in the frequency of her headaches. This was a turning point for Tiana, as it reinforced her sense of agency on her path towards recovery.

Narrative 2:

Rich, an army veteran in his late 40s, experienced a mild TBI 5 years prior to study enrollment. His symptoms included chronic pain and sleep disturbances. Before his TBI, Rich was deeply involved in his community and enjoyed his work. His injury forced him to retire early and significantly altered his daily life and social interactions.

Rich was introduced to TMS by his Whole Health counselor as part of a broader recovery program aimed at improving his overall wellness. Unlike Tiana, Rich had high expectations from the outset, driven by a desire to return to his prior life. He viewed TMS as a promising scientific advancement that would restore his lost capabilities.

Rich's attitude towards TMS was one of unbridled optimism. He had faith in medical technology and was eager to participate in what he considered a groundbreaking approach to recovery. He and the treatment team often discussed the science behind TMS and the individualized neuronavigational components of the study.

One of the unique challenges during Rich's TMS sessions was the calibration of the device, complicated by his tightly braided hair. This required extra time and adjustments during each session, initially causing frustration, but eventually leading to lighthearted interactions with treatment staff. These moments lightened the mood and helped Rich form a bond with the team, seeing them as partners in his recovery journey.

Rich's high hopes for TMS to eliminate his symptoms deflated when, after many sessions, he was still not experiencing improvement. After expressing his frustration, the treatment provider discussed the scientific nuances of TMS and brain recovery and counseled Rich on the current investigative clinical trial phase of TMS.

Rich's experience with TMS highlighted the importance of patient education, realistic expectations, and adaptation of treatment protocols to accommodate personal factors. His journey was shaped not only by his initial optimism but also by the responsive and adaptive approach of his treatment team. Much like other innovative technologies, continued investigation on responders and suboptimal responders is key to better understand factors for desired outcomes.

Narrative 3:

Anya, a woman in her late 30s, was diagnosed with chronic musculoskeletal pain after incurring a TBI in her early 20s from a military drill. Anya's chronic pain had persisted for more than a decade, deeply affecting her performance at work and her personal life. Despite her struggles, she maintained a highly demanding job, although she felt she was not living up to her potential due to her chronic pain.

Before considering TMS, Anya had explored numerous treatment options without success, including opioids. Her initial skepticism was high, she was wary of the promises of TMS, fearing another disappointment, but desperately hoped for a significant change.

Anya asked the research team many questions before and during the TMS calibration process; she was invested and concerned if the calibration was not 'perfect.' Anya's treatment team often engaged with her using detailed explanations of the TMS mechanisms to provide reassurance and support in a format Anya enjoyed.

Anya's TMS sessions were characterized by her intense focus on observing and quantifying any changes. She kept a detailed journal of her mood and cognitive reactions after each session. She also stated she had a 'low tolerance to pain' and found TMS uncomfortable and even painful at times. After several treatment sessions, Anya did not feel improvement and even reported feeling new symptoms such as lingering tingling and headaches. This led to a decrease in confidence, which intensified her doubts about the efficacy of TMS.

Patient and Clinician Resources on Neuromodulation Therapies

Neuromodulation treatments for TBI are currently under experimental investigation, but the field is rapidly expanding. The International Neuromodulation Society regularly updates information on common therapies by condition, which can be found here: <https://www.neuromodulation.com/therapies>.

For information about new techniques and devices under investigation, by conditions, please also see their research page for listings of clinical trials: <https://www.neuromodulation.com/nm-research>



At the end of the treatment sessions, Anya did not feel TMS made a difference in her short-term recovery, but she was hopeful her participation would impact research on TMS. However, Anya left with the feeling of validation that her chronic pain felt more tangible with neuroimaging and precision targeting, which offered concreteness and hope for healing.

Clinical Interactions

Each of these cases illustrates how personalized interactions between patients undergoing TMS and their healthcare providers not only enhance the therapeutic alliance, but also contribute to meaningful outcomes. Effective communication, empathy, and a thorough understanding of each patient's unique background and expectations are crucial components healthcare providers can promote in any context, but certainly in developing interventions such as TMS.

Integration of TMS Into Broader Therapeutic Programs

These cases highlight that TMS is often part of a comprehensive treatment plan, particularly for conditions like TBI where multimodal interventions are beneficial. For example, Anya continued psychiatric consultations and medications in conjunction with her TMS, addressing her chronic pain on multiple fronts. Similarly, Tiana combined speech therapy with TMS to improve cognitive-communication recovery and return to productivity. On the other hand, Rich benefited from yoga or mindfulness to reduce sleep disturbances and support a positive mindset. This integrative approach allows TMS to work synergistically with other treatments, potentially enhancing overall effectiveness.

Neuromodulation Course Sponsored by the Medical University of South Carolina

The Brain Stimulation Lab's course is highlighted in this issue as it started over 20 years ago and is a national and international leader in developing and testing new brain stimulation methods as potential treatments. Directed by Dr. Mark George, the course is a week-long training program offering a combination of pre-course readings and notes, in-person morning lectures with web-based streaming, followed by afternoons of observations of clinical and research uses. The course offers ample time for hands-on technique learning and practice.

Two tracks are offered, one leading to a training certificate in in TMS. The TMS course also includes additional didactics and hands on exposure where possible regarding VNS, DBS, tDCS and transcranial ultrasound. The curriculum is modified and adapted for those interested in either clinical or research use.

<https://medicine.musc.edu/departments/psychiatry/divisions-and-programs/divisions/brain-stimulation-lab/about/course>



Treatment Atmosphere

These cases also underscore how the environment of treatment with TMS plays a critical role in patient experiences and outcomes. Providers often strive to create a safe and reassuring psychological atmosphere to allow their patient to express concerns and ask questions, which is crucial for patients such as Anya, who needed to understand the process to feel engaged. Similarly, supportive interactions with healthcare providers, as seen in Rich's experience, can alleviate the stress associated with treatment. These cases highlight how in emerging technologies interventions, settings should be cognizant of the patient experience, as this can significantly influence patient comfort and treatment perception both within clinical trials and, eventually, during translation into clinical practice.

Conclusions

Treatment with TMS for TBI is actively being investigated and considered in the Phase II clinical trial stages. To facilitate future translation and integration of brain injury rehabilitation from TMS treatment, pairing clinical trial research with implementation science and qualitative work is essential. Furthermore, incorporating patient perspectives and provider experiences is vital to maximizing the effectiveness and acceptance of therapies such as TMS.

Suggested Readings

1. Lefaucheur J, Andre-Obadia N, Antal A, et al. Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS). *Clin Neurophysiol.* 2014;125(11):2150-2206. doi:10.1016/j.clinph.2014.05.021
2. Perera T, George MS, Grammer G, Janicak PG, Pascual-Leone A, Wirecki TS. The clinical TMS society consensus review and treatment recommendations for TMS therapy for major depressive disorder. *Brain Stimulat.* 2016;9(3):336-346.
3. Bender Pape TL, Herrold AA, Guernon A, Aaronson A, Rosenow JM. Neuromodulatory Interventions for Traumatic Brain Injury. *J Head Trauma Rehabil.* 2020;35(6):365. doi:10.1097/HTR.0000000000000643

Author Bios

Amy Kemp, PhD, is an assistant professor in the Department of Speech and Hearing Sciences at Washington State University. She has a clinical background as a speech-language pathologist with 9 years of experience in adult and geriatric populations. Her clinical, teaching, research addresses innovative assessment and treatments for enhancing the quality of life and functional outcomes for individuals who have experienced acquired brain injuries. Dr. Kemp also uses implementation science to develop, adapt, and assess accessible, efficient, and effective rehabilitation protocols for healthcare providers in rural areas.

Kelly Krese, DPT, completed her graduate studies at the University of Illinois-Chicago and became a Board-Certified Clinical Specialist in Neurologic Physical Therapy in 2020. She is an expert consultant for the Specialty Rehab Hospital of United Arab Emirates, mentoring clinicians on evidence-based PT practice, and is an adjunct faculty member at Northwestern University Feinberg School of Medicine. She has worked in both clinical and research settings with individuals with a variety of neurological diagnoses. Her research focuses on neuromodulation for people after mild to severe traumatic brain injuries.

Ibuola Kale, MPH, graduated from the University of Illinois-Chicago's School of Public Health in 2017. She is a Lead Social Science Program Coordinator at the Edward Hines, Jr. VA Hospital. Her years of research experience have been focused on populations with spinal cord injuries and disorders and those with mild traumatic brain injury. She has also done work in a wide range of topics, including neuromodulation, infectious disease, and healthcare implementation and evaluation.

Amy A. Herrold, PhD, is a Research Health Scientist at Edward Hines Jr. VA Hospital and an Adjunct Research Associate Professor at Northwestern University Feinberg School of Medicine. A neuroscientist with over 10 years of experience in traumatic brain injury, transcranial magnetic stimulation, and neuroimaging, she also has 20 years of expertise in addiction neuroscience. Dr. Herrold recently co-authored the "Traumatic Brain Injury and Substance Use Disorders" chapter in the 7th edition of the ASAM Principles of Addiction Medicine and contributed to The ASAM Criteria, 4th Edition: Cognitive Impairment.



SPECIALTY CARE FOR **COMPLEX PEDIATRIC PATIENTS.**

- Traumatic/acquired brain Injury
- Spinal cord Injury
- Seizure disorder
- Behavioral dysregulation
- Complex neurological conditions



Leveraging more than 30 years of brain and spinal cord injury rehabilitation with today's medical advancements, Nexus is **mending minds**.

Ready to get your pediatric patient on the path to recovery? **Let's talk.**
713.351.6633



nexushealthsystems.com

SAVE THE DATE!

6th Annual Conference on Pediatric Brain Injury

Calgary, Alberta, Canada
April 29 - May 2, 2026

CALGARY

www.ipbis.org

PM&R Clinical Adoption of Transcranial Magnetic Stimulation (TMS) in Traumatic Brain Injury (TBI) Rehabilitation

Ana Durand-Sanchez, MD

The field of Physical Medicine and Rehabilitation (PM&R) has witnessed impressive advancements in the realm of neuromodulatory interventions for the treatment of TBI-related deficits. Some of its most consequential interventions have stemmed from the use of Transcranial Magnetic Stimulation (TMS), a promising non-invasive technique for the enhancement of neural plasticity for cognitive and physical recovery. As a PM&R practitioner recognizing the therapeutic merits of TMS and anticipating future FDA approval of its use in TBI rehabilitation, here I share my journey with TMS and in preparing to incorporate TMS into clinical practice. This journey involved a structured approach encompassing education, practice, resource acquisition, understanding of the clinical setting and market where one practices, and thoughtful integration into the treatment armamentarium.

Learning How to Provide TMS for TBI Rehabilitation

This is a multifaceted process that begins with acquiring a foundational understanding of its scientific and technological principles, as well as its ascertained and potential clinical applications. In my case, this started with exposure to TMS research during residency and fellowship, directed reading of scientific articles and other foundational materials, and by attending formal instructional courses.

Training Courses and Education

My formal TMS training included the intensive mini-fellowship on TMS and tDCS offered through Harvard Continuing Medical Education, as well as workshops / courses at the conferences hosted by the American Congress of Rehabilitation Medicine and the International Brain Injury Association. Clinicians can also complete formal training via fellowships offered by Neuroscience departments of large Universities, NIH institutes and NIH-supported training centers like the Berenson-Allen Center for Noninvasive Brain Stimulation, the Core Resources of the Butler Hospital COBRE Center for Neuromodulation.

Alternatives to formal training, to enable provision of TMS in TBI rehabilitation, includes, at a minimum”

- **Basic Principles:** Understanding the physics and mechanisms of TMS, including safety considerations.
- **Clinical Applications:** Learning how to apply TMS techniques specifically for TBI rehabilitation, including protocol development and patient assessment as well as historically successful / failed interventions.

- **Hands-on Workshops:** These supervised practical sessions allow professionals to gain proficiency in operating TMS equipment and delivering TMS treatments safely and effectively.
- **Meeting professionals** to continue to learn from and collaborate within your area of interest. Some instructional courses allow practitioners to join Clinical TMS list serves for continued collaboration with the specialty community.

Practice Frequency

Certain aspects of the TMS treatment process require more practice than others due to their significant impact on the accuracy and overall success of the intervention. Determining each patient’s motor threshold for example, requires relatively less practice. While determining motor threshold is critical to determining each patient’s stimulus intensity for use in treatment, it will require less practice as it is based on EMG recordings. Proficiency in the use of TMS as a treatment tool for TBI rehabilitation, however, requires regular practice under supervision initially, followed by ongoing clinical experience. Practicing regularly allows for technique refinement, adjustment of treatment parameters based on individual patient responses, and the ability to troubleshoot effectively during sessions. Generally, an established practitioner would be expected to use this intervention at least every other month or have used it multiple times with multiple subjects/ patients in previous years. Practice opportunities can be found and/or created by collaborating with local labs and clinics.

Integration Into Clinical Practice - Sample Clinic Design and Needs

Integrating TMS into a Brain Rehabilitation clinic involves careful planning and consideration:

- **Staffing:** Depending on clinic size and patient volume, staffing may include a nurse, allied health practitioner and/or technician trained in and proficient in TMS motor thresholding and treatment procedures. Their roles would also include patient preparation, monitoring during sessions, and ensuring safety and comfort. Allied health staff may need a MD / Nurse on site for medical triaging depending on patient’s medical history/status and TMS protocol.
- **Time Allocation:** Allocating sufficient time for each TMS session is crucial. Sessions typically range from 20 to 40 minutes per treatment (including assessments and set-up), with frequency varying based on the treatment protocol and patient response. Of note, when paired with other therapeutic activities, the sessions could pass the 60-minute range.

- **Patient Selection:** Identifying candidates for TMS therapy involves conducting comprehensive evaluations to assess eligibility and potential benefits relative to risks. This may include review of medical history and current medications, risk factors, neurological / behavioral assessments, imaging studies, EEG, laboratory analyses, and collaboration with other specialists as needed.
- **Documentation and Monitoring:** Maintaining accurate records of each TMS session, documenting a motor threshold, treatment parameters, patient responses and any side effects or adverse events, is essential for continuity of care and treatment efficacy and evaluation of need for adjustments of discontinuation.
- **Reimbursement:** The financial sustainability of a clinical service or practice must be taken into consideration from the start, to ensure feasibility and survival. TMS is currently used as monotherapy or an adjunctive treatment for conditions including major depression, chronic neuropathic pain, neurodevelopmental disorders, migraines, tinnitus, epilepsy, dystonia, Parkinson's disease, and stroke. While most insurance plans are unlikely to cover TMS for many of these, one could consider:
 - Billing with a focus on depression when present. While there are multiple insurance plans that cover TMS for major depressive disorder, the specific requirements to qualify for coverage vary widely.
 - For non-covered conditions one should perform a financial analysis of whether this intervention will shorten the course of therapy and as a result decrease expenses related to clinical staffing, and whether qualified students or volunteers are available to assist at a lower cost, so as to limit the extra financial burden. Consider if your practice's structure lends itself to billing patients separately for this intervention. Examine institutional or other grants to supplement treatment in the interest of improved efficiency and benefit to low-income populations.
 - Timely awareness of new FDA approved indications for TMS will allow rehabilitation practitioners to increase their options to implement TMS as part of their treatment as a billable service.
- 3. **Clinical Space:** A dedicated clinical space equipped for TMS use is vital. This space should be designed to accommodate both the TMS equipment and the patient comfortably. Please note there are specific electrical power and wiring requirements for this room, so small structural alterations may be needed.
- 4. **Support Staff:** Depending on the scale of your practice, having trained support staff such as nurses, allied health clinicians and/or TMS technicians who are familiar with TMS procedures and patient care is crucial. Of note, often 2 people will be needed, at least for certain procedures. Furthermore, when TMS treatment is paired with established therapeutic interventions, minimizing time in between TMS delivery and rehabilitative therapy is important, so the TMS device should be located close to the gym or Speech Pathology office where the interventions will be delivered. This may further impact need for space, synchronization and other logistics.
- 5. **Educational Materials:** Access to up-to-date literature, guidelines, and resources on TMS in TBI rehabilitation is essential for staying informed about best practices and advancements in the field. An informed practitioner will be able to more efficiently and effectively design the intervention that is appropriate and likely to be successful for a given patient or group of patients.

Clinical Outcomes and Future Directions

The adoption of TMS in TBI rehabilitation holds promise for improving clinical outcomes and quality of life for patients, while decreasing the length of the course of rehabilitation. Research continues to explore novel applications, refine treatment protocols, and investigate the long-term effects of TMS on neural recovery and functional outcomes. Some of these efforts also result in new approved indications that are covered by insurance providers.

By embracing developing technologies like TMS, rehabilitation clinicians can expand treatment options, enhance patient care, and contribute to advancing the field of brain injury rehabilitation, offering new hope and possibilities for patients recovering from traumatic brain injuries.

Suggested Readings

1. Fried PJ, et al. Training in the practice of noninvasive brain stimulation: Recommendations from an IFCN committee. *Clin Neurophysiol.* 2021 Mar;132(3):819-837. doi: 10.1016/j.clinph.2020.11.018. Epub 2020 Dec 3.
2. Nardone R, et al. Repetitive transcranial magnetic stimulation in traumatic brain injury: Evidence from animal and human studies. *Brain Res Bull.* 2020 Jun;159:44-52. doi: 10.1016/j.brainresbull.2020.03.016. Epub 2020 Apr 3.
3. Begemann MJ, et al. Efficacy of non-invasive brain stimulation on cognitive functioning in brain disorders: a meta-analysis. *Psychol Med.* 2020 Nov;50(15):2465-2486.
4. He F, et al. Effects of 20 Hz Repetitive Transcranial Magnetic Stimulation on Disorders of Consciousness: A Resting-State Electroencephalography Study. *Neural Plast.* 2018 Mar 25;2018:5036184. doi: 10.1155/2018/5036184.

Resources Needed for TMS Implementation

To effectively integrate TMS into clinical practice, several key resources are essential:

1. **TMS Equipment:** This step involves selecting a device suitable for the intended clinical use, ensuring it meets safety standards and regulatory requirements. Of note, there are various types of TMS and not all stimulators are capable of delivering them (e.g. high frequency rTMS is useful for interventions aimed at supporting long-term potentiation whereas paired pulse protocols are useful for medically complex patients).
2. A TMS unit usually includes the generator/stimulator, coil for delivery of stimuli pulses; monitor(s) for the user to assess data in real time and adjust treatment delivery, a specialized chair that allows subjects / patients to comfortably remain in the intended position for the duration of the intervention. More and more commonly, treatment protocols for brain injury also call for the use of a brain navigation system, which necessitates brain navigation cameras, head sensors, and software - in order to transmit and pair acquired 3D images to the TMS software, to then superimpose these and ensure accuracy of treatment target with intra-rater, inter-rater, and inter-session reliability. This type of intervention also entails the use of other materials like disposable surface EMG electrodes, alcohol pads, wipes and in some cases caps.

Author Bios

Ana Durand-Sanchez, MD is a Brain Injury Specialist and the Medical Director of Moody Neurorehabilitation Institute. With a deep commitment to the field of neurorehabilitation, Dr. Durand-Sanchez has dedicated her career to helping individuals recover from traumatic brain injuries and other neurological conditions. She is known for her expertise in developing and overseeing personalized rehabilitation programs that incorporate the latest advancements in brain injury treatment. At Moody Neurorehabilitation Institute, Dr. Durand-Sanchez leads a multidisciplinary team focused on delivering comprehensive, patient-centered care aimed at maximizing recovery and improving quality of life. Her leadership and innovative approach have made her a respected figure in the field of brain injury rehabilitation.

Books You May Have Missed

Encyclopedia of the Human Brain, 2nd Edition

Editor: Jordan H. Grafman

Available for Pre-order at: <https://shop.elsevier.com/books/encyclopedia-of-the-human-brain/grafman/978-0-12-820480-1> (Expected Release Date-September 16, 2024)

Description: Encyclopedia of the Human Brain, Second Edition, Seven Volume Set builds on the success of the first edition, providing neuroscience researchers with the ideal 'one-stop' resource on all topics related to human brain understanding. Given the length of time since the first edition published, EHB2 is thoroughly revised, with substantial updates on many new and exciting topics, including areas such as human neuroimaging, non-invasive brain stimulation, molecular biology (including genetics and epigenetics), and the clinical diagnoses of brain disorders, along with chapters exploring the introduction of new theoretical and methodological ideas in areas ranging from cognitive neuroscience to evolution of the human brain. In total, there are 440 articles – a vast increase from 224 previously - thus reflecting the huge explosion in neuroscience research during the last 20 years. EHB2 provides a brand new generation of neuroscientists with the perfect tool with which to learn and master the fundamentals of how and why the human brain operates as it does.

The Oxford Handbook of Transcranial Stimulation, Second Edition

Editors: Eric Wassermann, Angel Peterchev, Sarah Lisanby, Ulf Ziemann, Vincent Walsh, and Hartwig Siebner

Available for purchase at: <https://global.oup.com/academic/product/the-oxford-handbook-of-transcranial-stimulation-9780198832256?cc=us&lang=en&>

Description: The most comprehensive and detailed book on noninvasive brain stimulation available. The book reflects the collected knowledge, as well as the cutting edge, of transcranial stimulation. It brings together a multidisciplinary set of contributors, with expertise in a broad range of fields. This edition includes new and revised chapters that reflect the enormous developments in the field since publication of the first edition in 2008. It brings together the latest developments and important advances in all areas of Transcranial stimulation. The new volume captures the rapid progress made since the first edition, and provides an authoritative and comprehensive review of the state of the art. It also highlights challenges, opportunities, and future directions for this rapidly changing field. The book focuses on the scientific and technical background required to understand transcranial stimulation techniques and a wide-ranging survey of their burgeoning applications in neurophysiology, neuroscience, and therapy.

Each of its six sections deals with a major area and is edited by an international authority therein. It will serve researchers, clinicians, students, and others as the definitive text in this area for years to come.

The ASAM Treatment Criteria for Addictive, Substance-Related, and Co-Occurring Conditions Fourth Edition Published by the American Society of Addiction Medicine

Available for purchase at: <https://www.asam.org/asam-criteria/asam-criteria-4th-edition>

Description: The ASAM Criteria, Fourth Edition, Volume 1 - Adults is a comprehensive set of guidelines that use a holistic, person-centered approach to developing treatment plans for patients with addiction and co-occurring conditions. The revised standards have been crafted using a rigorous methodology for scientific evidence review and consensus development. The result is an update that is easier to understand and apply for improved patient care. Updated guidelines reflect the current state of scientific evidence and clinical practice, and integrate more person-centered considerations when assessing level of care.

The ASAM Principles of Addiction Medicine: Print + eBook with Multimedia

Editors: Shannon C. Miller MD, DFASAM, DLFAPA, Richard N. Rosenthal MD, MA, DLFAPA, DFAAAP, F, Sharon Levy MD, MPH, FASAM, FAAP, Andrew J. Saxon MD, FASAM, Jeanette M. Tetrault MD, FACP, FASAM, Sarah E. Wakeman MD, FASAM

Available for purchase at: <https://shop.lww.com/The-ASAM-Principles-of-Addiction-Medicine--Print---eBook-with-Multimedia/p/9781975201562>

Description: Principles of Addiction Medicine, 7th ed is a fully reimagined resource, integrating the latest advancements and research in addiction treatment. Prepared for physicians in internal medicine, psychiatry, and nearly every medical specialty, the 7th edition is the most comprehensive publication in addiction medicine. It offers detailed information to help physicians navigate addiction treatment for all patients, not just those seeking treatment for substance use disorders. This foundational textbook for medical students, residents, and addiction medicine/addiction psychiatry fellows, medical librarians and institution, also serves as a comprehensive reference for everyday clinical practice and policymaking. Physicians, mental health practitioners, NP, PAs, or public officials who need reference material to recognize and treat substance use disorders will find this an invaluable addition to their professional libraries.

SEEKING RESEARCH PARTICIPANTS WITH MILD TRAUMATIC BRAIN INJURY

This research investigates treatment for symptoms that impact daily life after mild TBI for people with or without PTSD

ABOUT THE STUDY:



WHO IS ELIGIBLE?*

1. Between 18-80 years of age
2. Diagnosis of mild traumatic brain injury or concussion with or without post-traumatic stress disorder
3. At least 3 months post-injury
4. No history of epilepsy or active seizures
5. Ability to safely participate in MRI
6. No other neurologic conditions that affect thinking or moving



STUDY ACTIVITIES

- Tests of thinking, memory, and attention
- Self-report of daily function and mental health
- MRI
- Eye-tracking
- Experimental brain stimulation (transcranial magnetic stimulation)



STUDY LOCATIONS

Northwestern University, Chicago, IL
Moody Neurorehabilitation, Houston TX

***Additional eligibility criteria include: drug and alcohol use, mental health symptoms, medication, and medical history criteria will be screened prior to enrollment to ensure safety and appropriateness for this study**

MORE INFORMATION



Time commitment includes up to 9 weeks of with 4 of these weeks involving treatment.



You will be compensated for your time and, as indicated, for travel/parking



Study Title: Neuromodulation and Neurorehabilitation for Treatment of Functional Deficits after mTBI plus PTSD

PI: Theresa Bender Pape
NU IRB #: STU 00203773

STUDY PURPOSE

The purpose of this study is to determine the effect of brain stimulation paired with cognitive intervention has on improving functional outcomes after mTBI with and without PTSD.

CONTACT US

Chicago: Katie Kestner (708-878-0578)
Houston: Meredith Brown (409-797-1468)

<https://clinicaltrials.gov/study/NCT03819608>

ckestner@sralab.org; mbrown@moodyneuro.org



Chicago, IL
Houston, TX



Focus on healing, we'll handle the rest.

Navigate life's turns with Gluckstein: your expert partner,
providing full circle care in personal injury law since 1962.



GLUCKSTEIN
LAWYERS

Contact us today for a free consultation

1-866-308-7722 | gluckstein.com