# Cognitive Rehabilitation Following Traumatic Brain Injury: Assessment to Treatment

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## ABSTRACT

Cognitive rehabilitation refers to a set of interventions that aim to improve a person's ability to perform cognitive tasks by retraining previously learned skills and teaching compensatory strategies. Cognitive rehabilitation begins with a thorough neuropsychological assessment to identify cognitive strengths and weaknesses and the degree of change in cognitive ability following a brain injury. The conclusions of the assessment are used to formulate appropriate treatment plans. Common interventions for improvements in attention, memory, and executive function, as well as the nature of comprehensive programs, which combine treatment modalities, are reviewed. Cognitive rehabilitation is effective for mild-to-severe injuries and beneficial at any time post-injury. Sufficient evidence exists supporting the efficacy and effectiveness of cognitive rehabilitation, which has become the treatment of choice for cognitive impairments and leads to improvements in cognitive and psychosocial functioning. ***Mt Sinai J Med 76:173–181, 2009.*** **©** *2009 Mount Sinai School of Medicine*

**Key Words:** attention, cognitive deficits, cognitive rehabilitation, comprehensive day treatment, executive function, memory, traumatic brain injury.

Traumatic brain injury (TBI) often results in physical, cognitive, and emotional impairments that interfere with independent living and disrupt psychosocial and vocational functioning.[1] The consequences of TBI are debilitating and persistent, especially when they remain untreated. The aim of rehabilitation following TBI is to improve physical, cognitive, and psychosocial functioning, to foster independence, and to facilitate community integration.[2] Cognitive rehabilitation is often the treatment of choice for these diverse impairments. Although cognitive rehabilitation targets cognitive and psychosocial functioning more directly, improvements in cognitive functioning could lead to improvements in physical functioning indirectly. For example, improvements in memory may facilitate medication compliance, improvements in attention and comprehension may improve understanding of instructions given by medical personnel, and improvements in executive function may facilitate initiating medical appointments or improve decision-making with respect to treatment options.

The American Congress of Rehabilitation Medicine has defined cognitive rehabilitation as "a systematic, functionally oriented service of therapeutic activities that is based on assessment and understanding of the patient's brain-behavioral deficits" (Cicerone *et al.*,[3] p 1597). Thus, as in all medical or psychological interventions, diagnosis and treatment are tied together. The goal of cognitive rehabilitation is to improve the person's ability to perform cognitive tasks, cope with affective distress, and increase self-confidence, self-efficacy, and self-awareness. This is achieved by retraining previously learned skills and residual abilities, teaching the person compensatory strategies, making environmental modifications to the person's domestic and vocational setting, and facilitating adjustment to the cognitive disability by increasing awareness and acceptance. These approaches are often combined to optimize the effects of treatment.[3]

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# METHODOLOGY

The purpose of this article is 2-fold: to examine the available literature that supports cognitive rehabilitation as an efficacious and effective treatment following TBI and to provide an overview of commonly used cognitive rehabilitation interventions. The review of the evidence for cognitive rehabilitation is based on 3 systematic reviews that were conducted by a subcommittee of the Brain Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine and 1 review that was commissioned by the National Institute on Disability and Rehabilitation Research. The goal of these reviews was to examine the state of the evidence for cognitive rehabilitation interventions following TBI and stroke, and they have resulted in 3 seminal publications to date.[3–5] The methodology used in these publications, including the search terms used to identify publications, the number of articles identified and retained, and the level of evidence classification, is described in a subsequent section.

To accomplish the second goal, to provide an overview of common cognitive rehabilitation interventions, among the studies included in the published reviews,[3–5] those that focused on TBI were located and reviewed. The description of the cognitive rehabilitation interventions that follows is thus based on class I and class II studies with TBI samples.

# ROLE OF ASSESSMENT PRIOR TO COGNITIVE REHABILITATION

Neuropsychological assessment is the initial part of cognitive rehabilitation and serves several purposes. It identifies areas of cognitive function in need of treatment as the data that result from the assessment are used to make inferences about the nature and extent of the person's cognitive dysfunction. Awareness of the person's cognitive strengths and weakness provides a means of targeting the cognitive domains that will require remediation and capitalizing on the person's residual cognitive abilities to facilitate treatment. In addition, neuropsychological assessment provides a means for evaluating the effectiveness of treatment.[6]

Neuropsychological assessment examines several domains of cognitive function. The individual measures included in a neuropsychological battery are determined on a case-by-case basis according to the patient's self-report of his day-to-day cognitive failures and clinical observation. The most common domains of cognitive functioning that are assessed post-TBI include intellectual function, memory function, psychomotor speed, processing speed, attention, language, and executive function.

## General Intellectual Functioning

Neuropsychological assessment involves an evaluation of the individual's general intellectual functioning. Tests of intellectual function examine the performance of diverse mental functions, including attention, processing speed, visual-spatial perception and construction, concept formation and abstraction, judgment, verbal comprehension, and fund of knowledge. Assessing general intellectual functioning post-TBI provides the clinician with a means of determining the affected individual's cognitive reserve (preserved premorbid abilities and residual cognitive strengths), areas of cognitive function that need further assessment, and cognitive deficits that may interfere with the treatment, the extent of change in cognitive function with respect to estimates of premorbid function, and functional ability in real-life settings. The Wechsler scales [Wechsler Adult Intelligence Scale III (WAIS-III), Wechsler Abbreviated Scale of Intelligence, and Wechsler Intelligence Scale for Children IV] are commonly used to assess intellectual ability following TBI.

## Memory and Learning

Memory is one of the more vital cognitive functions. Memory deficits lead to dependency, isolation, and interruption of a sense of personal continuity.[6] Memory impairments affect the individual's ability to learn and retain new information. Memory impairments post-TBI often interfere with cognitive rehabilitation as they affect attendance and compliance. Assessment of memory facilitates the identification of impairments in particular memory systems (eg, explicit/implicit and verbal/visual) and in the specific memory process that has been affected (eg, encoding, storage, or retrieval). A variety of measures are used to assess verbal memory (eg, California Verbal Learning Test, Hopkins Verbal Learning Test, and Rey Auditory Verbal Learning Test) and visual memory (Benton Visual Retention Test and Rey-Osterrieth Complex Figure Test). In addition, there are comprehensive memory batteries, such as the Wechsler Memory Scale, that comprehensively examine aspects of auditory and visual declarative and working memory.[7]

## Psychomotor Function

Manual dexterity is used to examine changes in the differential superiority of the dominant hand

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versus the nondominant hand as a means of providing a quick assessment of the diffuseness of the brain injury. Measures such as finger tapping and grip strength provide additional useful information.[7] A handful of measures of motor function that are commonly included in a neuropsychological assessment following TBI include the Finger Tapping Test, Grooved Pegboard, and Purdue Pegboard.

### Processing Speed

In addition to motor speed, the speed at which information is processed is assessed post-TBI. Following TBI, the rate of mental activity may be slowed, and this reduction in speed manifests itself as a delayed reaction time and/or increased task completion time. Several commonly used tests that measure processing speed are embedded in comprehensive batteries, such as the WAIS-III (Digit-Symbol Coding and Symbol Search subtests) and the Woodcock-Johnson Test of Cognitive Abilities (Decision Speed and Visual Match subtests). Additionally, such measures as the Stroop Color Word Test and the Trail Making Test are used to examine processing speed.

### Attention

Attention is a complex mental activity that refers to how an individual receives and begins to process internal and external stimuli.[6] Impairments in attention following TBI may range from difficulty remaining focused and ignoring distractions to failure to complete tasks involving multiple steps and learning new information. Several aspects of attention are assessed after TBI, including orientation, concentration, vigilance, distractibility, working memory, and multitasking. Commonly used measures of visual attention include the Conner's Continuous Performance Test and the Symbol Digit Modalities Test. Measures of auditory attention include the Paced Auditory Serial Attention Test (PASAT) and subtests of the WAIS-III (Digit Span and Letter-Number Sequencing), which assess auditory attention.

### Language

Verbal communication following TBI may be impeded by deficits in receptive and expressive language. Individuals with TBI may have difficulty understanding conversation and instructions (oral or written), responding to requests for information, expressing their needs, and maintaining conversation. Language measures include comprehensive batteries (eg, the Multilingual Aphasia Examination and the Boston Diagnostic Aphasia Examination) or individual tests of specific language functions, such as the Boston Naming Test to assess visual naming ability, the Peabody Picture Vocabulary Test to assess receptive vocabulary, and the Controlled Oral Word Association Test to assess verbal fluency.

### Executive Function

Executive function refers to the mental capacity to "engage successfully in independent, purposive, self-serving behavior" (Lezak *et al.*,[6] p 31). Executive function impairments post-TBI affect the individual's ability to initiate, plan, set goals, monitor performance, anticipate consequences, and respond flexibly and adaptively.[7] Frequently, executive dysfunction is the most disabling of all cognitive impairments as difficulties in this domain are pervasive because they can affect all aspects of the person's ability to function effectively in his personal or professional life. There are several measures of executive function, including multitest batteries (eg, the Behavioral Assessment of the Dysexecutive Syndrome and the Delis-Kaplan Executive Function System) as well as single-test measures (eg, the Category Test, the Stroop Test, and the Wisconsin Card Sorting Test).

## EVIDENCE FOR EFFECTIVENESS OF COGNITIVE REHABILITATION

The toolkit of cognitive rehabilitation interventions has grown rapidly in the last 3 decades. Several interventions for individuals with TBI have been developed to improve visual-perceptual skills, language, attention, memory, and executive functioning. As cognitive rehabilitation interventions began to emerge and proliferate, the need for evidence supporting their efficacy and effectiveness grew as well. A subcommittee of the Brain Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine conducted 2 systematic reviews of the existing literature on cognitive rehabilitation interventions for TBI and stroke in order to assess the status of the evidence and to provide recommendations for clinical practice.[3,4] An extensive search using several keywords, including attention, awareness, cognition, communication, executive, language, memory, perception, problem solving, reasoning, rehabilitation, remediation, and training, was conducted. The studies that were identified were subsequently classified by the cognitive skill that was targeted for treatment: attention,

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visual perception, apraxia, language and communication, memory, executive functioning, problem solving and awareness, and comprehensive-holistic cognitive rehabilitation. The first review included 171 intervention studies published between 1971 and 1997.[3] Of these, 29 were rated as class I (prospective, randomized or quasi-randomized controlled studies), 35 were rated as class II (prospective, nonrandomized cohort or retrospective, nonrandomized case-control or clinical series with controls), and 107 were rated as class III (clinical series without controls or single-case designs). The second review included 87 studies published between 1998 and 2002; 17 were rated as class I, 8 were rated as class II, and 62 were rated as class III.[4] The same special interest group is currently reviewing cognitive rehabilitation studies published between 2003 and 2007.

The conclusions drawn from the 2 reviews supported the effectiveness of cognitive rehabilitation interventions. The authors reported that the cognitive rehabilitation interventions that they reviewed were more effective than traditional types of treatment.[3,4] Cicerone *et al*.[3,4] used these reviews to develop evidence-based practice standards, guidelines, and options for practitioners working with individuals with TBI in the domains of attention, memory, and executive function. Practice standards were based on solid evidence from class I or class II studies and affirmed the efficacy of cognitive rehabilitation interventions in the form of strategy training to improve attention and memory and interventions to improve functional communication and conversational skills. Practice guidelines were based on class II evidence and included recommendations for attention training (varying modalities, levels of complexity, and response demands), methods to improve reading comprehension and language formation, training in problem-solving strategies, and participation in comprehensive neuropsychological rehabilitation. Finally, practice options were based on class II and class III evidence and included the use of memory notebooks or other external aids to address memory impairments and the use of methods of self-instruction, self-questioning, and self-monitoring to improve executive function. In addition, Cicerone *et al*.[4] argued that the next step for cognitive rehabilitation research is to investigate the relationship between treatment outcome and patient characteristics.

## COGNITIVE REHABILITATION INTERVENTIONS AFTER TRAUMATIC BRAIN INJURY

Cognitive rehabilitation interventions are applicable at all stages of postinjury recovery (acute, subacute, and postacute) and in different settings (eg, inpatient, outpatient, and domestic environments). In addition, they can be administered in different modalities (eg, individual, family, and group) and by professionals in different disciplines (eg, neuropsychologists, occupational therapists, and speech-language pathologists) with proper training and supervision. The following sections include an overview of selective evidence-based cognitive rehabilitation interventions that address impairments in attention, memory, and executive functions following TBI.

### Cognitive Rehabilitation for Attention

Interventions for attention deficits range from simple tasks such as using flashcards to improve basic attention skills[8] to more complex tasks to improve complex attention and working memory using a variety of visual and verbal tasks.[9–11] Sohlberg and Mateer[12] developed a training program to improve visual and auditory attention. The Attention Process Training (APT) program (APT-I and APT-II) is a theory-based intervention that hierarchically organizes attention into 5 components: focused attention, sustained attention, selective attention, alternating attention, and divided attention. The training program consists of various tasks organized by increasing difficulty. Competence is achieved through repetition at a certain skill level and progression to a higher skill level when the easier task is mastered. In addition, the developers have incorporated generalization tasks within the intervention to increase generalizability. Treatment is provided through a combination of individual and group treatments by trained clinicians. There is ample evidence supporting the effectiveness of APT.[13–15] The ease of implementing the treatment notwithstanding, clinical skill is a necessary component of any intervention. The role of the clinician is indispensable, and the APT is a good tool only insofar as it is applied by therapists with a good understanding of the training program as well as the deficits of the person being treated.

Other interventions for attention have included using the PASAT or variations of the PASAT such as the n-back procedure. PASAT-type tasks require listening to a sequence of stimuli and responding according to a rule. For example, in the original

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PASAT, respondents are required to listen to a sequence of numbers and utter aloud the sum of each number when it is added to the number that immediately preceded it. Evidence suggests that use of these interventions leads to improvements in measures of working memory and self-report of attention difficulties.[9,11]

## Cognitive Rehabilitation for Memory

Interventions for improving memory are an essential component of cognitive rehabilitation. Several interventions focus on improving different aspects of memory, such as face-name associations, memory for past events, prospective memory, and learning new information. Memory interventions have included restorative approaches, such as word-list learning, paragraph listening, visual imagery, and use of mnemonic strategies,[16,17] as well as compensatory approaches, such as the use of memory notebooks and other methods of recording and tracking information and the use of assistive technology tools, including personal computers, portable electronic devices, voice recorders, and pagers, which have been found to be instrumental in enhancing prospective memory (ie, the ability to remember to carry out a certain action at a specified time in the future or in response to a specific future event).[18–21]

One of the most effective interventions for the rehabilitation of memory impairments post-TBI is the memory notebook. The use of a memory notebook has been supported empirically.[22,23] Sohlberg and Mateer[16] presented a systematic method for using a memory notebook to facilitate learning. A memory notebook usually includes sections for orientation (autobiographical and/of injury-related information), a memory log, a calendar, to-do lists, transportation (eg, maps, public transportation schedules, and taxi phone numbers), a feelings log (a section to record emotions occurring in certain situations), names (names and other identifying information about other individuals), and any other section that may be personally relevant. There are 3 phases to learning how to use a memory book: acquisition, application, and adaptation. During the acquisition phase, the individual with TBI becomes familiar with the different sections and the purpose of the notebook. During the application phase, the individual learns to use the memory notebook in simulated settings. Finally, during the adaptation phase, the person learns to extend the use of the memory notebook to naturalistic environments, such as household or vocational settings. There are several factors that interfere with the successful use of memory notebooks and other external memory aids. They include client characteristics (eg, a lack of awareness of the need for the memory notebook and an unwillingness to draw attention to oneself), features of the memory notebook per se (eg, too simple or too complicated), environmental factors (eg, a low level of demand, especially if the patient is home-bound), and clinician variables (eg, training approach and identification of client-relevant sections).[24]

## Cognitive Rehabilitation for Executive Functioning

Interventions to improve executive functioning following TBI have targeted problem solving,[25–28] planning and organization,[29,30] goal-directed behavior,[31,32] and self-monitoring and self-regulation.[25,33,34] In a meta-analysis of intervention studies for executive functioning post-TBI, Kennedy *et al.*[35] reported favorable findings in terms of improvements in problem solving, planning, organization, and multitasking. Improvements extended to personally relevant functional activities, and treatment effects were maintained and generalized. The authors concluded that interventions using metacognitive strategies appeared to be the most efficacious and effective. Metacognitive strategy instruction was the type of intervention used across several studies that were reviewed, including randomized clinical trials and single-case studies. Metacognitive strategy instruction includes using and internalizing step-by-step procedures intended to enhance problem solving, planning, organization, and multitasking by increasing the capacity for self-regulation.[35] Metacognitive strategies aim at improving self-regulation by increasing self-awareness, which promotes the formation of personally relevant goals, self-monitoring, which enables individuals to assess their performance and reduce or prevent errors, and self-control, which facilitates initiation and behavioral change.[35] Interventions for executive functioning are administered individually, in groups, or with a combination of individual and group treatments.

## Comprehensive-Holistic Day Treatment Programs

Comprehensive-holistic day treatment programs (CHPs) offer a combination of therapeutic services and are a popular treatment option for individuals with TBI. A typical CHP includes individual and group cognitive rehabilitation, psychotherapy, psycho-education, and family therapy. Interventions are focused on specific cognitive domains, and group interventions are used to focus on executive dysfunction and to promote generalization of learning.

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Within such programs, treatment goals are articulated clearly, and progress is monitored regularly. The goals of treatment include improving cognitive function, increasing awareness, and addressing interpersonal, social, and emotional concerns. Treatment is usually administered by a transdisciplinary team, it incorporates community activities and vocational trials, and involvement of significant others is highly encouraged.[36] The evidence supports the effectiveness of CHPs, which in addition to resulting in improvements in cognitive functioning appear to facilitate skill transfer and generalization and to increase self-awareness, behavioral and affective regulation, psychosocial functioning, and community integration.[3,4] Comprehensive-holistic approaches to treatment have thus become the standard of care in rehabilitation following TBI.[37]

Two randomized clinical trials are currently in progress at the Mount Sinai School of Medicine to examine the efficacy of a CHP consisting of individual and group interventions for executive dysfunction.[25] The intervention is based on a metacognitive strategy intended to improve problem-solving and self-regulation abilities. The intervention entails the following:

- Individual training to improve diverse aspects of attention (selective, sustained, alternating, and divided).
- Group and individual instruction in a step-by-step problem-solving procedure that facilitates identification of problems, awareness of various aspects of problems, generation of alternatives, initiation of action, and self-monitoring.
- Group and individual training in strategies to improve emotional regulation. Individualized goal setting, repetition, and feedback are used extensively in order to enhance maintenance of the self-instructional abilities and to achieve generalization of the use of the metacognitive strategies to a variety of real-life settings.

Individuals receive the experimental CHP treatment, a standard-of-care CHP treatment, or no treatment (wait-list control group). The efficacy of the experimental intervention will be based on differences in performance on standardized neuropsychological tests and psychosocial measures. It is expected that individuals with TBI receiving the experimental intervention will exhibit superior performance on neuropsychological measures and improved psychosocial outcome in comparison with the wait-list control group or the standard-of-care treatment group.

### Use of Technology in Cognitive Rehabilitation

The use of technology in neuropsychological rehabilitation ranges from using computers as passive tools to project visual and verbal stimuli during cognitive training to using technological aids actively and in naturalistic settings as compensatory tools or cognitive orthotics.[38] Computer use in cognitive rehabilitation extends to memory training,[39–41] attention,[39,42] problem solving,[39] and job simulation.[43] Technological aids are frequently used in cognitive rehabilitation to improve performance on cognitive tasks. For example, a recent randomized control trial showed that use of a pager has been found to enhance prospective memory, which refers to the ability to remember to perform an activity in the future.[19] In an extensive review of existing technological aids, LoPresti *et al*.[38] classified aids into technologies for memory and executive function impairments and technologies for information processing impairments. Devices for memory and executive function compensation include digital watches, alarms, voice organizers, mobile phone-computer interactive systems, and handheld devices, such as personal digital assistants. Devices for information processing impairments include a keyboard for typing instead of writing, software that alters the features of text (eg, size and color) on a computer screen to facilitate reading, and speech output/speech recognition software.

Although the use of technology in TBI rehabilitation permits the administration of tasks that would be otherwise difficult to administer (eg, tracking reaction time in milliseconds or using a pager to cue oneself), these aids are intended not to replace a therapist but to augment the therapeutic experience. Indeed, research has failed to show an advantage of computer-assisted interventions over traditional interventions,[39,42] once again reminding us that the clinician is an active ingredient in the treatment. The role of the therapist in cognitive rehabilitation is “to set and maintain the structure, determine treatment needs and readiness, provide feedback and guidance, teach and reinforce the use of tools, and process emotional reactions,”[44] which to date no technological aid can accomplish successfully.

## ROLE OF TIME SINCE INJURY IN COGNITIVE REHABILITATION

There is no empirical evidence supporting the idea that there is a critical period during which cognitive rehabilitation is more effective.[45] Research on the role of time since injury in treatment is divided,

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**Table 1.** *Key Concepts in Cognitive Rehabilitation Following Traumatic Brain Injury.*

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| Cognitive rehabilitation is a treatment for cognitive impairments related to traumatic brain injury that is strongly supported by well-designed research. |
| A neuropsychological assessment is required in order to assess cognitive function and develop an appropriate treatment plan. |
| Cognitive rehabilitation consists of diverse interventions that must be tailored to the individual patient. |
| Cognitive rehabilitation can be effective regardless of the length of time since the injury and the injury severity level. |
| Cognitive rehabilitation leads to improvements in cognitive and psychosocial functioning. |

with some studies showing no difference in terms of the benefits of treatment in neuropsychological measures and psychosocial and vocational outcomes and other studies showing only a slight advantage of early rehabilitation.[44] Recent studies about brain plasticity suggest that interventions delivered at later stages post-injury may be more beneficial.[46] The lack of strong evidence about the optimal timing of the intervention suggests that there is no critical window for new learning. Learning can occur at any point post-injury, and there are no time limits in terms of the benefits that can accrue to the person from cognitive rehabilitation. Making individuals with TBI aware that treatment is beneficial at any time post-injury is likely to instill hope and increase their motivation and eventually lead to improvements in cognitive, emotional, and psychosocial functioning.

## ROLE OF INJURY SEVERITY IN COGNITIVE REHABILITATION

Cognitive rehabilitation interventions are used in the treatment of individuals with TBI whose severity of injury ranges from mild to severe. Intervention studies typically report the level of severity of the participants using traditional measures of injury severity (eg, the Glasgow Coma Scale or the duration of posttraumatic amnesia). Little research, however, exists that directly examines the role of injury severity in cognitive rehabilitation.[45] The literature generally suggests that severity of injury per se may not be as instrumental in designing and delivering a cognitive rehabilitation intervention as is identifying particular cognitive strengths and weaknesses and functional deficits of the person.[46] The target, intensity, and difficulty level of the intervention are better determined by the individual's cognitive profile, functional ability, level of self-awareness, and availability of environmental supports than by severity of injury.

## CONCLUSION

Cognitive rehabilitation interventions have proliferated in the last 30 years and have been implemented widely in the treatment of the cognitive deficits resulting from TBI (Table 1TBL 1). The toolkit includes interventions that can be adapted to facilitate improvements in functioning at different levels of severity, and that is not limited by the length of time since injury. Evidence from class I and class II studies has been amassed that supports the effectiveness of these interventions not only in terms of improving cognitive functioning but also in terms of improved psychosocial functioning and vocational outcomes. In order to render these interventions more successful, "they must be embedded in an appropriate context, be delivered systematically and creatively, and be individualized to fit the unique cognitive and psychotherapeutic needs of each individual" (Gordon and Hibbard,[45] p 660). Further research is still needed to identify the patient and treatment factors that contribute to successful outcome, to explicate the theoretical models underlying the interventions, and to identify the extent of the clinical significance of these interventions. Cognitive rehabilitation interventions are promising treatments that contribute to the well-being and quality of life of individuals with TBI.

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## DISCLOSURES

*Potential conflict of interest:* Nothing to report.

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