Article published online: 2025-02-05

Cognitive Rehabilitation to Remediate Attention and Memory in Patients with Complicated Mild Traumatic Brain Injury: A Case Series

Saishree[1] Jay K. Ranjan[1] Nityanand Pandey[2] Hari S. Asthana[1]

[1] Department of Psychology, Banaras Hindu University, Varanasi, Uttar Pradesh, India
[2] Department of Neurosurgery, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Address for correspondence Jay Kumar Ranjan, PhD, Department of Psychology, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India (e-mail: jaykumarranjan@gmail.com).

Indian J Neurotrauma

Abstract

Attention and memory deficits are frequently observed in individuals suffering from mild traumatic brain injury (MTBI), particularly in those exhibiting neurostructural abnormalities, commonly referred to as complicated mild traumatic brain injury (C-MTBI). The present case series employed customized cognitive retraining interventions and compensatory techniques designed to enhance attention, memory, and activities of daily living (ADL) of C-MTBI patient. Scores on Glasgow Coma Scale (GCS) and neuroimaging abnormalities detected via computed tomography (CT) or magnetic resonance imaging (MRI) were used to categorize the cases as C-MTBI. All four cases in the present case series were selected using purposive sampling technique. Cognitive dysfunction of the cases was evaluated utilizing the PGI Battery of Brain Dysfunction (PGI-BBD), while assessment of ADL was measured through the Hindi version of the Cognitive Symptom Checklist (CSC). Patients with C-MTBI underwent cognitive rehabilitation (CR) specifically tailored to address the unique requirements and characteristics of their nature of cognitive deficits. Cognitive retraining sessions were systematically organized on a biweekly basis, complemented by an additional weekly session focused on compensatory strategies, which were conducted face to face or through telephonic/video conferencing. All four cases completed CR sessions and after competition of the CR sessions, cognitive functions and ADL were reassessed using the PGI-BBD and CSC, respectively. The present case series highlights the effectiveness of CR program combining cognitive retraining and compensatory strategies in improving attention, memory, and ADLs of C-MTBI patients. All four cases demonstrated significant improvements in cognitive functioning and ADL measures following the CR program, supporting its applicability and therapeutic value.

Keywords

- cognitive rehabilitation
- complicated mild traumatic brain injury
- attention
- memory
- case series

DOI https://doi.org/10.1055/s-0045-1802588.
ISSN 0973-0508.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

Mild traumatic brain injury (MTBI) is a significant public health concern that affects a substantial number of individuals globally each year.[1] Certain cases of MTBI combined with neuroimaging abnormalities, for example, edema, hemorrhage, lesions, and skull fractures, result in worse cognitive outcomes compared with cases of MTBI without neuroimaging abnormalities,[2–4] and are now classified as complicated mild traumatic brain injury (C-MTBI).[5] Three months postinjury, cases with C-MTBI demonstrated significant deficits and slower recovery in processing speed, memory, and executive functioning compared with those with uncomplicated MTBI.[6] Even after 6 months postinjury, patients with C-MTBI exhibited not only long-term cognitive impairments but also worse functional outcomes such as activities of daily living (ADLs) than cases with uncomplicated MTBI.[7,8]

Cognitive rehabilitation (CR) is a "…systematic, functionally oriented service of therapeutic activities based on the understanding and assessment of the patient's brain behavioural deficit."[9] CR is grounded in the principles of neuroplasticity, which involve the administration of restorative tasks and compensatory strategies.[10] Restoration focuses on repetitive tasks aimed at strengthening neural connections in the brain, while compensatory strategies are used either to compensate the lost functions or for optimization of the lost functions.[11,12]

CR has been shown efficacy in addressing attention and memory impairments in patients with MTBI.[10] However, only a limited number of studies have been conducted in India to evaluate the effectiveness of CR in MTBI patients.[13–17] Furthermore, none of these studies incorporated a combination of repetitive retraining exercises and compensatory strategies, which are considered essential components of comprehensive rehabilitation. Most Indian studies utilized cognitive tasks and activities developed and empirically validated in Western cultures, which may not be entirely appropriate for use in the Indian context.[16,18]

Further, a systematic review by Cicerone et al[11] highlighted the importance of combining retraining exercises with metacognitive strategies to achieve greater effectiveness in improving cognitive deficits. However, none of the aforementioned studies incorporated metacognitive strategies into their CR programs, except for a single case report by Banerjee et al.[14] Finally, there is a dearth of studies investigating the efficacy of CR on patients with C-MTBI.

Therefore, the purpose of the study was twofold: first, to present four cases to evaluate the effectiveness of CR in improving attention and memory deficits, as well as ADL of patients with C-MTBI. Second, to see the applicability and suitability of an indigenously developed CR program in Indian patients with C-MTBI.

Materials and Methods

Cases of C-MTBI were selected using a purposive sampling technique from neurosurgery department of one of the largest level I trauma center in India. The present study was conducted over 14 months, from May 2023 to July 2024. Only those patients with history of a sustained head injury, a Glasgow Coma Scale (GCS) score of 13 to 15, and neuroimaging abnormalities detected via computed tomography (CT) or magnetic resonance imaging (MRI) scans were included in this study. Additionally, cooperative patients, 1 to 3 months postinjury, aged between 20 and 45 years, educated to at least the eighth class, and having proficiency in either Hindi or English language were included in this study. Patients were excluded if they presented with significant motor, visual, or auditory impairments or if they had a history of mental illness or neurodevelopmental or neurodegenerative disorders. Written informed consent was obtained from all the participants before inclusion in the study. Based on these inclusion and exclusion criteria, 13 patients were initially found eligible for the study. However, seven declined to participate in the CR program (see ►**Fig. 1**). Among the six patients who gave their written consent for participation in the study, two did not complete the scheduled CR sessions and were therefore excluded from the final analysis. The final sample in this case series comprised four participants, labeled P1, P2, P3, and P4. The sociodemographic characteristics of these four participants are presented in ►**Table 1**. Ethical approval for the conduction of this study was obtained well in advance from the Institutional Ethics Committee.

GCS[19] was used to measure the severity of TBI cases based on eye-opening, verbal response, and motor responses of the patients. Further, PGI Battery of Brain Dysfunction (PGI-BBD) [20] was used to evaluate the presence of cognitive dysfunction in the patients. In PGI-BBD, detection of cognitive dysfunctions is typically based on memory, intelligence,

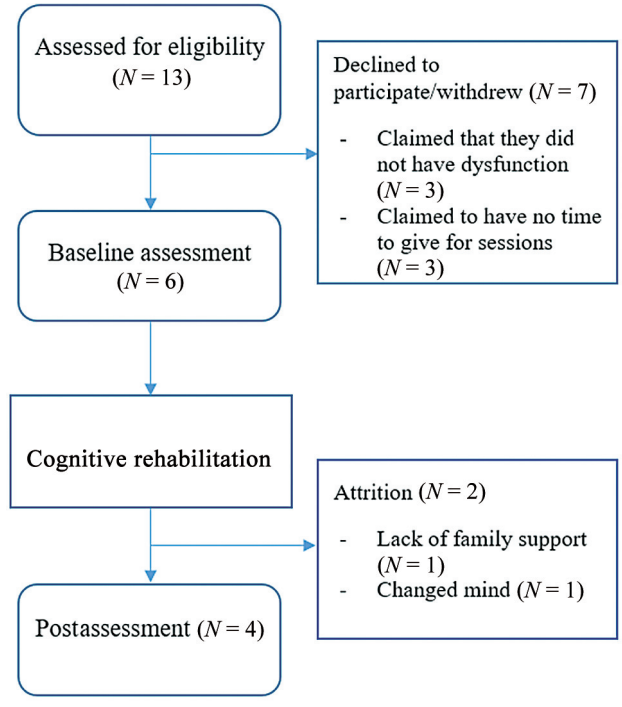

Fig. 1 Flowchart of the participants' progression through the study.

Table 1 Sociodemographic and clinical details of the patients

Patient	Age/sex	Education level	District	Injury site	GCS	Time taken to get the first line of treatment (min)	Mechanism of injury	Time since injury to rehabilitation (mo)
P1	20/F	Graduate	Patna district, Bihar	Left temporal contusion with SDH	15	30	Road traffic accident	2
P2	20/M	8th standard	Varanasi district, Uttar Pradesh	Parenchymal contusion in the right temporal lobe with SDH	15	30	Engaged in a physical altercation	1
P3	36/M	Graduate	Mirzapur district, Uttar Pradesh	Left temporal contusion with anomic aphasia	15	180	Road traffic accident	3
P4	34/F	Graduate	Varanasi district, Uttar Pradesh	Left frontal contusion	15	60	Road traffic accident	3

Abbreviations: GCS, Glasgow Coma Scale; SDH, subdural hematoma.

and visuospatial and visuomotor abilities of the patients. Additionally, the Hindi version of the Cognitive Symptom Checklist (CSC)[21] was used to evaluate ADL of the patients. The CSC is designed to measure ADL due to impairments in five cognitive domains, namely, attention, executive function, memory, visual processing, and language,[22] However, only attention and memory measures of the CSC were used in the present study.

Cognitive Retraining and Compensatory Strategies

The CR program is designed based on the principles of regeneration and compensations of neurocognitive rehabilitation.[23] The CR program implemented in this study aimed to address attention and memory deficits of the patients through psychoeducation, retraining exercises, and compensatory strategies.

Psychoeducation was the initial component of the CR program, and it was delivered prior to the implementation of retraining and compensatory cognitive exercises. During this phase, patients were provided with comprehensive information about MTBI, including the specific size and site of injury as indicated by neuroimaging reports, associated Post Concussion Syndrome (PCS), and the potential impact of the injury on daily functioning. Findings from assessments, including GCS, PGI-BBD, and CSC, were also communicated to the patients. The patients were informed about the rationale for implementing the CR program, emphasizing its potential benefits in improving cognitive functioning and overall quality of life. The concept of diaschisis and theoretical mechanisms underlying its resolution were explained in layman terms to enhance patient's understanding and engagement. Furthermore, the tentative frequency and duration of sessions, as well as the overall time required for effective implementation of the program, were discussed. The types of cognitive tasks and activities to be utilized during the CR program were also outlined. While providing psychoeducation, patients were encouraged to share their expectations of the program and discuss their daily routines. This collaborative approach allowed the rehabilitation team to establish personalized goals tailored to the patient's specific needs and lifestyles, thereby ensuring a patient-centered framework for the rehabilitation process.

The retraining exercises were taken from Brainwave-R cognitive retraining module.[24] Brainwave-R comprises

Table 2 Pre- and postoutcome measures for the patients with C-MTBI

Variable	Patient 1		Patient 2		Patient 3		Patient 4	
	Preoutome	Postout–come	Preout–come	Postout–come	Preout–come	Postout–come	Preout–come	Postout–come
PGI BBD	33	16	31	10	38	13	38	22
CSC-A	23	9	15	2	8	2	18	5
CSC-M	23	10	9	3	12	7	17	14

Abbreviations: CSC-A, attention-related cognitive symptom checklist; CSC-M, memory-related cognitive symptom checklist; PGI-BBD, PGI battery of brain dysfunction.

paper-based hierarchically graded modules targeting to enhance attention, visual processing, memory, information processing, and executive functions of head injury patients.[24] However, only attention- and memory-related tasks were used in the present study. Other retraining tasks were included through the modification of the existing tests of attention and memory (►**Supplementary Table S1**, available in the online version).[25–36] The retraining exercises addressing memory impairments primarily focused on procedural and working memory. As per difficulty levels, each attentional tasks for focused, sustained, selective, alternating, and divided attention were categorized into five hierarchical levels.

All the tasks are translated into the Hindi language and some of the tasks that are not suitable to implement in Indian setting were modified. To know about the expected time taken by the patient to finish the tasks and the number of errors that can be considered as acceptable, all the tasks were initially implemented into 30 individuals from the normal population and the total time taken to finish each task and number of errors were also recorded. Subsequently, mean and standard deviation (SD) of errors and response time were calculated (►**Supplementary Tables S2** and **S3,** available in the online version). Each modified task was further divided into two to three levels, arranged in order of task difficulty.

Compensatory strategies are based on the principle of compensation and aim to mitigate cognitive deficits through specific mechanisms including, remediation, substitution, assimilation, and accommodation.[37] Compensatory strategies are divided into internal and external strategies.[38] External compensatory strategies utilized in the current study included use of calendar to remember important dates (i.e., rehabilitation sessions, doctor's appointments, etc.), employing a notebook to track medication schedules, and recording the names of family members and friends to facilitate memory recall. In contrast, internal compensatory strategies encompassed techniques such as the method of loci, first-letter cues, and visual imagery.[39] The method of loci involves visualizing items to be memorized and situating them along an imagined journey, enhancing recall through spatial association.[40] First-letter cues entail using the initial letters of a list of items to form a mnemonic word, while visual imagery involves converting critical information into visual representations to improve memory retrieval.[40]

Metacognitive strategies were integrated into the CR program to enhance patients' self-awareness, self-prediction, and error evaluation regarding their performance.[41] Patients were encouraged to actively participate in their rehabilitation by rating their performance before and after completing each task. The performance rating scale ranged from 1 to 5, where a rating of 1 indicated an inability to perform the activity and a rating of 5 reflected proficiency in completing the activity without difficulty. Finally, objective feedbacks about their performances were provided to them.

During the implementation of the CR program, tasks were introduced in a hierarchical manner, starting with less complex activities, and gradually progressing to tasks of moderate and higher difficulty. In the initial trials, the primary focus was on completing tasks with accuracy. Once the patients demonstrated sufficient accuracy, time limits were introduced and gradually reduced over subsequent trials to enhance cognitive efficiency and processing speed. All tasks were presented in repeated drills, repeating until the patients achieved adequate mastery over increasingly complex tasks. Mastery was defined as achieving 90 to 95% accuracy in task performance. Upon reaching this level of proficiency, either the set time limits were further reduced or tasks with greater difficulty were introduced. Once patients demonstrated mastery over one group of tasks, another set of tasks with lower initial complexity was introduced, followed by a gradual increase in the complexity. This stepwise approach ensured a structured and progressive enhancement of cognitive skills, tailored to the individual performance and learning pace of each patient.

Procedure

The sample for the present study was selected from the Neurosurgery outpatient department (OPD) of the Banaras Hindu University (BHU) Trauma Centre using predefined inclusion and exclusion criteria. The purpose and nature of the study were thoroughly explained to the eligible participants, after which written informed consent was obtained. Patients with C-MTBI who consented to take part in the study underwent baseline assessments for their neuropsychological functioning and ADL. After completion of baseline assessment, all the patients were undergone through CR program. The CR sessions were led by a doctoral student, under the training and supervision of clinically trained professionals.

All patients participating in the CR program continued to receive standard pharmacological treatment as part of their routine clinical care. The CR program spanned approximately 11 weeks, with at least two sessions conducted per week. Depending on the patient's educational background and logistical considerations such as travel time and cost, sessions were delivered either through conventional face-to-face meetings or via telerehabilitation (e.g., phone or video calls). Tasks that required physical materials or hands-on interaction, such as puzzles and object-finding activities, were conducted exclusively in face-to-face sessions. Finally, participants were reassessed for their neuropsychological functioning and ADL after completion of CR program (►**Table 2**). In addition to findings from psychometric assessments, subjective reports were collected from participants regarding their perceived improvements in cognitive functioning and ADL.

Case Reports

Patient 1

Patient 1 (P1) is a 20-year-old female graduate student pursuing higher education who sustained a C-MTBI following a road traffic accident. On initial evaluation, she presented with a GCS score of 15, and her neuroimaging

revealed a contusion in the left temporal lobe. Within 30 minutes of the injury, she experienced two episodes of seizures. Postinjury, she exhibited PCS including fatigue, headache, generalized body pain, anger, memory loss, and nausea.

She was selected for CR 2 months after her injury. She lived in a remote location and had financial constraints; therefore, she preferred telerehabilitation, and CR program was entirely delivered through telephone and video calls. The patient adapted well to this format and remained comfortable throughout the therapy. She continued preparing for competitive examinations alongside the CR sessions.

On the PGI-BBD, the patient demonstrated adequate focused and sustained attention capacity. However, impairments were observed in higher-order attentional processes, particularly in alternating and divided attention. Additionally, marked deficits were observed in subtests related to working memory and short-term memory, for example, verbal retention for similar and dissimilar pairs, visual retention, and recognition tasks. The first session started with discussions on the PCS symptoms experienced by the patient and her difficulties in managing day-to-day activities associated with the symptoms. She reported significant difficulty in concentrating while reading, with an inability to study for more than 30 minutes at a time. Furthermore, she struggled to retain information learned an hour earlier. The patient explained how she often burned her fingers while cooking due to forgetting the temperature of the vessels she was handling. She reported difficulties in understanding the instructions given to her by others and would often forget to take her medicines. Following this, the patient was provided with psychoeducation regarding the prognosis of C-MTBI and how rehabilitation may alleviate her day-to-day issues by targeting her cognitive functions. The second session was initiated; the patient was given tasks of selective attention (►**Supplementary Table S4**, available in the online version), which she was able to complete with good accuracy. By the third session, she was given tasks of alternating attention. Initially she was apprehensive about making mistakes; her confidence and commitment increased progressively with successful completion of each task. By the end of the fourth session, the patient was able to complete the easier levels of alternating attention tasks with good accuracy but made a few errors in the final level (level 3). After six sessions targeting attention, the patient completed all the tasks with good accuracy and thus the therapy transitioned to memory-focused tasks. A total of seven sessions of retraining program was implemented specifically targeting the short-term memory and working memory capacity of the P1. The initial tasks from the 7th to the 10th session included simple memory tasks involving picture and color cards targeting immediate recall. For example, the patient was given shapes and was asked to recall objects that matched the given shape. Successive tasks required the patient to recall the sequences of color cards as they were pointed out. In the 12th and 13th sessions, the patient demonstrated the ability to accurately recall the color sequence solely by listening to the sequence without relying on visual cues. By the 14th session, the patient progressed to more complex, abstract memory tasks. These tasks incorporated distractions, such as mental calculations included within the primary memory task, to challenge and enhance the patient's cognitive flexibility. By the final session, the patient was able to complete the complex tasks with good accuracy.

Compensatory strategies were also employed to address challenges experienced by her in day-to-day life due to memory-related difficulties. For instance, the patient created a table with columns to record medication dosage and timing, marking each dose after consumption. To prevent accidental burns, she placed a note in the kitchen reminding her to use a cloth while handling hot cooking vessels. Additionally, she was taught the PQRST (*Preview, Question, Read, Self-recite, and Test*) method to enhance her retention and recall of study material. Coloring activities were assigned as part of her homework assignment to improve concentration and promote relaxation.

After competition of the 15 sessions of the CR program, significant improvements were observed in her performance. Her Dysfunction Rating Score (DRS) on the PGI-BBD decreased markedly from a pretest score of 33 to a posttest score of 16. Posttest scores demonstrated substantial improvements in subtests related to recent memory and concentration. However, no significant change has been observed in immediate recall subtest. Similarly, her scores on the CSC improved markedly, with attention scores decreasing markedly from 23 to 9 and memory scores decreasing from 23 to 10.

The patient reported noticeable enhancements in her ability to retain study material and recall important instructions. She also successfully adhered to her medication schedule. However, some challenges persisted, including occasional headaches and intermittent difficulty in retrieving specific words during conversations. Additionally, her attentional capacity and retention capacity were very limited for the difficult tasks as she compared her cognitive capacity to the premorbid level of functioning.

Patient 2

Patient 2 (P2), a 20-year-old male vegetable seller, completed education up to the eighth standard. He sustained a head injury during a fight between two individuals. At the time of admission, his GCS score was 15, with a history of loss of consciousness for 2 to 3 minutes. Following the injury, he experienced PCS including vomiting, headache, fatigue, dizziness, depressed mood, memory loss, and blackouts. Neuroimaging revealed parenchymal contusions in the right temporal lobe.

He was selected for CR after the first month of his injury. His presenting complaints comprised difficulties in performing simple calculations while working at his vegetable shop and frequent episodes of forgetting about where he kept valuable items, such as his phone, watch, and wallet. On PGI-BBD assessment, deficits were detected across multiple memory domains, namely, immediate, recent, and

delayed memory. The Digit Span Test further revealed marked impairment in attention and concentration. His verbal and performance intelligence scores were found to be at a borderline level, primarily due to attention and memory-related difficulties.

The patient opted for a rehabilitation plan consisting of face-to-face sessions twice a week, supplemented by weekly telephonic sessions to monitor homework and compensatory strategies. In the initial CR session, it became evident that P2 lacked insight into the degree of his cognitive impairment and its functional consequences. Therefore, psychoeducation was provided to connect his injury to his cognitive challenges and daily life difficulties. This intervention markedly reduced his agitation and confusion, allowing him to participate actively in subsequent sessions. The second session focused on addressing sustained attention deficits using retraining tasks, such as continuously adding the number 2 to a presented digit. Initially, the patient performed the task with poor accuracy. Using a metacognitive approach, errors were analyzed in conjunction with the patient's self-assessment. During these discussions, it was identified that P2 prioritized speed over accuracy, leading to frequent errors. Recommendations were provided to encourage the patient on taking more time in answering; following this, a notable improvement in the patient's accuracy was observed, indicating the effectiveness of the strategy. As a cognitive exercise, P2 was assigned a coloring task as homework to enhance his sustained attention. By the fourth session, he completed sustained attention tasks with minimal errors. Subsequently, the tasks for selective attention were introduced, which involved counting the occurrence of two target numbers in succession in a series. With some practice drills, P2 was able to perform well. During this time, he struggled to attend sessions for more than 30 minutes. To accommodate this, small breaks were incorporated into the sessions. By the sixth session, alternating attention tasks were introduced. During the implementation of these tasks, P2 demonstrated a tendency to be highly self-critical, perceiving himself as a failure upon making mistakes. To address this, positive reinforcement was provided through verbal praise for each correct response, and for sincere attempts. Initially, he struggled to maintain accuracy, but after repeated drills, his performance improved significantly. By the eighth session, his accuracy had increased, and he was introduced to tasks related to divided attention capacity. At this stage, his ability to attend sessions increased to 2 hours. From the 12th session onward, memory retraining tasks were introduced, involving both visual and auditory stimuli, which were progressively upgraded to auditory-only tasks. Since his primary concern was difficulty with calculations, calculation grids were assigned as part of his homework exercises to improve numerical processing.

To address the patient's frequent misplacement of valuable items, a compensatory strategy was implemented. For that, a poster was created, depicting pictures of valuable items (e.g., phone, watch, and wallet) along with designated locations for storage. This poster was placed both at home and in his shop. This strategy helped him to locate his valuables more efficiently in real-life settings.

At the completion of CR, the postassessment scores on the PGI-BBD reflected significant improvement, with DRS reducing from 31 to 10. Marked improvements were observed across all domains of attention and memory; as CSC scores for attention (from 15 to 2) and memory (from 9 to 3) improved markedly. His verbal and performance intelligence scores improved markedly aligned with his enhanced attention and memory abilities. His postconcussion symptoms had largely resolved, except for occasional episodes of stress and sadness. Functionally, P2 demonstrated significant improvement in daily life activities. He could now store essential objects in designated places and stand for extended durations at work, effectively addressing his initial concerns.

Patient 3

Patient 3 (P3), a 36-year-old male graduate who owns a transportation business, sustained a head injury after colliding with a stray animal while riding his motorcycle on a highway. At the time of preassessment, his GCS score was 13, and neuroimaging revealed a left temporal lobe contusion. PCS included dizziness, headache, irritability, and memory loss. According to a family member, the patient exhibited significant cognitive difficulties, such as the inability to recognize close relatives, including his wife and their 15-year-old son. Anomic aphasia was also observed, as the patient often failed to recall the names of familiar objects (e.g., vegetables, people, and frequently visited places) despite recognizing their characteristic features. He was selected for CR on the third month after his injury.

His residence was close to the trauma center; therefore, the patient opted for face-to-face sessions as part of the CR. Similar to previous cases, psychoeducation was provided during the first session. The patient shared his experiences of memory difficulties, which caused him significant embarrassment. For instance, he described being unable to recall the names of relatives despite recognizing them, forgetting the names of vegetables cooked at home, and failing to remember earlier conversations with his employees, etc.

On PGI-BBD, higher-level attentional processes were found impaired. Therefore, starting with the second session, tasks related to selective attention were implemented. After implementation of tasks into repeated drills, the patient gained mastery over these tasks and was able to perform them within an optimum duration. From the fourth to sixth sessions onward, the retraining program progressed to tasks addressing alternating and divided attention. While performing the metacognitive strategy of rating their own performance, the patient often rated themselves lower than his actual performance. To address this discrepancy, a discourse was initiated, involving discussions on the observed gap between the self-rating and the actual performance. This process aimed to

enhance the patient's self-awareness, encourage more accurate self-assessment, and build confidence by acknowledging their true capabilities and achievements.

Given the patient's difficulty in recalling specific words, the "picture recall" task was introduced and continued throughout the CR program. This task involved presenting cards depicting animals, vegetables, fruits, and modes of transportation. After briefly viewing the cards, the patient was required to recall the names of the items. In the initial sessions, he struggled to recall the names and exhibited frustration. However, with consistent practice, his recall performance showed progressive improvement. By the ninth session, he demonstrated an ability to perform complex attentional tasks and successfully engaged in divided attention exercises.

Memory retraining tasks were introduced from the 10th session onward (detailed descriptions are provided in ►**Supplementary Table S4**, available in the online version). Alongside retraining exercises, compensatory strategies were implemented. The "first-letter cue method" as a compensatory strategy was implemented. In this task, the patient was shown pictures of loved ones along with their names. The picture was then removed, and a new picture was shown with only part of the names visible, as the initial letters were intentionally removed. The patient was required to recall the names based on the cues. As sessions progressed, fewer letters were provided as cues. After repeated practice, the patient successfully recalled and recognized the names of his family members. This task was later extended to other categories, such as fruits, vegetables, and grocery items.

To address spatial orientation difficulties, the patient was taught to observe and note landmarks when navigating to destinations. Visual imagery techniques were also employed, where the patient was encouraged to break down names into smaller, meaningful segments and create mental images for each segment. For example, to remember the name "Aakash" (sky), he is supposed to visualize a person standing under a clear blue sky.

At the completion of the CR program, the postassessment scores on the PGI-BBD showed significant improvements, with the DRS decreasing from 38 to 13. Memory functions and verbal intelligence demonstrated marked enhancement, except in the domains of delayed recall and visual retention. The CSC scores also reflected improvements, with attention scores decreasing from 8 to 2 and memory scores reducing from 12 to 7.

The patient reported a notable ability to perform multiple tasks simultaneously and showed improvement in recalling the names of relatives and objects in his environment. Although occasional difficulties remained, such as identifying specific vegetables, overall cognitive and functional outcomes indicated substantial progress. Family members also reported marked improvements in the patient's functioning and reduction in symptomatic behavior.

During a follow-up interview, the patient expressed some degree of anxiety and agitation regarding complete recovery. These concerns were addressed through supportive counseling techniques, including persuasion and reassurance. Although the patient occasionally consumed alcohol prior to the injury, he maintained complete abstinence throughout the implementation of CR program, and till recovery.

Brief Clinical Details of Patient 4

Patient 4 (P4) is a 30-year-old female graduate who was involved in a road accident, which resulted in a left frontal lobe contusion. She presented with PCS including dizziness, headache, nausea, forgetfulness, and fatigue. Additionally, the patient experienced significant fatigue, preventing her from performing household chores for more than 30 minutes at a time. She also expressed difficulty in crossing the road and found it challenging to calculate prices when shopping for groceries. Additionally, the patient reported her inability to recite holy books by heart, which affected her religious practices. The patient encountered substantial familial restrictions, particularly, she was not allowed to leave her house without being accompanied by a male family member, making it difficult for her to travel to the center for face-to-face rehabilitation sessions. Consequently, all sessions were conducted via telerehabilitation. She was selected for CR 3 months after her injury.

The sessions started with a discussion on her daily routine and her struggles, and the objectives of the CR program were discussed. She was educated about PCS that can occur as a result of brain injury and the likely prognosis for TBI patients with mild severity. In the subsequent session, the patient was given tasks of selective attention. The patient experienced anxiety and fatigue, which limited her ability to attend sessions for more than an hour. To address these issues, the sessions were structured with frequent short breaks between tasks. From the fourth session onward, she was given tasks of alternating attention. During this time, she reported being irritable with her family members, which slightly distressed her. The patient showed satisfactory performance in the given tasks; therefore, the tasks for divided attention started in the sixth session. The patient made multiple errors in the task for divided attention; through repeated drills, the patient improved and by the eighth session the memory tasks were introduced. The patient performed well in tasks like "Name it!" However, she had some difficulties in completing numerical tasks requiring mathematical calculations. To target this, the patient was given mathematical calculations as homework. By the 12th session, she performed the tasks with good accuracy. Since the inability to recite holy books was identified as the primary concern, the method of loci was introduced as an internal compensatory strategy to aid in memorization.

The pretest assessment indicated an overall DRS of 38, which decreased to 22 posttest. Improvement was noted in the subtests of remote and recent memory, visuospatial ability, and perceptual acuity. However, no significant changes were observed in the subtests for attention and concentration, visual retention, and verbal intelligence. On the CSC, the patient's attention scores decreased from 18 to 5, and memory scores decreased from 17 to 14. Following the

rehabilitation program, the patient demonstrated the ability to perform multiple tasks simultaneously without making errors. Additionally, she was able to remember instructions more effectively and recite her prayers by heart, which was her primary concern at the start of the rehabilitation.

Discussion

The present case series aimed to investigate the effectiveness of cognitive retraining and compensatory strategies in treating attention and memory dysfunctions, as well as related ADL, in patients with C-MTBI. As per the literature survey, the present study is first research evaluating the effectiveness of CR in the C-MTBI group. The results indicated that all four patients demonstrated significant improvements in overall brain dysfunctions and ADL measures after the implementation of the CR program. The findings of the present study align with previous studies that have also reported that CR is effective in enhancing the attention and memory functions of patients with MTBI.[42,43] The present findings also align with an Indian case study that reported that both retraining and compensatory methods were effective in managing cognitive dysfunction in a severe TBI patient. Similarly, an empirical Indian study reported that CR is effective in managing cognitive dysfunction in severe TBI patients, although the study only used retraining methods for this purpose.[13]

In the present study, retraining tasks were administered as repeated drills, progressing from the least difficult to the most difficult levels and these tasks were implemented from no time constraints to the implementation of optimum time limits. The optimal time limits for each task were determined based on performance data obtained from 34 individuals from the normative samples.

The recovery of cognitive functions specially attention and memory functioning of C-MTBI patients following CR programs can be explained through various theories and mechanisms of recovery of functions. These include the resolution of diaschisis, reorganization of functional systems, and compensation for performance-related deficits.[43–45] Diaschisis refers to the disruption of intact systems caused by damaged brain structures following TBI, resulting in physiological imbalances, and cognitive retraining can mitigate these disruptions, facilitating recovery.[46] Functional reorganization involves undamaged brain areas taking over functions previously performed by damaged regions.[46] Compensation, on the other hand, is the process of overcoming deficits through recognizable mechanisms, which are particularly important when the restoration of functions is not feasible.[47,48] Further, studies suggest that compensatory mechanisms can enhance functionality in TBI patients, particularly those with reduced efficiency in the frontal[49] and temporal regions,[50] and imparting independence and less reliance on their caregivers.[51] Therefore, Bayley et al[52] have also advocated for integration of retraining tasks along with compensatory strategies to enhance the effectiveness of CR.

Additionally, two participants, both women, faced challenges in attending face-to-face rehabilitation due to financial constraints, low family support, and their remote locations. Consequently, their CR sessions were conducted through telerehabilitation, and notable improvements were observed both in their cognitive dysfunctions and ADL measures. The findings are similar with the findings documented by Laver et al[53] who reported that telerehabilitation is as effective as conventional face-to-face rehabilitation for enhancing ADL in patients with brain injury. The use of telerehabilitation has surged since the COVID-19 pandemic, facilitating client–therapist interactions for patients in remote areas.[54]

In the present study, psychoeducation was integrated with conventional cognitive retraining and methods of compensation in the CR programs. As observed in all four cases, psychoeducation creates awareness about deficits following TBI, impact of cognitive deficits on ADLs, PCS, and the detrimental effects of an inactive lifestyle on their symptoms. In a previous study, psychoeducation with CR was found to be effective in reducing PCS among MTBI patients.[55]

Throughout the rehabilitation program, metacognitive strategies emerged as an effective component in enhancing patient outcomes. These strategies increased the patient's self-awareness, particularly regarding the discrepancies between their perceived performance and actual accuracy. This was especially beneficial in the cases involving patients with low literacy levels who often exhibited limited insight into their own performance. Metacognitive strategies also played a critical role in fostering patient engagement. By recognizing specific issues that required improvement, the patients became more actively involved in their rehabilitation. Furthermore, as the patients identified their errors during tasks, they were able to draw parallels to similar mistakes made in daily activities. For instance, P1 was encouraged to take time before responding to tasks, which, when applied to her study habits, resulted in a more deliberate and effective approach to learning.

Although the present case series is the first study to evaluate the effectiveness of a retraining- and compensatory-based CR program in managing cognitive dysfunctions and ADLs of four cases with C-MTBI patients, the present study has its own limitations. For instance, the findings of the present case series are based on only four cases, which limit the generalizability of the findings. Additionally, it was difficult to determine whether the improvements in cognitive functioning and ADLs were directly attributable to CR or the improvements occurred due to the brain's natural neuronal plasticity, as the progressions of cases in the control group were not observed in this study. Therefore, it is recommended that in the future, for a broader understanding of the effectiveness of CR, the present study may be replicated as randomized controlled trials comprising larger samples. Furthermore, the empirical validity of the cognitive retraining tasks used in this study has not been established, although we followed the principles and processes of cognitive retraining as outlined in the Brainwave-R retraining module. Further, we did not measure the subclinical level of comorbid psychiatric symptoms; for example, anxiety and depression in the patients could also be possible limitations of the study as

the presence of these psychiatric symptoms may also infer the recovery trajectory of the patients.

Conclusion

The cognitive retraining program, combined with compensatory strategies, is effective in improving attention, memory, and ADLs of patients with C-MTBI. The incorporation of psychoeducation in the CR program fostered awareness and active participation in the treatment regimen. Implementation of the CR program through a telerehabilitation mode also emerged as an effective alternative for patients facing barriers to face-to-face sessions. The findings of the present study will be helpful for health professionals, researchers, and policymakers to make informed clinical decisions while planning treatment and policies related to the integrated biopsychosocial management of C-MTBI patients.

Funding
This research was supported by the University Grants Commission (UGC) through the Junior Research Fellowship (JRF) awarded to the first author. The authors thank for the assistance and support.

Conflict of Interest
None declared.

References

1 Mavroudis I, Ciobica A, Bejenariu AC, et al. Cognitive impairment following mild traumatic brain injury (mTBI): a review. Medicina (Kaunas) 2024;60(03):380
2 Gardner JE, Teramoto M, Hansen C. Factors associated with degree and length of recovery in children with mild and complicated mild traumatic brain injury. Neurosurgery 2019;85(05): E842–E850
3 Hansen C, Battikha M, Teramoto M. Complicated mild traumatic brain injury at a level I pediatric trauma center: burden of care and imaging findings. Pediatr Neurol 2019;90:31–36
4 Karr JE, Iverson GL, Berghem K, Kotilainen AK, Terry DP, Luoto TM. Complicated mild traumatic brain injury in older adults: post-concussion symptoms and functional outcome at one week post injury. Brain Inj 2020;34(01):26–33
5 Hansen C, Waller LC, Brady D, Teramoto M. Relationship between CT head findings and long-term recovery in children with complicated mild traumatic brain injury. Brain Inj 2022;36(01): 77–86
6 Hacker D, Jones CA, Yasin E, et al. Cognitive outcome after complicated mild traumatic brain injury: a literature review and meta-analysis. J Neurotrauma 2023;40(19-20):1995–2014
7 Voormolen DC, Zeldovich M, Haagsma JA, et al. Outcomes after complicated and uncomplicated mild traumatic brain injury at three-and six-months post-injury: results from the CENTER-TBI study. J Clin Med 2020;9(05):1525
8 Hart T, Novack TA, Temkin N, et al. Duration of posttraumatic amnesia predicts neuropsychological and global outcome in complicated mild traumatic brain injury. J Head Trauma Rehabil 2016;31(06):E1–E9
9 Cicerone KD, Dahlberg C, Kalmar K, et al. Evidence-based cognitive rehabilitation: recommendations for clinical practice. Arch Phys Med Rehabil 2000;81(12):1596–1615
10 Johnson LW, Weinberg A. Cognitive rehabilitation approaches to traumatic brain injury: a review of efficacy and outcomes. Med Res Arch 2023;11(08)
11 Cicerone KD, Goldin Y, Ganci K, et al. Evidence-based cognitive rehabilitation: systematic review of the literature from 2009 through 2014. Arch Phys Med Rehabil 2019;100(08):1515–1533
12 Velikonja D, Ponsford J, Janzen S, et al. INCOG 2.0 guidelines for cognitive rehabilitation following traumatic brain injury, part V: memory. J Head Trauma Rehabil 2023;38(01):83–102
13 Afsar M, Shukla D, Bhaskarapillai B, Rajeswaran J. Cognitive retraining in traumatic brain injury: experience from tertiary care center in southern India. J Neurosci Rural Pract 2021;12(02): 295–301
14 Banerjee M, Hegde S, Thippeswamy H, Kulkarni GB, Rao N. In search of the "self": holistic rehabilitation in restoring cognition and recovering the "self" following traumatic brain injury: a case report. NeuroRehabilitation 2021;48(02):231–242
15 Kanchan A, Singh AR, Khan NA, Jahan M, Raman R, Sathyanarayana Rao TS. Impact of neuropsychological rehabilitation on activities of daily living and community reintegration of patients with traumatic brain injury. Indian J Psychiatry 2018;60(01):38–48
16 Kannan S, Chandramohan V, Ramesh Kannan S. Efficacy of cognitive intervention using CogSMART in the management of cognitive problems in mild traumatic brain injury. Indian J Health Wellbeing 2017;8(09):1008–1011
17 Sunny AM. Feasibility of home-based attention retraining on people with mild and moderate traumatic brain injury. Int J Indian Psychol 2016;4(01)
18 Chatterjee P, Kumar DA, Naqushbandi S, et al. Effect of Multimodal Intervention (computer based cognitive training, diet and exercise) in comparison to health awareness among older adults with subjective cognitive impairment (MISCI-Trial): a pilot randomized control trial. PLoS One 2022;17(11):e0276986
19 Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet 1974;2(7872):81–84
20 Pershad D, Verma SK. Handbook of PGI Battery of Brain Dysfunction (PGI-BBD). Agra, India: National Psychological Corporation; 1990
21 Mukherjee P, Singh DK, Trikey L, Kumari A. Application of Cognitive Symptom Checklist on patients with psychosis in remission. Research project report. Ranchi: Ranchi Institute of Neuro-Psychiatry & Allied Sciences; 2007
22 O'hara C, Harrell M, Bellingrath E, Lisicia K. Cognitive Symptom Checklists: Clinician's Guide. Odessa, FL: Psychological Assessment Resources; 1993
23 Nagappan PG, Chen H, Wang D-Y. Neuroregeneration and plasticity: a review of the physiological mechanisms for achieving functional recovery postinjury. Mil Med Res 2020;7(01):30
24 Malia KB, Bewick KC, Raymond MJ, Bennett TL. Brainwave-R: Cognitive Strategies and Techniques for Brain Injury Rehabilitation. Austin, TX: Pro-Ed; 1997
25 White JP, Schembri A, Edgar CJ, Lim YY, Masters CL, Maruff P. A paradox in digital memory assessment: increased sensitivity with reduced difficulty. Front Digit Health 2021;3:780303
26 Wechsler D. Wechsler Adult Intelligence Scale. San Antonio, TX: Psychological Corporation; 1997
27 Tolan GA, Tehan G. Determinants of short-term forgetting: decay, retroactive interference, or proactive interference? Int J Psychol 1999;34(5–6):285–292
28 Salthouse TA. Mental exercise and mental aging: evaluating the validity of the "use it or lose it" hypothesis. Perspect Psychol Sci 2006;1(01):68–87
29 Reitan RM. The relation of the trail making test to organic brain damage. J Consult Psychol 1955;19(05):393–394
30 Miyake A, Friedman NP. The nature and organization of individual differences in executive functions: four general conclusions. Curr Dir Psychol Sci 2012;21(01):8–14

31 Lumley FH, Calhoon SW. Memory span for words presented auditorially. J Appl Psychol 1934;18(06):773–784
32 Gronwall DM. Paced auditory serial-addition task: a measure of recovery from concussion. Percept Mot Skills 1977;44(02):367–373
33 Daneman M, Carpenter PA. Individual differences in working memory and reading. J Verbal Learn Verbal Behav 1980;19(04): 450–466
34 Case R, Kurland DM, Goldberg J. Operational efficiency and the growth of short-term memory span. J Exp Child Psychol 1982;33 (03):386–404
35 Buschke H. Selective reminding for analysis of memory and learning. J Verbal Learn Verbal Behav 1973;12(05):543–550
36 Broadway JM, Engle RW. Validating running memory span: measurement of working memory capacity and links with fluid intelligence. Behav Res Methods 2010;42(02):563–570
37 Rahmani M, Rahimian Boogar I, Talepasand S, Nokani M. Comparing the effectiveness of computer-based, manual-based, and combined cognitive rehabilitation on cognitive functions in relapsing-remitting multiple sclerosis patients. Basic Clin Neurosci 2020;11(01):99–110
38 Allott K, van-der-El K, Bryce S, et al. Compensatory interventions for cognitive impairments in psychosis: a systematic review and meta-analysis. Schizophr Bull 2020;46(04):869–883
39 Gopi Y, Wilding E, Madan CR. Memory rehabilitation: restorative, specific knowledge acquisition, compensatory, and holistic approaches. Cogn Process 2022;23(04):537–557
40 Kluger FE, Oladimeji DM, Tan Y, Brown NR, Caplan JB. Mnemonic scaffolds vary in effectiveness for serial recall. Memory 2022;30 (07):869–894
41 Fleming J, Hamilton C, Ownsworth T, et al. The perspectives of participants with traumatic brain injury on prospective memory rehabilitation incorporating compensatory and metacognitive skills training. Patient Educ Couns 2024;118:108023
42 Cooper DB, Bowles AO, Kennedy JE, et al. Cognitive rehabilitation for military service members with mild traumatic brain injury: a randomized clinical trial. J Head Trauma Rehabil 2017;32(03): E1–E15
43 Storzbach D, Twamley EW, Roost MS, et al. Compensatory cognitive training for operation enduring freedom/operation Iraqi freedom/operation new dawn veterans with mild traumatic brain injury. J Head Trauma Rehabil 2017;32(01):16–24
44 Kolb B, Whishaw IQ. Fundamentals of Human Neuropsychology. 3rd ed. New York, NY: W H Freeman/Times Books/Henry Holt & Co; 1990
45 Von Monakow C. Disachisis. In: Pribram KH, ed. Brain and Behavior I: Mood States and Mind. Baltimore, MD: Penguin; 1969:27–36
46 Stuss DT, Winocur G, Robertson IH. Cognitive Neurorehabilitation: Evidence and Application. 2nd ed. Cambridge: Cambridge University Press; 2010
47 Hylin MJ, Kerr AL, Holden R. Understanding the mechanisms of recovery and/or compensation following injury. Neural Plast 2017;2017(01):7125057
48 Wilson BA. Compensating for cognitive deficits following brain injury. Neuropsychol Rev 2000;10(04):233–243
49 Jacqmain J, Nudi ET, Fluharty S, Smith JS. Pre and post-injury environmental enrichment effects functional recovery following medial frontal cortical contusion injury in rats. Behav Brain Res 2014;275:201–211
50 Jang SH, Lee HD. Compensatory neural tract from contralesional fornical body to ipsilesional medial temporal lobe in a patient with mild traumatic brain injury: a case report. Am J Phys Med Rehabil 2016;95(02):e14–e17
51 Withiel TD, Sharp VL, Wong D, Ponsford JL, Warren N, Stolwyk RJ. Understanding the experience of compensatory and restorative memory rehabilitation: a qualitative study of stroke survivors. Neuropsychol Rehabil 2020;30(03):503–522
52 Bayley MT, Janzen S, Harnett A, et al. INCOG 2.0 guidelines for cognitive rehabilitation following traumatic brain injury: methods, overview, and principles. J Head Trauma Rehabil 2023;38(01):7–23
53 Laver KE, Adey-Wakeling Z, Crotty M, Lannin NA, George S, Sherrington C. Telerehabilitation services for stroke. Cochrane Database Syst Rev 2020;1(01):CD010255
54 Mantovani E, Zucchella C, Bottiroli S, et al. Telemedicine and virtual reality for cognitive rehabilitation: a roadmap for the COVID-19 pandemic. Front Neurol 2020;11:926
55 Heslot C, Cogné M, Guillouët E, et al. Management of unfavorable outcome after mild traumatic brain injury: review of physical and cognitive rehabilitation and of psychological care in post-concussive syndrome. Neurochirurgie 2021;67(03): 283–289

