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# Self-Efficacy Intervention Combined With Staged Rehabilitation Training Improves Neurological Function, Motor Performance, and Prognosis in Patients After Traumatic Brain Injury Surgery: A Retrospective Cohort Study

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AIM: This study aimed to investigate the efficacy of self-efficacy intervention combined with staged rehabilitation training on neurological function, motor performance, psychological status, and mid-term prognosis in patients after traumatic brain injury (TBI) surgery.
METHODS: This retrospective cohort study recruited 162 TBI patients who underwent surgical treatment between January 2022 and January 2025. Patients were divided into the observation group (n = 75, routine care + self-efficacy intervention + staged rehabilitation training) and the control group (n = 87, routine care only). The primary outcome was a favourable prognosis (Glasgow Outcome Scale [GOS] scores 4–5) at 6-month follow-up. Secondary outcomes included changes in National Institutes of Health Stroke Scale (NIHSS), Fugl-Meyer Assessment (FMA), General Self-Efficacy Scale (GSES), Self-Rating Anxiety Scale (SAS), Self-Rating Depression Scale (SDS), Barthel Index (BI), 36-Item Short Form Health Survey (SF-36) scores, and postoperative complication rates.
RESULTS: Baseline characteristics were comparable between groups ($p > 0.05$). Post-intervention, the observation group showed significantly lower NIHSS scores ($17.57 \pm 4.19$ vs. $20.14 \pm 4.95$, $p < 0.001$) and higher FMA scores for upper ($49.84 \pm 3.26$ vs. $44.57 \pm 3.55$) and lower limbs ($25.84 \pm 2.74$ vs. $22.68 \pm 2.49$) than the control group ($p < 0.001$). The observation group also had higher GSES ($31.16 \pm 2.83$ vs. $26.57 \pm 3.19$) and BI scores ($44.59 \pm 4.81$ vs. $39.94 \pm 4.37$), lower SAS ($43.61 \pm 7.17$ vs. $46.34 \pm 6.94$) and SDS scores ($42.17 \pm 4.20$ vs. $44.25 \pm 4.74$), and superior SF-36 subscale scores ($p < 0.001$). The incidence of postoperative complications was lower in the observation group (6.67% vs. 18.39%, $p = 0.027$). The proportion of favourable prognosis was higher in the observation group (74.67% vs. 56.32%, $p = 0.015$), and the combined intervention was an independent predictor of favourable outcome (adjusted odds ratio [aOR] = 2.09, 95% confidence interval [CI]: 1.05–4.16, $p = 0.035$).
CONCLUSIONS: Self-efficacy intervention combined with staged rehabilitation training effectively improves neurological function, motor recovery, psychological well-being, daily living ability, and mid-term prognosis, while reducing complications in patients after TBI surgery, representing a valuable clinical rehabilitation strategy.

**Keywords:** traumatic brain injury; self-efficacy intervention; staged rehabilitation training; neurological function; prognosis

## Introduction

Traumatic brain injury (TBI) constitutes a major global public health concern, associated with high mortality rates and significant long-term disability, imposing a substantial burden on affected individuals, their families, and healthcare systems [1,2]. Global epidemiological estimates demonstrate that approximately 20.84 million new cases of TBI were reported in 2021, with the incidence continuing to rise [3,4]. TBI most often results from high-energy events such as traffic accidents, falls, and violence, all of which not only cause primary mechanical damage to the brain but also complex events of secondary pathophysiological processes, including cerebral edema, neuroinflammation, and cerebral ischemia [5]. At present, surgical intervention remains the primary treatment option for moderate to severe TBI. Procedures such as removing intracranial haematomas and reducing intracranial pressure can effectively prevent further neurological deterioration and reduce mortality risk [6]. However, in patients after TBI surgery, the restoration of neurological function and improvement in functional impairment still necessitate scientifically structured rehabilitation interventions [7].

Conventional post-operative interventions primarily focus on physiological stabilisation, including infection control, intracranial pressure reduction, and neurotrophic support, with insufficient attention paid to patients' psychological status and active participation in rehabilitation frameworks [8]. Furthermore, many rehabilitation training programmes often follow a standardised protocol that does not adequately reflect the dynamic and stage-specific nature of neurological recovery. Consequently, functional outcomes may largely remain unsatisfactory.

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Self-efficacy interventions, through personalized health guidance, motivation, goal setting and feedback, can effectively stimulate patients' subjective initiative in rehabilitation, enhance their confidence in dealing with diseases and self-care ability, and have been verified in the postoperative rehabilitation of various diseases [9,10]. In parallel, phased rehabilitation training dynamically adjusts the content and intensity of rehabilitation according to the distinct pathophysiological characteristics after TBI, including the cerebral oedema phase, stabilisation phase, and functional recovery phase, thereby achieving precise, stepwise functional restoration training [11]. Although both self-efficacy interventions and phased rehabilitation approaches have individually demonstrated promising clinical application, evidence regarding their integrated use in patients after TBI surgery remains limited. Particularly, their potential combined effects on neurological recovery, motor function, and mid-term prognosis warrant further comprehensive investigation.

Given this, the present retrospective study aims to assess the clinical efficacy of an integrated approach combining self-efficacy intervention with phased rehabilitation training, compared with conventional rehabilitation care. Outcomes of interest include the degree of neurological deficits, limb motor function, self-efficacy level, activities of daily living, quality of life, and mid-term neurological prognosis in patients after TBI surgery. The study hypothesises that the patients undergoing combined intervention will demonstrate greater improvement across all key functional and patient-reported parameters compared with those receiving standard care. This will provide high-level clinical evidence for establishing a new, efficient rehabilitation model centred on patient agency and integrating physical and psychological aspects.

## Methods

*Study Participants and Research Design*

This retrospective cohort study aimed to evaluate the impact of different postoperative rehabilitation strategies on functional outcomes in patients with TBI. Data were retrieved from the hospital's electronic medical records system. A total of 162 patients who underwent surgical intervention for TBI at The Affiliated Hospital of Southwest Medical University between January 2022 and January 2025 met the predetermined inclusion criteria and were consecutively included in the analysis. Patients were grouped according to the rehabilitation programme they actually received during routine care. The combined intervention was formally introduced in our department in January 2024, and patients admitted after this date received the combined intervention and were assigned to the observation group (n = 75). Patients treated before January 2024 received routine care and were included in the control group (n = 87). Group allocation was based on the timing of clinical protocol implementation rather than clinician preference, thereby minimizing selection bias. This study strictly adheres to all the requirements of the Declaration of Helsinki. Ethical approval was obtained from the Medical Ethics Committee of The Affiliated Hospital of Southwest Medical University (KY2026040), and all patients provided signed informed consent after understanding the research objectives and study procedures.

*Inclusion and Exclusion Criteria*

Inclusion criteria for patient selection were as follows: (1) patients aged $\geq$18 years; (2) a confirmed diagnosis of TBI based on computed tomography (CT) or magnetic resonance imaging (MRI), followed by either emergency or elective surgical intervention, such as haematoma evacuation or decompressive craniectomy; and (3) availability of complete clinical records, including documentation of at least six-month postoperative follow-up.

However, individuals with a history of severe psychiatric illness or significant cognitive impairment that could interfere with assessment or participation in rehabilitation, the presence of concurrent medical conditions, such as multi-organ failure or advanced malignant tumours, those with incomplete clinical data or who lost to follow-up during the 6-month postoperative observation period, were excluded from the study cohort.

*Rehabilitation Strategies*

All patients received standardised routine postoperative care, including continuous vital signs monitoring, intracranial pressure management, anti-infective therapy, basic rehabilitation guidance, nutritional support, and structured postoperative pain control. Pain was managed through a standardised protocol: patients reporting mild pain (Visual Analogue Scale [VAS] 1–3) received oral acetaminophen, while those with moderate pain (VAS 4–6) were administered tramadol. This treatment was complemented by non-pharmacological measures, including local cold compress and appropriate positioning to enhance comfort adjustment.

The control group received only postoperative routine care. Rehabilitation guidance in this group comprised a single verbal instruction session, primarily focusing on educating family members to assist patients with passive joint mobilisation. Patients in the observation group, in addition to standard care, received a structured two-month rehabilitation programme integrating self-efficacy intervention with phased rehabilitation training. The intervention was delivered by a uniformly trained multidisciplinary team.

Self-efficacy intervention was implemented throughout the rehabilitation period and delivered by a multidisciplinary team consisting of rehabilitation nurses and clinical psychologists who received unified professional training in psychological support for neurological recovery. The intervention included four major strategies applied with standardised frequency and duration. First, goal setting and feedback involved the establishment of short-term, quantifiable rehabilitation targets together with structured progress tracking and chart records upon achievement. Second, role model demonstration was applied to improve motivation through experience sharing and short video materials illustrating successful recovery cases. Third, active persuasion was provided through daily one-on-one motivational communication sessions for at least 20 minutes, performed by trained rehabilitation nurses and clinical psychologists, followed by 10-minute supportive interaction involving family members to build patient confidence and adherence. Fourth, emotional regulation approaches were provided through tailored psychological support sessions arranged twice weekly by clinical psychologists, each session lasting 30 minutes. This session included guided coping approaches and relaxation techniques, such as diaphragmatic breathing and progressive muscle relaxation. These rehabilitation activities were conducted under control and tolerable levels of discomfort to reduce negative emotional experiences, with psychological support as the core of emotional regulation to help patients cope with anxiety or depressive symptoms commonly observed during recovery.

Staged rehabilitation training was implemented in three progressive phases based on the postoperative recovery process. During the acute phase (1–2 weeks after surgery), rehabilitation primarily focused on passive activities, including appropriate limb positioning, scheduled turning over or repositioning, passive full-range joint movement practices, and neuromuscular electrical stimulation. In the stabilisation phase (2–6 weeks after surgery), once the patient showed stable vital signs and improved consciousness, rehabilitation supported active exercises such as bridge exercises in bed, sitting balance training, and center of gravity transfer training. During the recovery phase (6 weeks to 2 months after surgery), patients with sufficient sitting balance progressed to more complex functional training. These activities included sit-to-stand practice (starting from 45° bed elevation and gradually progressing to full upright standing while maintaining a knee angle at 90° during transition, usually 10 repetitions per session, twice daily), assisted walking (initially with a front-wheeled walker for weight-bearing support, progressing to a quad cane and then to a single-point cane as tolerated; gait training conducted in parallel bars for safety with physical therapist guarding), going up and down stairs (step-to-gait pattern with handrail support, starting with 3–5 steps and progressing to full flight), and targeted daily living activities. Daily living exercises included dressing practice, starting with the unaffected limb and assisted feeding using adapted utensils with stabilised support. All functional tasks followed a standardized protocol manual with visual demonstration materials and adjusted intensity levels (low/moderate/high) based on patient tolerance and clinical condition.

For implementation and follow-up, personalized rehabilitation records were established for each patient in the observation group by the specially trained rehabilitation nurses and clinical psychologists responsible for the self-efficacy intervention. Rehabilitation plans were tailored according to patient-specific clinical features, including age, general health status, surgical procedure, baseline motor function assessed using Fugl-Meyer Assessment (FMA) and neurological deficit evaluated using National Institutes of Health Stroke Scale (NIHSS). The multidisciplinary team conducted weekly evaluations to monitor recovery progress and adjust rehabilitation intensity accordingly. At discharge, patients and their caregivers were provided with tailored home rehabilitation plans. A follow-up evaluation was conducted at 1, 3, and 6 months after the operation to support continuity of rehabilitation and maintain treatment effects.

### *Data Sources and Outcome Measures*

All data were obtained through retrospective review of electronic medical records, nursing records, rehabilitation therapy records, and outpatient follow-up files. The primary outcome measure was functional prognosis at 6 months post-surgery, assessed using the Glasgow Outcome Scale (GOS) [12]. A GOS score of 4 (moderate disability with independent living) and 5 (good recovery) was defined as a favourable outcome. Secondary outcome measures encompassed functional recovery, psychological status, and postoperative complications. Functional recovery and psychological status were assessed at two time points: baseline (within 3–7 days after surgery) and post-intervention (approximately two months after surgery). Postoperative complications were monitored continuously throughout the follow-up period, and their cumulative incidence was compared between groups. The assessed parameters are detailed below.

(1) *Degree of neurological deficit*: Evaluated using the National Institutes of Health Stroke Scale (NIHSS), with higher scores indicating more severe neurological impairment [13].

(2) *Motor function*: Assessed using the Fugl-Meyer Assessment (FMA) scale, which includes separate subscales for upper limb function (maximum score 66 points) and lower limb function (maximum score 34 points), yielding a total score out of 100 points [14]. A higher score indicates better motor function.

(3) *Self-efficacy*: Assessed using the Chinese version of the General Self-Efficacy Scale (GSES) [15], which consists of 10 items, with a maximum score of 40 points. Higher scores indicate greater self-efficacy to manage challenges and perform necessary behaviour.

(4) *Anxiety and depression status*: Psychological status was assessed using the Self-Rating Anxiety Scale (SAS) [16] and the Self-Rating Depression Scale (SDS) [17]. Each scale comprises 20 items scored on a 4-point scale. Raw scores are summed and then multiplied by 1.25 to obtain a standardised score, which is rounded to the nearest whole number. According to the Chinese population reference

**Table 1. Comparison of baseline characteristics between the two groups.**

| Variable | Total (n = 162) | Control group (n = 87) | Observation group (n = 75) | Statistic | $p$-value |
|---|---|---|---|---|---|
| Age (years, mean ± SD) | 52.98 ± 6.41 | 53.26 ± 6.67 | 52.64 ± 6.13 | $t$ = 0.62 | 0.538 |
| Gender, n (%) | | | | $\chi^2$ = 0.14 | 0.706 |
| Female | 58 (35.80) | 30 (34.48) | 28 (37.33) | | |
| Male | 104 (64.20) | 57 (65.52) | 47 (62.67) | | |
| BMI (kg/m$^2$, mean ± SD) | 23.57 ± 1.25 | 23.65 ± 1.27 | 23.47 ± 1.23 | $t$ = 0.91 | 0.363 |
| Smoking, n (%) | | | | $\chi^2$ = 1.77 | 0.183 |
| No | 89 (54.94) | 52 (59.77) | 37 (49.33) | | |
| Yes | 73 (45.06) | 35 (40.23) | 38 (50.67) | | |
| Drinking, n (%) | | | | $\chi^2$ = 0.01 | 0.918 |
| No | 103 (63.58) | 55 (63.22) | 48 (64.00) | | |
| Yes | 59 (36.42) | 32 (36.78) | 27 (36.00) | | |
| Hypertension, n (%) | | | | $\chi^2$ = 0.14 | 0.706 |
| No | 99 (61.11) | 52 (59.77) | 47 (62.67) | | |
| Yes | 63 (38.89) | 35 (40.23) | 28 (37.33) | | |
| Diabetes, n (%) | | | | $\chi^2$ = 0.04 | 0.833 |
| No | 135 (83.33) | 72 (82.76) | 63 (84.00) | | |
| Yes | 27 (16.67) | 15 (17.24) | 12 (16.00) | | |
| Cause of injury, n (%) | | | | $\chi^2$ = 1.02 | 0.602 |
| Traffic accident | 86 (53.09) | 44 (50.57) | 42 (56.00) | | |
| Fall from a height | 54 (33.33) | 32 (36.78) | 22 (29.33) | | |
| Others | 22 (13.58) | 11 (12.64) | 11 (14.67) | | |
| Surgical procedure, n (%) | | | | $\chi^2$ = 0.81 | 0.667 |
| Hematoma evacuation | 92 (56.79) | 51 (58.62) | 41 (54.67) | | |
| Decompressive craniectomy | 58 (35.80) | 31 (35.63) | 27 (36.00) | | |
| Combined surgery | 12 (7.41) | 5 (5.75) | 7 (9.33) | | |
| Time to admission (h, mean ± SD) | 4.59 ± 0.82 | 4.52 ± 0.88 | 4.67 ± 0.74 | $t$ = –1.24 | 0.218 |
| Preoperative GCS (mean ± SD) | 10.01 ± 2.17 | 9.86 ± 2.24 | 10.17 ± 2.08 | $t$ = –0.91 | 0.363 |

SD, standard deviation; BMI, body mass index; GCS, Glasgow Coma Scale.

value, a standardised SAS score of ≥50 indicates the presence of anxiety symptoms, while an SDS standardised score of ≥53 indicates depressive symptoms.

(5) *Activities of daily living*: Functional independence in daily living activities was assessed using the Barthel Index (BI) [18], which ranges from 0 to 100 points, with higher scores indicating greater independence in performing activities.

(6) *Quality of Life*: Health-related quality of life was evaluated via the 36-Item Short Form Health Survey (SF-36) [19]. Four representative dimensions were included in this analysis: Physical Functioning (PF), Physical Role (PR), Bodily Pain (BP), and General Health (GH). Scores for each dimension were converted to a 0–100 from 0 to 100 scale, with higher scores indicating better quality of life.

(7) *Postoperative complications*: Complications occurring between hospital admission and completion of the intervention were recorded. These included pressure injuries, pulmonary infections, surgical site infections, and acute kidney injury (AKI). AKI was diagnosed in accordance with the Kidney Disease: Improving Global Outcomes (KDIGO) 2012 clinical practice guidelines [20], based on either an elevation in serum creatinine levels (≥0.3 mg/dL increase within 48 h or ≥1.5-fold increase within 7 days), or a reduction in urine output (<0.5 mL/kg/h for ≥6 h).

*Statistical Analysis*

Statistical analyses were performed using SPSS Statistics (Version 27.0, IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Shapiro-Wilk test and further examined using Quantile-Quantile (Q-Q) plots. Variables with a Shapiro-Wilk test $p$-value $> 0.05$ were considered to follow a normal distribution. Normally distributed continuous variables were presented as mean ± standard deviation (SD), with between-group comparison performed using independent $t$-tests and within-group comparison using paired $t$-tests. Non-normally distributed variables (Shapiro-Wilk $p < 0.05$) were analysed using the Mann-Whitney U test (between-group) or the Wilcoxon signed-rank test (within-group), and the results were presented as median with interquartile range (IQR). Categorical variables were presented as n (%), and comparisons between groups were conducted using the $\chi^2$ or Fisher's exact test.

To explore independent factors associated with a favourable prognosis, defined as GOS scores of 4 or 5, binary logis-

**Table 2. Comparison of neurological deficit (National Institutes of Health Stroke Scale [NIHSS]) scores before and after intervention.**

| Group | n | Pre-intervention (mean ± SD) | Post-intervention (mean ± SD) | Change (Δ, mean ± SD) | $p$-value (within group)[a] |
|---|---|---|---|---|---|
| Control | 87 | 29.36 ± 6.46 | 20.14 ± 4.95 | –9.22 ± 8.46 | <0.001 |
| Observation | 75 | 28.77 ± 6.54 | 17.57 ± 4.19 | –11.20 ± 7.97 | <0.001 |
| $p$-value (between groups)[b] | | 0.570 | <0.001 | | |

[a] Paired $t$-test; [b] Independent $t$-test.

**Table 3. Comparison of motor function (Fugl-Meyer Assessment [FMA]) scores before and after intervention.**

| Domain | Group | Pre-intervention (mean ± SD) | Post-intervention (mean ± SD) | Change (Δ, mean ± SD) | $p$-value (within group)[a] |
|---|---|---|---|---|---|
| Upper limbs | Control | 28.82 ± 2.35 | 44.57 ± 3.55 | 15.76 ± 3.77 | <0.001 |
| | Observation | 29.25 ± 2.56 | 49.84 ± 3.26 | 20.59 ± 4.16 | <0.001 |
| | $p$-value (between groups)[b] | 0.259 | <0.001 | | |
| Lower limbs | Control | 17.11 ± 2.34 | 22.68 ± 2.49 | 5.56 ± 3.35 | <0.001 |
| | Observation | 16.69 ± 2.26 | 25.84 ± 2.74 | 9.15 ± 3.36 | <0.001 |
| | $p$-value (between groups)[b] | 0.248 | <0.001 | | |

[a] Paired $t$-test; [b] Independent $t$-test.

tic regression analysis was conducted. A favourable outcome (GOS 4–5) was considered as the dependent variable (coded as 1 for a favourable outcome and 0 otherwise). The primary independent variable was the type of rehabilitation intervention (Observation = 1, Control = 0).

The analysis was adjusted for three predefined potential confounders selected based on clinical relevance: age (continuous variable), preoperative Glasgow Coma Scale (GCS, continuous variable), and the occurrence of major postoperative complications (Yes = 1, No = 0). Major complications were dichotomised as clinically significant adverse events that could substantially affect neurological recovery, such as pressure injuries, pulmonary infections, and other postoperative conditions. For model development, these complications were combined into a single binary variable to reflect the overall impact of clinically critical complications on recovery outcomes. This strategy is consistent with commonly used statistical modeling practices in TBI outcome research and enables adjustment for variation in baseline disease severity and perioperative clinical status that may independently affect both complication risk and mid-term prognosis. The relatively low complication rate in the study cohort ensures minimal risk of model overadjustment. Results from the regression analysis were expressed as adjusted odds ratios (aORs) with 95% confidence intervals (95% CIs). Model calibration was assessed using the Hosmer-Lemeshow test. A two-sided $p$-value of $<0.05$ was considered significant.

## Results

### *Baseline Characteristics and Patient Comparability*

Baseline characteristics of the two groups are summarised in Table 1. No statistically significant differences were observed between the observation and control groups regarding age (52.64 ± 6.13 vs. 53.26 ± 6.67 years, $p$ = 0.538), gender distribution, body mass index (BMI), smoking and drinking history, prevalence of hypertension or diabetes mellitus, cause of injury, type of surgical procedure, time interval from injury to hospital admission, or preoperative GCS score ($p > 0.05$). These results indicate that the two groups were well-balanced and comparable at baseline.

### *Neurological Functional Recovery*

The severity of neurological deficit was assessed using the NIHSS before and after completion of the intervention period. As shown in Table 2, a significant reduction in post-intervention NIHSS scores was observed in both the control and observation groups ($p < 0.001$) compared with baseline values. Crucially, the post-intervention NIHSS score was significantly lower in the observation group (17.57 ± 4.19) compared to the control group (20.14 ± 4.95), indicating that patients receiving the combined intervention experienced superior neurological recovery ($p < 0.001$). However, baseline NIHSS scores did not differ between the groups ($p$ = 0.570), indicating the comparability of neurological severity before intervention.

### *Motor Function Outcomes*

Motor recovery was evaluated using the FMA for both upper and lower limbs. The results are summarised in Table 3. Following the intervention, patients in the observation group exhibited significantly better motor function than those in the control group. This was evidenced by higher post-intervention FMA scores for both upper limbs (49.84 ± 3.26 vs. 44.57 ± 3.55, $p < 0.001$) and lower limbs (25.84 ± 2.74 vs. 22.68 ± 2.49, $p < 0.001$). Baseline FMA scores for both upper and lower domains were comparable between groups ($p > 0.05$).

**Table 4. Comparison of psychological status and self-efficacy scores.**

| Scale | Group | Pre-intervention (mean ± SD) | Post-intervention (mean ± SD) | Change (Δ, mean ± SD) | $p$-value (within group)[a] |
|---|---|---|---|---|---|
| Self-Efficacy | Control | 20.57 ± 3.63 | 26.57 ± 3.19 | 6.00 ± 4.74 | <0.001 |
| | Observation | 19.97 ± 3.37 | 31.16 ± 2.83 | 11.19 ± 4.73 | <0.001 |
| | $p$-value (between groups)[b] | 0.279 | <0.001 | | |
| Anxiety | Control | 49.57 ± 6.86 | 46.34 ± 6.94 | –3.23 ± 10.15 | 0.004 |
| | Observation | 50.49 ± 6.61 | 43.61 ± 7.17 | –6.88 ± 10.34 | <0.001 |
| | $p$-value (between groups)[b] | 0.389 | 0.015 | | |
| Depression | Control | 47.46 ± 5.69 | 44.25 ± 4.74 | –3.21 ± 6.92 | <0.001 |
| | Observation | 48.17 ± 5.84 | 42.17 ± 4.20 | –6.00 ± 6.22 | <0.001 |
| | $p$-value (between groups)[b] | 0.433 | 0.004 | | |

[a]Paired $t$-test; [b]Independent $t$-test.

**Table 5. Comparison of daily living ability and quality of life scores between the two groups.**

| Scale (Dimension) | Group | Pre-intervention (mean ± SD) | Post-intervention (mean ± SD) | Change (Δ, mean ± SD) | $p$-value (within group)[a] |
|---|---|---|---|---|---|
| Barthel Index | Control | 24.26 ± 4.36 | 39.94 ± 4.37 | 15.68 ± 5.48 | <0.001 |
| | Observation | 23.65 ± 4.25 | 44.59 ± 4.81 | 20.93 ± 6.56 | <0.001 |
| | $p$-value (between groups)[b] | 0.369 | <0.001 | | |
| SF-36: PF | Control | 59.41 ± 5.53 | 74.64 ± 4.56 | 15.23 ± 7.74 | <0.001 |
| | Observation | 58.69 ± 5.90 | 78.52 ± 4.28 | 19.83 ± 7.89 | <0.001 |
| | $p$-value (between groups)[b] | 0.424 | <0.001 | | |
| SF-36: PR | Control | 53.14 ± 4.33 | 67.39 ± 4.71 | 14.25 ± 6.55 | <0.001 |
| | Observation | 53.55 ± 4.16 | 72.52 ± 4.83 | 18.97 ± 5.95 | <0.001 |
| | $p$-value (between groups)[b] | 0.543 | <0.001 | | |
| SF-36: BP | Control | 56.18 ± 5.47 | 77.69 ± 4.89 | 21.51 ± 7.43 | <0.001 |
| | Observation | 55.37 ± 5.63 | 81.92 ± 4.26 | 26.55 ± 6.97 | <0.001 |
| | $p$-value (between groups)[b] | 0.355 | <0.001 | | |
| SF-36: GH | Control | 62.91 ± 5.26 | 78.25 ± 5.12 | 15.34 ± 7.62 | <0.001 |
| | Observation | 62.53 ± 5.06 | 83.16 ± 4.52 | 20.63 ± 6.81 | <0.001 |
| | $p$-value (between groups)[b] | 0.646 | <0.001 | | |

[a]Paired $t$-test; [b]Independent $t$-test.

SF-36, 36-Item Short Form Health Survey; PF, Physical Functioning; PR, Physical Role; BP, Bodily Pain; GH, General Health.

*Psychological Status and Self-Efficacy*

Changes in psychological metrics are summarised in Table 4. Post-intervention, the observation group demonstrated a significantly higher level of general self-efficacy (GSES score: 31.16 ± 2.83) than the control group (26.57 ± 3.19, $p < 0.001$), despite comparable baseline scores ($p = 0.279$), accompanied by significant anxiety and depressive symptom improvement. Regarding emotional state, both groups showed significant reductions in anxiety and depression scale scores (SAS/SDS) after the intervention (within-group comparison, $p \leq 0.004$). However, the observation group achieved significantly lower post-intervention SAS and SDS scores ($p = 0.015$ and $p = 0.004$, respectively), indicating a pronounced reduction in anxiety and depressive symptoms among patients receiving the combined rehabilitation approach.

*Daily Living Ability and Quality of Life*

The impact of intervention on functional independence and health-related quality of life is presented in Table 5. After the intervention period, patients in the observation group showed significantly higher Barthel Index (BI) scores compared to those in the control group (44.59 ± 4.81 vs. 39.94 ± 4.37, $p < 0.001$), indicating greater independence in performing activities of daily living. Similarly, across all four selected dimensions of the SF-36 questionnaire—PF, PR, BP, and GH—post-intervention scores were significantly higher in the observation group ($p < 0.001$). These findings reflect that the combined intervention was linked with significant improvement in both daily functional activities and overall health-related quality of life.

**Table 6. Comparison of postoperative complication rates between the two groups.**

| Group | n | Pressure ulcer | Pulmonary infection | Incision infection | AKI | Total |
|---|---|---|---|---|---|---|
| Control | 87 | 7 (8.05) | 4 (4.60) | 3 (3.45) | 2 (2.30) | 16 (18.39) |
| Observation | 75 | 2 (2.67) | 2 (2.67) | 1 (1.33) | 0 (0.00) | 5 (6.67) |
| $\chi^2$ value | | | | | | 4.91 |
| *p*-value | | | | | | 0.027 |

AKI, acute kidney injury.

**Table 7. Distribution of GOS scores at 6-month follow-up across the study participants.**

| GOS score & category | Observation group (n = 75) | Control group (n = 87) | *p*-value |
|---|---|---|---|
| 1 - Death | 0 (0.00) | 1 (1.15) | |
| 2 - Persistent vegetative state | 1 (1.33) | 3 (3.45) | |
| 3 - Severe disability | 18 (24.00) | 34 (39.08) | |
| 4 - Moderate disability | 35 (46.67) | 32 (36.78) | |
| 5 - Good recovery | 21 (28.00) | 17 (19.54) | |
| Favourable outcome[a], n (%) | 56 (74.67) | 49 (56.32) | 0.015 |

[a] A favourable outcome is defined as GOS 4 and 5. GOS, Glasgow Outcome Scale.

**Table 8. Multivariable logistic regression analysis of factors associated with favourable outcomes (GOS 4–5).**

| Variable (Reference) | B | S.E. | Wald $\chi^2$ | *p*-value | Adjusted OR | 95% CI for OR |
|---|---|---|---|---|---|---|
| Intervention group (Observation vs. Control) | 0.74 | 0.35 | 4.44 | 0.035 | 2.09 | 1.05~4.16 |
| Age (per year increase) | –0.03 | 0.03 | 0.92 | 0.338 | 0.98 | 0.93~1.03 |
| Preoperative GCS (per point increase) | 0.11 | 0.08 | 1.82 | 0.177 | 1.11 | 0.95~1.30 |
| Major postoperative complications (Yes vs. No) | –0.46 | 0.49 | 0.90 | 0.343 | 0.63 | 0.24~1.64 |
| Constant | 0.62 | 1.68 | 0.14 | 0.710 | - | - |

GCS, Glasgow Coma Scale; OR, odds ratio; CI, confidence interval; S.E, standard error.

### *The Incidence of Postoperative Complications*

The safety profile of the rehabilitation strategies was assessed by comparing the occurrence of major postoperative complications during the study period, as presented in Table 6. The overall incidence of complications was significantly lower in the observation group (5/75, 6.67%) than in the control group (16/87, 18.39%) ($p = 0.027$). These observations indicate that the combined intervention effectively reduced the risk of clinically critical postoperative complications.

### *Mid-term Functional Prognosis Across the Study Participants*

Mid-term neurological recovery was assessed at the 6-month follow-up using GOS. As detailed in Table 7, a favourable outcome, defined as a GOS score of 4 or 5, was observed in a significantly greater proportion of patients in the observation group (56/75, 74.67%) compared to the control group (49/87, 56.32%) ($p = 0.015$).

### *Multivariable Analysis of Factors Associated With Favourable Outcome*

To assess whether the observed effect of the intervention remains significant after accounting for other potential prognostic factors, a multivariable logistic regression analysis was performed (Table 8). A favourable functional outcome at 6 months (GOS 4–5) was applied as the dependent variable. After adjusting for age, preoperative GCS score, and the occurrence of major postoperative complications, assignment to the observation group (combined intervention) remained as an independent predictor of favourable prognosis (aOR = 2.09, 95% CI: 1.05–4.16, $p = 0.035$). The other covariates included in the model did not show a statistically significant independent association with the mid-term outcome in this analysis. Model calibration was satisfactory, as the Hosmer-Lemeshow goodness-of-fit test ($p = 0.240$).

## Discussion

Traumatic brain injury represents a significant global health concern, with postoperative functional recovery relying on systematic, personalised, and scientifically-grounded rehabilitation strategies [21]. While surgical intervention is for survival in moderate to severe TBI, conventional postoperative care often falls short in systematically activating patient initiative and aligning with their dynamic recovery trajectory [22]. This retrospective cohort study demonstrated that an integrated protocol combining self-efficacy intervention with staged rehabilitation training demonstrated significantly superior outcomes compared to conventional care across multiple domains. Improvements were found in neurological deficit (assessed by the National Institutes of Health Stroke Scale [NIHSS]), motor function (Fugl-Meyer Assessment [FMA]), self-efficacy (General Self-Efficacy Scale [GSES]), anxiety and depression (Self-Rating Anxiety Scale [SAS]/Self-Rating Depression Scale [SDS]), functional independence (Barthel Index [BI]), and health-related quality of life (36-Item Short Form Health Survey [SF-36]) Furthermore, patients in the observation group also achieved a favourable mid-term functional prognosis at 6 months, as evidenced by higher GOS scores. Multivariable logistic regression analysis further confirmed that receiving the combined intervention remained an independent predictor of a favourable mid-term outcome, even after adjusting for age, preoperative injury severity, and major postoperative complications. These findings collectively underscore the significant and independent benefits of this integrated approach for both short-term functional recovery and mid-term prognosis in patients after TBI surgery. However, we acknowledge that this association does not establish causality: residual confounding from unmeasured factors (e.g., baseline motivation, family support) and the temporal relationship between complications and prognosis (where complications may both influence and result from functional status) limit definitive causal inference. Notably, the relatively high baseline SF-36 scores observed in this cohort appear inconsistent with the high NIHSS and low BI scores, highlighting a discrepancy between subjective and objective assessments. This inconsistency may be attributed to several factors. First, the SF-36 primarily reflects patients' perceived health status rather than their actual physical functioning, and thus may not directly capture the severity of neurological deficits or the extent of functional dependence. Second, not all SF-36 dimensions equally reflect functional status. Although dimensions such as GH and BP are inherently more subjective, PF and PR would be expected to correlate more closely with objective functional impairment. Nevertheless, even PF and PR scores were relatively high in this study, suggesting potential measurement bias. Third, proxy reporting by family members for patients with impaired consciousness may lead to overestimation of health status. Fourth, the early postoperative timing of assessment may introduce optimism bias, leading patients or caregivers to perceive recovery more favorably than objective measures would indicate. Finally, the SF-36 may have limited sensitivity in detecting severe functional impairment during the acute or early recovery phase of traumatic brain injury. Therefore, interpretations of SF-36 results in this context should be approached with caution.

One of the core findings of this study is the significant improvement in neurological and motor function associated with the combined intervention approach. These outcomes can be explained by the synergistic effects of neuroplasticity and behavioural psychology. In previous studies, Lu *et al*. [23] found that TBI patients who received early intensive training had better recovery effects on cognitive and motor abilities. Williams *et al*. [24] also reported that systematic rehabilitation training is beneficial to the postoperative recovery of patients with TBI. These research results are similar to those of this study, all demonstrating the significance of scientific and systematic rehabilitation training after surgery [25]. Staged rehabilitation training, by design, provides repetitive, task-oriented practice that is precisely calibrated in intensity and complexity to match the natural pathophysiological stages of the central nervous system (CNS) [26]. During the acute phase, passive mobilisation and appropriate positioning of the limb help maintain joint mobility and soft tissue flexibility, thereby preserving the necessary anatomical and physiological conditions required for subsequent active rehabilitation [27]. In the stable and recovery phases, gradual introduction of active-assisted exercises, balance training, and functional tasks delivers targeted sensorimotor input to impaired neural networks. The efficacy of such task-oriented, repetitive training is well-supported by principles of experience-dependent neuroplasticity [28,29].

Concurrently, the integrated self-efficacy intervention may enhance patients' confidence and intrinsic motivation to engage in these challenging tasks through goal setting, mastery experiences, vicarious learning, and supportive verbal persuasion [30]. Enhanced self-efficacy is a well-established determinant of greater rehabilitation adherence, effort persistence, and more adaptive coping strategies when facing difficulties. Therefore, the combination of the "I can do it" belief (psychological) and the "structured stimulation" (physiological) likely creates a synergistic effect greater than the sum of its parts, jointly driving superior neural remodeling and motor learning efficiency. We caution that the observed association between lower complication rates and favourable outcomes in the observation group may reflect confounding by indication—patients with better functional recovery may have been both less prone to complications and more capable of engaging in rehabilitation, rather than a direct causal effect of the intervention on complication prevention. High self-efficacy further promotes consistent rehabilitation participation, correct motor movement execution and active pain coping behaviors, which are key behavioral mediators linking psychological cognition to physical recovery. This synergy provides a plausible mechanism for the more substantial improvements in NIHSS and FMA scores observed in the observation group.

Furthermore, the integrated intervention demonstrated meaningful advantages in psychosocial adaptation and mid-term prognosis. Post-TBI anxiety, depression, and uncertainty about future capabilities are significant barriers to recovery [31]. Our results indicate that the observation group not only achieved greater improvements in self-efficacy but also experienced a significant reduction in anxiety and depressive symptom scores. This suggests that self-efficacy intervention may enhance emotional regulation and cognitive appraisal, contributing to reduced severity of anxiety- and depression-related symptoms [32]. Importantly, these findings reflect symptom-level improvement measured by psychometric scales rather than treatment of clinical anxiety or depressive disorders. The intervention was designed to support rehabilitation adherence rather than replace specialised psychiatric treatment. The multivariable analysis reinforced the independence of this association. We hypothesise that the mechanism may involve both behavioral and functional pathways. Enhanced self-efficacy and improved anxiety and depressive symptoms via score reduction, the integrated intervention enhances patients' willingness and behavioral persistence in mid-term home- or community-based rehabilitation after discharge [33]. In parallel, staged training may improve functional independence and adaptability, enabling individuals to better manage daily activities and integrate into social environments. Together, these aspects may reduce the risk of secondary complications associated with mid-term immobility and functional dependence, ultimately improving mid-term quality of life and capacity for independent living. Similar associations between baseline functional status and postoperative outcomes have been reported in other neurological conditions. For instance, a study on cervical spondylotic myelopathy (CSM) has identified age, symptom duration, preoperative Japanese Orthopaedic Association (JOA) scores, spinal cord compression ratio, regulatory T-cell counts, number of surgical levels, and diabetes history as independent predictors of postoperative prognosis [34]. Notably, the preoperative JOA score—a functional scale analogous to the GOS in assessing neurological impairment—emerged as a significant predictor of recovery, reinforcing the broader principle that baseline functional status consistently informs prognosis across different central nervous system disorders. These parallels underscore the reliability of using standardised functional assessments, such as the GOS in our TBI cohort, to predict recovery trajectories and evaluate intervention efficacy. Furthermore, these shared prognostic determinants highlight the importance of accounting for baseline characteristics when interpreting treatment effects, as conducted through multivariable adjustment in our analysis.

From a clinical translation and practical perspective, our findings carry significant implications. They validate the feasibility and effectiveness of a novel rehabilitation paradigm that deeply integrates psychosocial intervention with physical functional training, tailored to different recovery phases. This multimodal intervention aligns with the shared goal of functional recovery optimisation across neuro-trauma disciplines; recent spinal trauma studies have shown targeted interventions reduce surgical stress and improve VAS, Oswestry Disability Index (ODI) functional outcomes, and our combined protocol mirrors the global Enhanced Recovery After Surgery (ERAS) trend in neurosurgery that advocates synergistic integration of psychological support, pain management and early rehabilitation [35]. Recent bibliometric analyses on neurosurgical ERAS have confirmed this systematic perioperative care as the cutting-edge clinical development direction [36], further supporting the clinical value of our intervention strategy. This suggests a shift for clinicians from a traditional, therapist-centered training model to a patient-centered "empowerment" model. Specifically, the rehabilitation team (including physicians, therapists, nurses, and psychologists) should initiate a systematic assessment of the patient's emotional well-being before the intervention, incorporating this as a core element in developing personalised rehabilitation plans. These plans should be explicitly phased, with each phase containing quantifiable functional goals paired with psychological support strategies (e.g., celebrating small victories, peer support groups). The structured intervention framework provided in this study (detailing training foci and self-efficacy enhancement strategies for the acute, stable, and recovery phases) can serve as a valuable template for clinical practice, aiding in the standardisation of postoperative TBI rehabilitation.

This study has several limitations that should be acknowledged. First, as a retrospective cohort study, it is susceptible to selection bias. The study grouped patients by the timing of implementation of the combined intervention in our department, and despite comparable baseline characteristics, temporal differences in clinical management may introduce potential selection bias, and patients in the observation group may have had higher healthcare adherence, which could confound outcomes. While surgical procedures were balanced between groups, we acknowledge that specific procedural details (e.g., laterality, extent of decompression, intraoperative complications) were not analysed as potential effect modifiers; future studies should stratify analyses by surgical complexity. Second, the single-center design with a relatively modest sample size limits the generalizability of the findings. Third, the 6-month follow-up period is insufficient to evaluate the mid-term effects of the intervention on outcomes such as social reintegration and cognitive function, and future prospective studies are strongly recommended to extend the follow-up period to 1–2 years to investigate the sustained mid-term efficacy of the combined intervention on TBI chronic recovery. Finally, subgroup analyses based on age, injury severity, and injury type were not performed, which could provide valuable insights into the intervention's efficacy across different patient populations. Future research should address these limitations through large-scale, multicenter randomised controlled trials to validate the intervention's effectiveness. Extending the follow-up period will help assess mid-term outcomes, while subgroup analyses can inform the development of personalised rehabilitation strategies. Notably, the manual verbal persuasion in the current intervention is labor-intensive; emerging digital and artificial intelligence technologies show great potential for delivering standardised, scalable self-efficacy support, which can overcome human resource limitations and facilitate the clinical popularisation of the combined intervention [37].

## Conclusions

This retrospective cohort study demonstrates that an integrated rehabilitation protocol combining self-efficacy enhancement with staged rehabilitation training significantly improves both short- and mid-term functional outcomes in patients following TBI surgery. Compared with conventional postoperative care, the combined intervention was associated with greater improvement in neurological and motor function, greater gains in self-efficacy and psychological well-being, enhanced independence in daily living, and a higher likelihood of achieving a favourable mid-term prognosis. The intervention was also associated with a lower incidence of major postoperative complications. These findings suggest that this patient-centered, multidimensional approach should be considered as a valuable and effective strategy to optimise functional recovery and quality of life in the postoperative management of traumatic brain injury.

## Availability of Data and Materials

All data included in this study can be obtained by contacting the corresponding author if needed.

## Author Contributions

RL conceived and designed the research, performed the study, collected and analyzed the data and drafted the manuscript. XWL contributed to the study design and data analysis. Both authors contributed to the critical revision of the manuscript for important intellectual content. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

## Ethics Approval and Consent to Participate

This study strictly adheres to all the requirements of the Declaration of Helsinki. This study was approved by the Medical Ethics Committee of The Affiliated Hospital of Southwest Medical University (KY2026040). All patients provided signed informed consent after understanding the research objectives.

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## Conflict of Interest

The authors declare no conflict of interest.

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