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Improving Postoperative Outcomes After Intracerebral Hematoma Evacuation: Effect of a Modified Critical Care Nursing Protocol

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ABSTRACT

Background: The nursing care protocol is evidence-based and systematically applied to patients undergoing intracerebral hemorrhage (ICH) evacuation surgery to improve postoperative outcomes. **Objectives:** To evaluate the effect of implementing a modified critical care nursing protocol on postoperative outcomes among patients undergoing ICH evacuation. **Methods:** A quasi-experimental study was conducted on a purposive sample of 60 patients undergoing ICH evacuation surgery in the Neurosurgical Intensive Care Unit (ICU), Neurological Hospital, Assiut University Hospitals, Egypt. Patients were alternately allocated according to a predetermined admission order into two equal groups: a control group (n = 30) and a study group (n = 30). Data were collected using a Clinical Data Sheet, Neurological Deficit Assessment Scale, Muscle Power Assessment Scale, Level of Independence in Daily Living Activities Scale, and Patient Outcomes Tool through medical record review, clinical assessment, and direct observation. **Results:** Compared to controls, the study group demonstrated significantly greater improvements in the overall trajectories of neurological status, muscle power, and functional independence over time ($p < 0.05$). The incidence of postoperative pulmonary infection and pressure ulcers, as well as ICU length of stay, was significantly lower in the study group ($p < 0.05$), whereas no statistically significant differences were observed in deep vein thrombosis or mortality between the groups ($p > 0.05$). **Conclusion:** Implementation of the Modified critical care nursing protocol was associated with greater improvements in neurological status, muscle power, and functional independence over time, and with fewer postoperative complications and a shorter ICU stay. Future large-scale, multi-centre studies are recommended to validate these findings.

Keywords: Critical Care Nursing Protocol; Intensive Care Units; Intracranial Hematoma; Nursing Protocols; Postoperative Care; Treatment Outcome

INTRODUCTION

Intracerebral hemorrhage (ICH) is an acute cerebrovascular disorder caused by rupture of cerebral blood vessels, resulting in blood accumulation within the brain parenchyma. ICH remains a major public health concern due to its high incidence, disability, and mortality. Most cases are spontaneous and associated with hypertension, whereas secondary ICH may result from trauma, vascular abnormalities, tumors, or coagulation disorders (Wang *et al*., 2026). Although surgical evacuation is a lifesaving procedure, it may be associated with postoperative complications that impair recovery (de Oliveira *et al*., 2026). Conventional postoperative care may not adequately address the complex needs of ICH patients, emphasizing the need for structured evidence-based nursing care (Xiao & Wang, 2024).

Early rehabilitation is a key strategy for improving outcomes in intensive care units, with nurses playing a central role in delivering individualized, patient-centered care according to patients' clinical condition (Nie *et al*., 2026). Evidence indicates that interventions such as neuromuscular electrical stimulation (NMES) and early progressive mobilization enhance recovery following intracerebral hematoma evacuation (Doi *et al*., 2024; Liang *et al*., 2025; Yang *et al*., 2023). However, standardized nursing protocols integrating these evidence-based

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interventions into routine neurosurgical intensive care practice remain limited, and gaps in nurses' knowledge and competence persist in the absence of formal protocols (Ali *et al*., 2025; Kamel *et al*., 2026).

Significance of the Study

Postoperative care practices vary across neurosurgical centers, particularly regarding patient mobilization. Although prolonged bed rest is commonly used to reduce hematoma recurrence risk, it may increase pressure ulcers, deep vein thrombosis (DVT), and pneumonia, delaying recovery and increasing healthcare costs (Ong *et al*., 2026). Despite growing evidence supporting early rehabilitation after intracerebral hemorrhage, protocolized critical care nursing after hematoma evacuation remains limited, and standardized rehabilitation protocols in neurosurgical intensive care units are lacking (Feng *et al*., 2025).

Unlike isolated neurocritical care or rehabilitation programmes, the present protocol integrates both into a standardized, nurse-led intervention tailored to patients following surgical hematoma evacuation during their critical ICU stay. Its novelty lies in providing a structured continuum from neurocritical stabilization and complication prevention to progressive respiratory, motor, mobility, and functional rehabilitation according to clinical stability. The present study aimed to evaluate the effect of protocolized critical care nursing incorporating early rehabilitation on postoperative outcomes.

Research Objectives

The primary objective is to evaluate the effect of implementing a modified critical care nursing protocol on neurological deficits in patients undergoing intracerebral hematoma evacuation. The primary assessment time point is ICU discharge.

Secondary objectives are to evaluate the effect of implementing the protocol on improving muscle power and independence in activities of daily living (ADLs), and to evaluate its effect on postoperative outcomes, including pulmonary infections, pressure ulcers, DVT, ICU length of stay, and mortality.

Research Hypotheses

H_1: Patients in the study group will demonstrate a significantly lower level of neurological deficits compared to those in the control group**.**

H_2: Patients in the study group will show significantly greater improvement in muscle strength and ADLs compared to those in the control group.

H_3: Patients in the study group will have significantly lower rates of postoperative complications and shorter ICU stays compared to those in the control group.

METHODOLOGY

Study Design and Sample

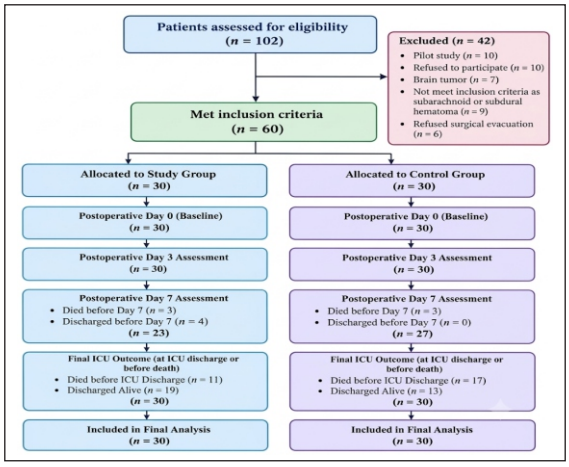


Figure 1: Flow Diagram Showing Participant Allocation, Follow-up, Outcome

A quasi-experimental design was used. The study was conducted at the Neurosurgical Critical Care Unit of the Neurological Hospital at Assiut University Hospitals, Egypt. Data were collected over 12 months from July 2024 to July 2025. A purposive sampling technique was used according to predefined inclusion and exclusion criteria. Sample size was calculated using G*Power (version 3.1.9.7) based on the expected National Institutes of Health Stroke Scale (NIHSS). difference reported by Wang and Ding (2022). With a two-sided significance level of 0.05, 80% study power, and Cohen's *d* of 0.80, the calculated required sample size was 52 patients (26 per group). To provide a margin beyond the calculated minimum, the sample size was increased to 60 patients, with 30 allocated to each group. This calculation was based on a single-time-point between-group comparison and was not specifically designed to detect group-by-time effects or differences in secondary outcomes.

Eligible patients were enrolled consecutively by the principal investigator (Figure 1). Inclusion criteria comprised adults (≥18 years) of both sexes with computed tomography (CT)-confirmed spontaneous intracerebral hematoma who underwent surgical evacuation and were admitted postoperatively to the neurosurgical ICU. Exclusion criteria included traumatic intracerebral hemorrhage, brain tumors, refusal of surgical evacuation, or refusal by the patient or their legally authorized surrogates to provide informed consent to participate in the study. Hematoma location and preoperative Glasgow Coma Scale (GCS) were recorded as baseline variables. Rehabilitation was initiated after hemodynamic stability was confirmed by the treating ICU team.

Participants were assigned in a 1:1 ratio using a predetermined alternate sequence according to admission order, with the first eligible patient assigned to the control group and the second to the study group. The principal investigator screened eligible patients and performed allocation according to this sequence with no discretionary reassignment. The principal investigator received guidance from the study supervisors on administering and scoring the NIHSS, Medical Research Council (MRC) Muscle Power Scale, and Modified Barthel Index, followed the standardized instructions for each instrument, and performed all outcome assessments. Because the investigator was involved in both allocation and outcome assessment, blinding was not feasible. The statistician was blinded to group allocation during analysis. The potential for assessment bias was acknowledged as a study limitation.

Research Tools

Five tools were used to collect data-

Tool I

Clinical Data Sheet: Developed by the researcher based on relevant literature (Zheng *et al*., 2021). It included patients' demographic and clinical characteristics, including age, sex, hematoma location and size, and comorbidities.

Tool II

Neurological Deficit Assessment Scale: The National Institutes of Health Stroke Scale (NIHSS), adopted from Mohamed *et al*. (2015), was used to assess neurological deficits. The NIHSS comprises 11 domains with a total score ranging from 0 to 42, where higher scores indicate greater neurological impairment.

Tool III

Muscle Power Assessment Scale: The Medical Research Council (MRC) Muscle Power Scale, adopted from Mohamed *et al*. (2019), was used to assess muscle power. The total score ranges from 0 to 60, with higher scores indicating better muscle power.

Tool IV

Level of Independence in Activities of Daily Living Scale: The Modified Barthel Index (MBI), adopted from Kamdi *et al*. (2023), was used to assess independence in activities of daily living. Total scores range from 0 to 100, with higher scores indicating greater functional independence.

Tool V

Patient Outcomes Tool

A clinical outcomes sheet developed by the researcher based on relevant literature (Shalaby *et al*., 2021) to

assess postoperative complications (pulmonary infection, pressure ulcer, and DVT), ICU length of stay, and mortality. All assessed complications relied on confirmed physician diagnoses documented in the patients' medical records based on standardized diagnostic criteria (such as chest x-ray, lab tests, Doppler ultrasound and clinical signs).

The Study Intervention Integrated Two Frameworks Adapted for Post-ICH Surgery. Early rehabilitation (adapted from Srivastava *et al.*, 2021) and standardized nursing care (adopted from Dahi *et al.*, 2020). Protocol adjustments omitted non-feasible modalities and included NMES, automated vibration therapy, abdominal massage and session duration adjustments.

Content Validity and Reliability

The content validity of the study tools was assessed by a panel of five experts, including two professors of neurosurgery and three professors of critical care and emergency nursing. The experts evaluated the tools for clarity, relevance, comprehensiveness, applicability, and simplicity. Internal consistency substantiated through Cronbach's alpha coefficient analysis, as follows: tool I: $\alpha = 0.736$, tool II: $\alpha = 0.92$, tool III: $\alpha = 0.97$, tool IV: $\alpha = 0.896$, tool V: $\alpha = 0.743$.

Pilot Study

A pilot study of 10 patients assessed instrument clarity, feasibility, and applicability. Pilot participants were excluded from the final sample and analysis.

Data Collection Procedure

Prior to data collection, formal approval was obtained from the hospital administration.

Patient Clinical Data and Outcome Assessments

Postoperative clinical data were collected on ICU admission using Tool I. Neurological deficit, muscle power, and functional independence were assessed using Tools II, III, and IV on postoperative day 0 (initial baseline assessment at ICU admission), day 3, day 7, and at ICU discharge. For survivors, the discharge assessment was performed before discharge; for patients who died during the ICU stay, the last recorded assessment before death was considered the final in-ICU assessment. Patients who died or were discharged before day 7 were not assessed at that time point. Postoperative complications, ICU length of stay, and mortality were assessed using Tool V. The primary efficacy endpoint was NIHSS at ICU discharge. All participants, including those who died, were included in the final analysis.

Control Group

Participants received the standard postoperative neurosurgical ICU care routinely provided by the unit according to individual clinical needs and physician orders. This included prescribed osmotic therapy and EVD care when indicated, respiratory and hemodynamic support, seizure management, glycaemic and temperature control, nutritional support, and routine prevention of pressure injuries and DVT. Routine repositioning and other preventive nursing measures were provided as part of usual care, but their implementation was not guided by the study-specific protocol (Table 1).

Table 1: Standard Care Provided to Both Groups and Additional Protocolized Nursing Interventions in the Study Group

Goal	Standard care provided to both groups	Additional/protocolized interventions in the study group
Maintain ICP <20 mmHg and CPP 50–70 mmHg	Head-of-bed elevation to 30°; prescribed osmotic therapy; monitoring of serum sodium, fluid balance, neurological status, and response to therapy.	Neutral head position, proper neck alignment, avoidance of ETT ties compressing neck veins, and appropriate cervical stabilization.
Maintain Respiratory Function	Prescribed oxygen therapy, ventilator support, suctioning when indicated, and monitoring of SpO_2 and ABGs.	Structured respiratory care according to the study protocol (Tables 2 and 3).
Maintain Hemodynamic Stability	Hemodynamic monitoring and prescribed fluids/vasoactive medications.	Precise hourly fluid-balance monitoring.
Prevent Seizures	Prescribed antiepileptic therapy and monitoring for seizure activity.	—

Prevent Pressure Injuries and DVT	Routine repositioning, pressure - relieving mattresses, prescribed elastic stockings, and anticoagulants when indicated.	Regular protocolized repositioning, proper body alignment, lower-limb ROM exercises, and calf massage.
Maintain Adequate Nutrition	Enteral nutrition within 48 hours, hydration, and prescribed nutritional therapy.	Structured nutritional care, including oral care every 2–4 hours, feeding-tolerance monitoring by gastric residual volume assessment, and avoidance of routine prokinetic use.
Maintain Glycemic Control	Blood glucose monitoring and prescribed insulin therapy according to the institutional protocol.	—
Maintain Normothermia	Temperature monitoring, prescribed antipyretics, and cooling measures when clinically indicated.	—

Note:Protocol implementation was coordinated by the principal investigator in collaboration with ICU medical and nursing staff, and protocol-based interventions were delivered by trained personnel under the continuous supervision of the principal investigator, critical care physicians, and head nurses. ABGs: arterial blood gases; CPP: cerebral perfusion pressure; DVT: deep vein thrombosis; ETT: endotracheal tube; ICP: intracranial pressure; ROM: range of motion; SpO_2: peripheral oxygen saturation; no additional intervention

Study Group

Participants received the same standard postoperative neurosurgical ICU care as the control group, in addition to the modified critical care nursing protocol. The protocol included structured nutritional and respiratory care, optimal head and neck alignment for ICP/CPP management, protocolized prevention of pressure injuries and DVT through regular repositioning and proper body alignment, lower-limb range-of-motion exercises and massage, and a structured early rehabilitation program delivered in two sequential phases.

Phase One (from ICU admission until recovery of consciousness)

Focused on recovery of consciousness and preservation of muscle function through pulmonary care, abdominal massage, repositioning, automated vibration therapy, passive and assisted exercises, and NMES (Table 2).

Table 2: Protocolized Early Rehabilitation Interventions for the Study Group, Phase 1 (from ICU Admission to Recovery of Consciousness)

Intervention Category	Specific Intervention	Frequency / Duration	Target / Purpose	Notes
Consciousness Recovery	Sound therapy via earphones	5–10 min per shift	Promote recovery of consciousness	Administered according to patient tolerance; music was selected according to the patient's preference.
	Tactile stimulation (tapping, brushing distal → proximal)	Twice daily, 5 repetitions per limb	Coma stimulation	Upper extremity: the researcher tapped along the whole limb from distal to proximal (fingers to shoulder). Lower extremity: the researcher tapped along the whole limb from distal to proximal (toes to hip).
Pulmonary Care	Percussion and mechanical chest vibration	Twice daily, 3 –5 min	Prevent pulmonary complications, reduce secretions	A mechanical vibrator was applied to the anterior, posterior, and lateral chest wall, focusing on the most affected lobe.
	Suctioning (nasal, oral, tracheal)	As needed	Maintain airway patency	Administered by trained staff
Gastrointestinal Support	Abdominal massage via mechanical vibration device	3 times/day, 5 min each	Promote GI motility	Adjusted per patient tolerance
Mobility and Muscle Tone	Passive range-of-motion exercises	5 repetitions per joint each shift	Prevent muscle wasting, maintain joint mobility	Upper & lower limbs
	Neuromuscular electrical stimulation (NMES)	30 min/day	Maintain muscle tone and strength	Quadriceps femoris & triceps brachii
	Calf massage via vibration device	3 times/day, 10 min	Reduce risk of muscle atrophy	Lower extremities
	Repositioning	Every 2 hours	Prevent pressure injuries	Guided by a turning clock

Note: GI- Gastrointestinal; NMES: Neuromuscular Electrical Stimulation; Phase Two (from recovery of consciousness until discharge)

Focused on respiratory independence, progressive mobility, sensory and cognitive rehabilitation, and functional recovery through continued pulmonary care, active rehabilitation exercises, automated vibration therapy, NMES, and graded mobility training (Table 3).

Table 3: Protocolized Early Rehabilitation Interventions for the Study Group, Phase 2 (from Recovery of Consciousness To ICU Discharge)

Intervention Category	Specific Intervention	Frequency / Duration	Target / Purpose	Notes
Respiratory Independence	Percussion and mechanical chest vibration	Twice daily, 3–5 min	Prevent pulmonary complications	A mechanical vibrator was applied to the anterior, posterior, and lateral chest wall, focusing on the most affected lobe.
	Suctioning (nasal, oral, tracheal)	As needed	Maintain airway patency	Administered by trained staff
	Diaphragmatic breathing, coughing exercise, incentive spirometer, paper blowing	5 repetitions per shift	Improve respiratory function	The patient was placed in a semi -Fowler's position with hips and knees slightly flexed, placed a hand on the lower chest/abdomen, inhaled deeply to expand the abdomen, and then exhaled slowly or coughed. An incentive spirometer with three colored balls was used for deep inspirations, and the patient blew on a tissue held in front of the face after deep inspiration.
Gastrointestinal Support	Abdominal massage via mechanical vibration device	Twice daily	Promote GI motility	Adjusted per patient tolerance
Mobility and Muscle Strength	Neuromuscular electrical stimulation (NMES)	30 min/day	Maintain muscle tone & strength	Quadriceps femoris & triceps brachii Stimulation intensity (range 0–120 mA) was increased until contraction of the rectus femoris and vastus medialis was visible and tension of the patellar ligament was palpable. Each session was preceded by a 5-minute warm-up of submaximal stimulation (frequency 20–50 Hz; pulse duration 300–600 μs; 10 s on, 20 s off).
	Active-assisted and active ROM exercises	5 repetitions per joint each shift	Enhance mobility	Upper & lower limbs
	Repositioning	Every 2 hours	Prevent pressure injuries	Combined with stretching
	Stretching (calf and biceps)	2 min per shift	Reduce contractures	The patient was instructed to self-stretch the biceps brachii, triceps brachii, and calf muscles.
Sensory Re-education	Tactile stimulation (brushing/tapping)	Twice daily	Improve sensory awareness	Upper extremity: the researcher tapped along the whole limb from distal to proximal (fingers to shoulder). Lower extremity: the researcher tapped along the whole limb from distal to proximal (toes to hip).
Cognitive Recovery	Tactile discrimination (cotton ball, pin)	Twice daily	Improve cognitive function	With eyes closed, the patient identified the stimulus.
Motor Re-education	Assisted sitting	3 min, twice daily	Promote postural control	Bedside sitting assisted by the researcher and trained team.
	In-bed mobility	1 min, twice daily	Enhance independence	The patient performed tasks such as picking up an object from the side table, choosing a color named by the researcher, and passing objects from one hand to the other.
	Wheelchair activities	2 min per session	Improve functional mobility	The patient was mobilized using a wheelchair.
	Weight transfer	10 min per session	Improve balance & strength	Progressive transfers: supine to high sitting, high sitting to wheelchair, wheelchair to supported standing, supported standing to upright standing, and double-limb stance.
	Assisted standing	2 min per session	Promote upright control	Assisted by the researcher and trained team.
	Assisted gait training	5 min, twice daily	Improve walking ability	—

Note: GI: gastrointestinal; NMES: neuromuscular electrical stimulation; ROM: range of motion; —: not specified

Protocol Delivery, Staffing, and Intervention

The neurosurgical ICU maintained a 1:1 nurse-to-patient ratio throughout the study period. Protocol implementation was coordinated by the principal investigator in collaboration with ICU physicians, bedside critical care nurses, and supervised nursing internship trainees assigned to the unit during their clinical rotation. Before study initiation, trainees received structured orientation and practical training regarding the rehabilitation procedures and their assigned responsibilities. Detailed protocol components, frequencies, durations, progression criteria, and technical parameters are presented in Supplementary Tables 1–4.

Table 4: Intervention Parameters and Progression Criteria

Intervention	Parameters	Frequency	Progression Criteria
ROM	5 repetitions/joint	Each shift	Passive → active-assisted → active when patient demonstrates ability to follow simple commands
NMES	30 min/day, quadriceps and triceps	Daily	Visible muscle contraction and absence of hemodynamic instability
Chest percussion	3–5 min/lung segment	Twice daily	Continued until reduction in secretion burden
Sound therapy	Preferred music, 5–10 min	Each shift	Improved responsiveness and tolerance
Assisted sitting	3 min	Twice daily	Stable vital signs and adequate trunk control
Standing	2 min/session	As tolerated	Ability to maintain sitting balance
Gait training	5 min	Twice daily	Ability to stand with support

Note: Progression between mobilization stages was based on hemodynamic stability, level of consciousness, ability to follow commands, postural control, and patient tolerance. NMES: neuromuscular electrical stimulation; ROM: range of motion

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 24.0. Continuous and categorical variables were summarized as mean ± SD and frequencies (%), respectively. Between-group comparisons were performed using the independent-samples *t*-test or Pearson's chi-square test, as appropriate; Fisher's exact test or Fisher–Freeman–Halton exact test was used when chi-square assumptions were not met. Repeated measures of the NIHSS, MRC scale, and Barthel Index were analyzed using linear mixed-effects models with group, time, and group × time interaction effects, where individual subjects were included as a random effect, and an appropriate covariance structure was selected based on model fit criteria (AIC/BIC). Missing data were handled under the missing-at-random (MAR) assumption using Restricted Maximum Likelihood (REML) estimation. This approach ensures robust inferences despite potential floor effects and non-normal distributions at baseline, followed by Sidak-adjusted comparisons. Effect sizes were reported as partial eta squared (η^2), Cohen's *d*, or ORs with 95% CIs. For zero-cell contingency tables, ORs and 95% CIs were estimated using the Haldane–Anscombe correction. Statistical significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval was obtained from the Faculty of Nursing Research Ethics Committee, Assiut University, Egypt with the reference number 1120240815 on 27th May 2024.

RESULTS

Table 5: Distribution of Baseline Characteristics of Patients in the Study and Control Groups (n= 60)

Patient baseline data	Study group	Control group	*p*-value
Mean age (years) ± SD	59.7 ± 12.3	58.3 ± 12.5	0.671
Gender n (%)			
Male	24 (80.0)	21 (70.0)	0.371
Female	6 (20.0)	9 (30.0)	
Site of hematoma n (%)			
Lobar	13 (43.3)	16 (53.3)	0.540
Basal ganglionic	11 (36.7)	11 (36.7)	
Cerebellar	6 (20.0)	3 (10.0)	

Volume of Hematoma (ml) n (%)			
30–<50	10 (33.3)	11 (36.7)	0.787
≥ 50	20 (66.7)	19 (63.3)	
Preoperative Glasgow Coma Scale			
Mean ± SD	8.6 ± 1.6	9.3 ± 2.9	0.250
Comorbidity n (%)			
Hypertension	30 (100.0)	25 (83.3)	0.053
Diabetes mellitus	10 (33.3)	10 (33.3)	1.000

Note: SD: Standard Deviation; Significant Difference at $p < 0.05$; n: number

Table 5 presents the baseline characteristics of the patients studied. No statistically significant differences were observed between the study and control groups regarding any baseline demographic or clinical characteristics (all $p > 0.05$).

Table 6: Comparison of the Degree of Neurological Deficit between the Study and Control Groups Across Postoperative Assessment Time Points

NIHSS	**ICU Admission Day (0 day)**	**Third Day**	**Seventh Day**	**ICU Discharge Day**
Study Group (Mean ± SD)	32.3 ± 5.4	24.7 ± 8.1	17.6 ± 9.8	16.1 ± 14.7
Control Group (Mean ± SD)	32.3 ± 4.9	29 ± 5.7	24.1 ± 6.1	27.8 ± 12.2
95% CI	-3.43 to 3.43	-8.89 to 0.49	-12.70 to -0.39	-20.75 to -2.78
Sidak-Adjusted Post-hoc *p*-value	0.9999	0.0599	0.0334 *	0.0054*
Cohen's *d*	0.000	0.610	0.800	0.876
Mixed-effects Model	***p*-value**		**Partial η^2**	
Time Factor	<0.0001*		0.435	
Group Factor	0.0041*		0.140	
Time × Group Interaction	0.0004 *			0.154

*NIHSS: National Institutes of Health Stroke Scale; SD: standard deviation; CI: confidence interval of the mean difference; F: F-statistic derived from the linear mixed-effects model; Partial η^2: partial eta-squared effect size; * significant difference at $p < 0.05$*

Table 6 shows a significant time-by-group interaction effect on NIHSS scores ($p = 0.0004$, partial $\eta^2 = 0.154$). Sidak-adjusted post hoc comparisons revealed significantly lower NIHSS scores in the study group than in the control group on the seventh postoperative day and at discharge ($p < 0.05$).

Table 7: Comparison of Muscle Strength Scores between the Study and Control Groups Across Postoperative Assessment Time Points

MRC	**ICU Admission Day (0 day)**	**Third day**	**Seventh day**	**ICU Discharge Day**
Study Group (Mean ± SD)	9.9 ± 9.4	26.1 ± 12.1	41.8 ± 10.5	48.3 ± 12.9
Control Group (Mean ± SD)	9.8 ± 7.9	15.4 ± 7.1	25 ± 9.1	31.8 ± 19.3
95% CI	-5.709 to 5.776	4.013 to 17.32	9.578 to 24.15	7.376 to 30.02
Sidak-adjusted Post-hoc *p*-value	>0.9999	0.0006*	<0.0001*	0.0004*
Cohen's *d*	0.012	1.079	1.710	1.005
Mixed-effects Model	***p*-value**		**Partial η^2**	
Time Factor	<0.0001*		0.729	
Group Factor	<0.0001*		0.276	
Time × Group Interaction	<0.0001*		0.224	

*MRC: Medical Research Council; SD: standard deviation; CI: confidence interval mean of the difference; Partial η^2: partial eta-squared effect size; *significant difference at $p < 0.05$*

Table 7 demonstrates a significant time-by-group interaction effect on MRC scores ($p < 0.0001$, partial $\eta^2 = 0.224$), indicating different patterns of muscle strength recovery between the study and control groups over time. Sidak-adjusted post hoc comparisons revealed significantly higher MRC scores in the study group than in the control group on the third postoperative day, seventh postoperative day, and at discharge (all $p < 0.01$).

Table 8 : Comparison of the Level of Independence in Activities of Daily Living Between the Study and Control Groups Across Postoperative Assessment Time Points

Barthel index	ICU Admission Day (0 day)	Third day	Seventh day	ICU Discharge Day
Study Group (Mean ± SD)	0 ± 0	11.5 ± 14.8	31.7 ± 29.1	52.7 ± 42.1
Control Group (Mean ± SD)	0 ± 0	5.2 ± 3.8	13.4 ± 7.1	27.4 ± 34.7
95% CI	-	-1.023 to 13.69	1.775 to 35.41	-0.3476 to 50.95
Sidak-adjusted Post-hoc *p*-value	-	0.1147	0.0260*	0.0546
Cohen's *d*	-	0.587	0.867	0.657
Mixed-effects model	***p*-value**		**Partial η^2**	
Time Factor	<0.0001*		0.449	
Group Factor	0.0017*		0.157	
Time × Group Interaction	0.0106*		0.090	

*Note: SD: Standard Deviation; CI: Confidence Interval of the mean Difference; Partial η^2: partial eta-squared effect size; *: significant difference at $p < 0.05$*

Table 8 demonstrates a significant time-by-group interaction effect on Barthel Index scores ($p = 0.0106$, partial $\eta^2 = 0.090$), indicating different patterns of functional recovery between the study and control groups over time. Sidak-adjusted post hoc comparisons revealed significantly higher Barthel Index scores in the study group than in the control group on the seventh postoperative day ($p = 0.026$).

Table 9 : Comparison of Post-operative Complications between the Study Group and the Control Group

Complication	Study group		Control group		Test used	95% CI	Odds Ratio	*p*-value
	n	%	n	%				
Pulmonary Infection								
No	22	73.3	12	40.0	$\chi^2 = 6.79$	0.0894 to 0.7638	0.242	0.009*
Yes	8	26.7	18	60.0				
Pressure Ulcer								
No	30	100.0	23	76.7	Fisher's exact test	0.0028–0.9456	0.051	0.011*
Yes	0	0.0	7	23.3				
Deep Vein Thrombosis								
No	28	93.3	25	83.3	Fisher's exact test	0.0675 to 2.0070	0.357	0.424
Yes	2	6.7	5	16.7				

*Note: n: Number of participants; χ^2: chi-square test; CI: 95% Confidence Interval of the odds ratio; *: significant difference at $p < 0.05$. The odds ratio for pressure ulcer was estimated using the Haldane–Anscombe correction because of a zero cell*

Table 9 demonstrates significantly lower incidences of pulmonary infection and pressure ulcers in the study group ($p < 0.05$), while no significant difference was found regarding deep venous thrombosis between the groups ($p > 0.05$).

Table 10: Comparison of ICU Length of Stay and Mortality Rates between the Study Group and the Control Group

Variables		Study group	Control group	Test used	95% CI	Effect size	*p*-value
ICU Length of Stay (Mean ± SD**)**		13.5 ± 9.5	19.7 ± 11.9	*t*= -2.241	0.6596 to 11.81	Cohen's *d* = 0.5786	0.029*
ICU Length of Stay for Survivals (Mean ± SD**)**		11.4±7.2	27.8±10.4	*t*= -5.30	-22.82 to -10.13	Cohen's *d* = 1.902	<0.001*
Mortality Rate n (%)	Yes	11 (36.7%)	17 (56.7%)	χ^2= 2.411	0.1583 to 1.304	OR = 0.4427	0.121
	No	19 (63.3%)	13(43.3%)				

*SD: standard deviation; n: number of participants; ICU: Intensive Care Unit; t: independent-samples t-test; χ^2: Chi-square test; CI: confidence interval; Cohen's d: effect size for the independent-samples t-test; OR: odds ratio; *: significant difference at $p < 0.05$*

Table 10 shows that ICU length of stay was significantly shorter in the study group compared with the control group ($p = 0.03$), while no significant difference was observed in mortality rates between the two groups ($p > 0.05$).

DISCUSSION

Intracerebral hemorrhage (ICH) is associated with high disability and mortality, representing a major public health concern. Although prompt surgical evacuation is essential, disparities in healthcare practices and patient-related factors continue to adversely affect recovery (Elmahdy *et al*., 2026; Wang *et al*., 2026). Therefore, standardized nursing care plays a pivotal role in improving postoperative outcomes and preventing complications (Feng *et al*., 2025). The study population had a mean age of 59.7 years in the study group and 58.3 years in the control group, with hypertension being the most prevalent comorbidity in both groups, consistent with the typical epidemiological profile of intracerebral hemorrhage. Similar findings were reported by Rahmatisa and Lasanudin (2024), who observed a mean age of 54.9 years and a high prevalence of hypertension.

Males predominated in both groups, consistent with previous reports showing a higher prevalence of intracerebral hemorrhage among men, possibly because of a greater burden of vascular risk factors (Cliteur *et al*., 2026; Purnama *et al*., 2024). Lobar hemorrhage was the most common hematoma location, followed by basal ganglionic and cerebellar hemorrhages, consistent with Hosameldin *et al*. (2026). The mean preoperative GCS score was below 12 in both groups, reflecting the severity of the study population and consistent with Rahmatisa and Lasanudin (2024), who reported that 70.7% of patients presented with GCS scores below 13.

Baseline analysis showed no significant differences in demographic or clinical characteristics between both groups, indicating baseline comparability. This is important in quasi-experimental studies for reducing confounding and supporting interpretation of intervention effects. These findings are consistent with Ye *et al*. (2025), who similarly reported no significant baseline differences between study arms. However, residual confounding cannot be completely excluded, as noted in the study limitations.

The present study demonstrated that, compared with the control group, patients in the study group showed a significantly more favorable overall trajectory of neurological recovery over time (group-by-time interaction $p = 0.0004$), with significantly lower NIHSS scores observed by day 7 and at discharge. These findings were supported by large effect sizes (Cohen's $d = 0.80$ and 0.88, respectively) and a significant group-by-time interaction (partial $\eta^2 = 0.154$), indicating a substantial difference in neurological recovery over time. This improvement is hypothesized to be potentially mediated by structured evidence-based nursing interventions and early rehabilitation, which may have helped preserve neuromuscular activation, limit disuse atrophy, and enhance peripheral circulation. These findings are consistent with those of Zheng *et al*. (2021) and Zheng *et al.* (2025), who reported improved neurological outcomes following structured rehabilitation interventions. Therefore, H1 was supported.

Although the control group showed initial improvement in NIHSS scores, the higher final score should be interpreted cautiously. Assessment timing varied according to ICU discharge or death, and the last available NIHSS before death was used for deceased patients; therefore, the final assessments did not represent a uniform postoperative time point. Changes in NIHSS scores over time have been associated with clinical outcomes and mortality (Du *et al*., 2023), while NIHSS is strongly associated with dependency or death after spontaneous intracerebral hemorrhage (Kazaryan *et al*., 2024). Thus, the higher final NIHSS score in the control group may reflect differences in clinical course and mortality rather than uniform neurological deterioration across the group.

Muscle strength improved significantly in the study group from postoperative day 3 until ICU discharge. The large effect size at discharge (Cohen's $d = 1.005$) and group-by-time interaction (partial $\eta^2 = 0.224$) indicate a substantial difference in muscle strength recovery over time, suggesting enhanced motor recovery and greater potential for early mobilization. The observed benefit is conceptually consistent with the structured

implementation of NMES, range-of-motion exercises, stretching, and massage. Similar improvements in muscle strength following NMES- and ROM-based interventions have been reported by Mohamed *et al*. (2019) and Rahiminezhad *et al*. (2022).

These findings demonstrated greater improvement in functional independence over time in the study group. Although the between-group difference at ICU discharge did not reach statistical significance, the significant group-by-time interaction (partial $\eta^2 = 0.090$) indicated different patterns of functional recovery over time, suggesting potential improvement in functional independence. Although the underlying mechanisms were not directly assessed, this finding is clinically plausible and likely related to concurrent improvements in neuromuscular function. These findings are consistent with Abidin *et al*. (2022), Cetin *et al*. (2024), and Liang *et al*. (2025), who reported improvements in Barthel Index scores following early rehabilitation and functional training interventions. Accordingly, H2 was supported for muscle power and partially supported for independence in ADLs.

The study findings showed a lower incidence of postoperative complications, particularly pulmonary infections and pressure ulcers, in the study group compared with the control group. This may be attributed to improved airway clearance, secretion management, and regular repositioning. These findings are consistent with Li and Luo (2024) and Lv *et al*. (2025), who reported reduced rates of similar complications following structured nursing interventions. Although DVT incidence was lower in the study group, the difference was not statistically significant, consistent with Tan *et al*. (2024). The study group also had a significantly shorter ICU length of stay, which may be related to earlier clinical stabilization, fewer complications, and better functional recovery. These findings are consistent with Gu *et al*. (2025) and Qi and Li (2025) who reported shorter ICU and hospital stays following structured, evidence-based nursing care.

Although mortality was lower in the study group, the difference was not statistically significant. This may be explained by mortality after intracerebral hemorrhage being largely determined by baseline disease severity, hematoma characteristics, and neurological status rather than supportive nursing interventions alone (Abulhasan *et al*., 2023). While structured nursing care may improve monitoring and early complication detection, its direct effect on mortality remains limited. Overall, H3 was partially supported: pulmonary infections, pressure ulcers, and ICU length of stay were reduced, whereas DVT and mortality did not differ significantly.

Limitations

First, its quasi-experimental, non-randomized, single-center design, alternate allocation, and non-blinded outcome assessment may have introduced selection and assessment biases. Second, residual confounding cannot be ruled out because several prognostic variables, including intraventricular extension, hydrocephalus, surgical technique, duration of MV, sedation status, and time to surgery, were not systematically recorded. Hematoma volume was recorded categorically, and hypertension prevalence differed numerically between groups (100% versus 83.3%; $p = 0.053$). No covariate-adjusted analysis was performed; therefore, the influence of measured and unmeasured prognostic factors cannot be excluded. Third, quantitative protocol adherence metrics and delivered intervention doses were not tracked, and potential Hawthorne effects and variability in usual care remain inherent constraints. Fourth, the modest sample size may have limited statistical power, particularly for infrequent secondary outcomes such as mortality and deep vein thrombosis. The sample size calculation was based on an anticipated effect derived from a single, relatively small study and a single-time-point between-group comparison rather than the group-by-time interaction assessed in the longitudinal analysis. Finally, outcomes were assessed only during the neuro-ICU stay, without post-discharge follow-up. Nevertheless, the study provides practical insights into protocolized critical care nursing, and its findings should be interpreted cautiously within these methodological constraints.

Future Scope

Future multicenter randomized studies with larger samples are needed to confirm these findings. Further research should evaluate long-term patient outcomes and the cost-effectiveness of implementing the modified nursing protocol in different healthcare settings.

CONCLUSION

Implementation of the modified critical care nursing protocol was associated with greater improvements in neurological status, muscle strength, and functional independence over time among patients undergoing intracerebral hematoma evacuation. Patients who received the protocol also had fewer pulmonary infections and pressure ulcers and shorter intensive care unit (ICU) stays. Between-group differences in deep vein thrombosis and mortality were not statistically significant. These findings suggest that combining structured postoperative nursing care with early rehabilitation may support recovery during the neurosurgical ICU stay.

Recommendation

Future large-scale, multi-centre studies involving diverse clinical settings in Upper Egypt and incorporating post-discharge follow-up are recommended to validate these findings and evaluate the long-term impact of critical care nursing interventions beyond the neuro-ICU stay. Subject to local institutional policies, integrating this modified critical care nursing protocol into routine care pathways within neurosurgical intensive care units could be considered as a beneficial practice framework.

CRediT Authorship Contribution Statement

I.M.A.: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft and Review & Editing. **M.A.A.:** Supervision, Validation, Methodology, Critical Review and Editing. **A.A.E.:** Supervision, Validation, Clinical Supervision, Review and Editing. **M.A.A.:** Methodology, Validation, Data Interpretation, Review and Editing.

AI Assistance Declaration

The authors declare that generative AI tools (such as ChatGPT) were used only for language enhancement and grammar correction during the preparation of this manuscript. Authors carefully reviewed and revised the content and will take full responsibility for the final version of the manuscript.

Conflict of Interest

Authors affirm that they have no competing interests.

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