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Effect of Vestibular Stimulation Exercises on the Level of Consciousness in Patients With Intracerebral Hemorrhage: A Systematic Review

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Abstract

Intracerebral hemorrhage (ICH) commonly disrupts cortical, subcortical, and brainstem arousal circuits, leaving many survivors with a reduced level of consciousness (LOC) that delays active rehabilitation. Conventional multisensory stimulation is the standard bedside approach used to promote arousal in such patients, and graded vestibular stimulation has recently been proposed as an adjunct, since vestibular afferents project extensively to brainstem reticular structures and cortical arousal networks through the vestibulo-thalamo-cortical pathway.

This study aims to systematically review randomized controlled trial (RCT) and cross-sectional evidence published between 2010 and 2026 on vestibular and related sensory stimulation approaches for improving LOC in patients with ICH, and to place this evidence alongside closely related trials and validation studies in comatose, traumatic brain injury (TBI), and neuro-critical populations.

PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar were searched for English-language RCTs and cross-sectional studies published from January 2010 to June 2026 that evaluated vestibular, multisensory, auditory, affective, or related sensory stimulation interventions, or that validated a bedside LOC-assessment tool in adults with ICH or closely related severe brain injury. Risk of bias in the randomized trials was appraised with the Cochrane RoB 2 tool; the cross-sectional and prospective observational studies were appraised with the Appraisal Tool for Cross-Sectional Studies (AXIS).

Twelve studies met the eligibility criteria: eight RCTs and four cross-sectional/prospective observational studies. The single trial testing vestibular stimulation directly in ICH found that adding graded vestibular exercises to conventional multisensory stimulation produced significantly higher Glasgow Coma Scale (GCS) and Full Outline of UnResponsiveness (FOUR) scores at day 7 and day 14 than multisensory stimulation alone. Seven further randomized trials in comatose, TBI, or acquired brain injury (ABI) populations tested auditory/voice stimulation, family-centered affective stimulation, nurse- and family-delivered multisensory stimulation, median nerve plus auricular stimulation, and dedicated vestibular rehabilitation, and consistently reported improvement in LOC-related or closely linked functional outcomes. Four cross-sectional or prospective observational studies confirmed that GCS and FOUR scores are valid, reliable, and prognostically useful bedside measures of consciousness in neuro-critical populations, including cohorts in which ICH was the leading diagnosis. Direct evidence for vestibular stimulation in ICH remains confined to one small trial, but its findings are biologically consistent with a wider body of sensory-stimulation research in comatose and severely brain-injured patients, and with cross-sectional evidence supporting GCS and FOUR score as appropriate outcome measures. Larger, multi-center, time-matched randomized trials are required before graded vestibular stimulation can be recommended as a standard adjunct in ICH rehabilitation.

Categories: Therapeutics, Neurology, Physical Medicine & Rehabilitation
Keywords: four score, glasgow coma scale, level of consciousness, multisensory stimulation, neurorehabilitation, systematic review, vestibular stimulation

Introduction And Background

Intracerebral hemorrhage (ICH) is among the most severe forms of stroke, representing approximately 10-20% of all stroke cases while accounting for a disproportionately high share of stroke-related mortality and long-term disability [1,2]. Despite significant advances in acute medical and neurosurgical treatment, the prognosis following ICH remains unfavorable. Nearly half of affected patients die within the first month, and only a small proportion regain functional independence. Survivors often experience persistent neurological impairments, cognitive dysfunction, and prolonged disorders of consciousness, imposing a considerable burden on healthcare systems and society.

ICH is one of the most disabling forms of stroke, with impaired level of consciousness (LOC) representing one of its earliest and most significant prognostic indicators. Reduced consciousness results not only from the primary injury caused by the hematoma but also from secondary pathological mechanisms, including perihematomal edema, increased intracranial pressure, intraventricular hemorrhage, hydrocephalus, cerebral hypoperfusion, and disruption of the ascending reticular activating system (ARAS) and its thalamo-cortical connections [3]. The extent and persistence of impaired consciousness are closely associated with higher mortality rates, longer stays in the intensive care unit (ICU), delayed initiation of rehabilitation, and less favorable long-term functional outcomes [4].

Early neurological rehabilitation is widely regarded as a fundamental aspect of comprehensive stroke management. However, individuals with impaired consciousness are frequently unable to engage actively in conventional rehabilitation because of reduced responsiveness and an inability to follow verbal commands [5]. Consequently, structured sensory stimulation programs are commonly implemented during the acute phase to promote arousal, improve awareness of the surrounding environment, and support recovery of consciousness while reducing the adverse effects associated with prolonged immobility and sensory deprivation [6]. Conventional multisensory stimulation programs involve the systematic delivery of graded visual, auditory, tactile, olfactory, and proprioceptive stimuli. These interventions have shown modest yet clinically relevant improvements in arousal and responsiveness among patients with disorders of consciousness, particularly those with traumatic brain injury (TBI). Although the supporting evidence is heterogeneous, multisensory stimulation remains widely used in neurocritical care because it is safe, cost-effective, and easily implemented at the bedside [7].

Recent evidence published between 2020 and 2026 has further supported the potential role of sensory and multimodal stimulation in disorders of consciousness. Contemporary reviews and clinical studies suggest that structured sensory stimulation may influence arousal and behavioral responsiveness, although the effects vary according to the sensory modality, intervention dose, patient population, and outcome measure. A 2022 systematic review of sensory stimulation following TBI highlighted the continuing use of multimodal approaches to facilitate arousal and awareness, while a 2024 systematic review and meta-analysis of coma arousal therapy reported evidence of benefit across several stimulation-based approaches, including multisensory and positional interventions. More recent evidence has also examined tactile and multimodal sensory stimulation, emphasizing short-term changes in behavioral and physiological indicators of consciousness and the need for standardized intervention protocols. Vestibular stimulation has been suggested as a valuable adjunct to conventional multisensory stimulation. The vestibular system maintains extensive bidirectional connections with the vestibular nuclei, cerebellum, reticular formation, thalamus, basal ganglia, and several cortical regions responsible for attention, spatial orientation, and consciousness [8].

Under normal physiological conditions, vestibular stimulation begins when head movement or changes in head position activate the semicircular canals and otolith organs of the inner ear. These receptors transmit afferent information through the vestibular division of the eighth cranial nerve to the vestibular nuclei in the brainstem and, in part, directly to the cerebellum. From the vestibular nuclei, ascending projections reach the thalamus and are subsequently distributed to cortical vestibular areas, while vestibular connections with the brainstem reticular formation and other arousal-related structures provide a potential pathway through which vestibular input can influence alertness and cortical activation. Vestibular information is therefore integrated with visual, proprioceptive, somatosensory, and autonomic information to support orientation, postural control, attention, and interaction with the environment. The vestibulo-thalamo-cortical pathway provides an anatomical basis for vestibular influences on higher-order cortical processing.

In severe neurological injury such as ICH, disruption of cortical-subcortical networks, brainstem arousal systems, thalamocortical connections, increased intracranial pressure, perihematomal edema, hydrocephalus, and intraventricular extension may impair the integration and processing of sensory information. Because the ascending reticular activating system and thalamocortical networks are central to maintaining arousal, disruption of these networks may contribute to reduced LOC. Vestibular stimulation may provide an additional afferent sensory input to brainstem and thalamocortical networks and may therefore contribute to arousal through sensory activation and multisensory integration. However, this mechanism remains biologically plausible rather than definitively established as a specific therapeutic mechanism in ICH.

Activation of the vestibuloreticular and vestibulo-thalamo-cortical pathways through graded vestibular stimulation, including controlled head and trunk movements, positional changes, rocking, wheelchair mobilization, gaze stabilization, and optokinetic stimulation, may promote cortical activation, enhance sensory integration, and facilitate recovery of consciousness beyond the effects of conventional multisensory stimulation alone. Furthermore, neurophysiological evidence suggests that vestibular stimulation influences widespread cortical networks involved in arousal and cognitive processing, providing a plausible biological basis for its therapeutic use in patients with disorders of consciousness [9]. Similarly, most studies on vestibular rehabilitation have concentrated on improving balance, gait, dizziness, and functional mobility in conscious individuals with neurological disorders rather than addressing impaired consciousness during the acute phase of injury. As a result, the evidence regarding the effectiveness of

vestibular stimulation for improving LOC in patients with ICH has not yet been comprehensively synthesized [10].

The primary population of interest in this review is adults with ICH and impaired LOC. As direct evidence evaluating vestibular stimulation specifically in ICH is limited, evidence from related acquired brain injury and disorders-of-consciousness populations was considered as indirect contextual evidence to inform the potential biological and clinical relevance of sensory-based stimulation. Findings from these populations were not assumed to be directly generalizable to ICH and were interpreted separately from ICH-specific evidence.

Accordingly, this systematic review was conducted to identify, critically evaluate, and synthesize the available randomized and observational evidence on the effectiveness of vestibular stimulation and related sensory stimulation interventions for improving the LOC in patients with ICH. As direct ICH-specific evidence is limited, findings from TBI, acquired brain injury, and other disorders of consciousness were examined as indirect contextual evidence rather than as direct evidence of vestibular stimulation efficacy in ICH.

Review

Methods

Study Design

This systematic review followed PRISMA 2020 reporting principles and included randomized controlled trials (RCTs) and cross-sectional or prospective observational studies published from January 2010 through June 2026 [11]. The starting year of 2010 was selected to capture foundational clinical evidence on sensory stimulation, vestibular-related interventions, and assessment of LOC, while the search was extended through June 2026 to incorporate the most recent evidence. Restricting the review exclusively to 2020-2026 would risk excluding earlier studies that provide important foundational evidence regarding sensory stimulation and the reliability and prognostic utility of consciousness assessment tools. The 2020-2026 literature was therefore incorporated as an updated body of evidence within the broader 2010-2026 search period [11].

Search Strategy

A structured search of PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar was conducted for studies published from 1 January 2010 to 30 June 2026. The starting year of 2010 was selected to capture contemporary and foundational evidence on sensory stimulation, vestibular-related interventions, and assessment of LOC while maintaining a clinically relevant literature period. Recent evidence published between 2020 and 2026 was additionally considered to ensure that the synthesis reflected current developments in sensory and vestibular stimulation for disorders of consciousness. Search terms combined MeSH headings and free text keywords across three concept blocks: (1) population - (“intracerebral hemorrhage” OR ICH OR “hemorrhagic stroke” OR “traumatic brain injury” OR coma OR “disorders of consciousness”); (2) intervention - (“vestibular stimulation” OR “vestibular rehabilitation” OR “multisensory stimulation” OR “sensory stimulation” OR “affective stimulation” OR “auditory stimulation”); and (3) outcome - (“level of consciousness” OR “Glasgow Coma Scale” OR “Full Outline of Unresponsiveness” OR arousal OR responsiveness). Reference lists of retrieved trials and reviews were screened manually for further eligible studies.

Eligibility Criteria

Inclusion criteria included the following: (1) adults aged 18 years or older with ICH or a closely related acute severe brain injury affecting consciousness; (2) RCTs evaluating vestibular, multisensory, auditory, affective, or related sensory stimulation interventions, or cross-sectional/prospective observational studies reporting a validated LOC assessment in a population that includes ICH; (3) outcomes related to LOC (Glasgow Coma Scale (GCS), Full Outline of UnResponsiveness (FOUR) score, Coma Recovery Scale-Revised) or a closely linked functional outcome in a vestibular rehabilitation context; and (4) publication in English between January 2010 and June 2026 with an accessible full text and a digital object identifier (DOI).

Exclusion criteria included the following: pediatric studies, case reports, conference abstracts without extractable data, narrative reviews, quasi-experimental studies without randomization, animal studies, study protocols without completed patient-outcome data, duplicate publications, and studies with no consciousness-related or directly linked functional outcome.

Study Selection

Titles and abstracts were screened for relevance, followed by full-text review. Several RCT protocols evaluating neuromodulation (repetitive transcranial magnetic stimulation, transcranial direct current

stimulation, median nerve electrical stimulation, and vagus nerve stimulation) for disorders of consciousness after ICH were identified during the search but excluded from the evidence tables because they had not reported completed outcome data at the time of this review; they are referenced in the discussion as evidence of active research interest in this population. Quasi-experimental studies without a randomized or true cross-sectional design were also excluded to maintain internal validity of the evidence base.

Data Extraction

For each included study, the following data were extracted: author, year, country/setting, design, sample size, population and intervention/exposure, outcome measures, main results, and conclusion. For randomized trials, details of the stimulation protocol, comparator, and blinding were also extracted.

Quality Assessment

Methodological quality was assessed according to study design. The revised Cochrane Risk of Bias tool (RoB 2) [12] was used for the eight RCTs, evaluating the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. The Appraisal Tool for Cross-Sectional Studies (AXIS) was used for the four cross-sectional/prospective observational studies, evaluating clarity of aims and sampling, justification of sample size, assessment of non-response bias, and reliability of measurement tools [13].

Results

Search Results and Study Characteristics

A systematic literature search was conducted using PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. A total of 615 records were identified through database searching. After removing 148 duplicate records, 467 studies remained for title and abstract screening, of which 421 were excluded. Ultimately, 42 full-text articles were assessed for eligibility, and 30 studies were excluded due to the wrong study design, no consciousness-related articles, or no complete results. Ultimately, 12 studies met the predefined eligibility criteria and were included in the qualitative synthesis, of which eight were RCTs and four were cross-sectional studies. The study selection process is illustrated in the PRISMA 2020 flow diagram (Figure *1*).

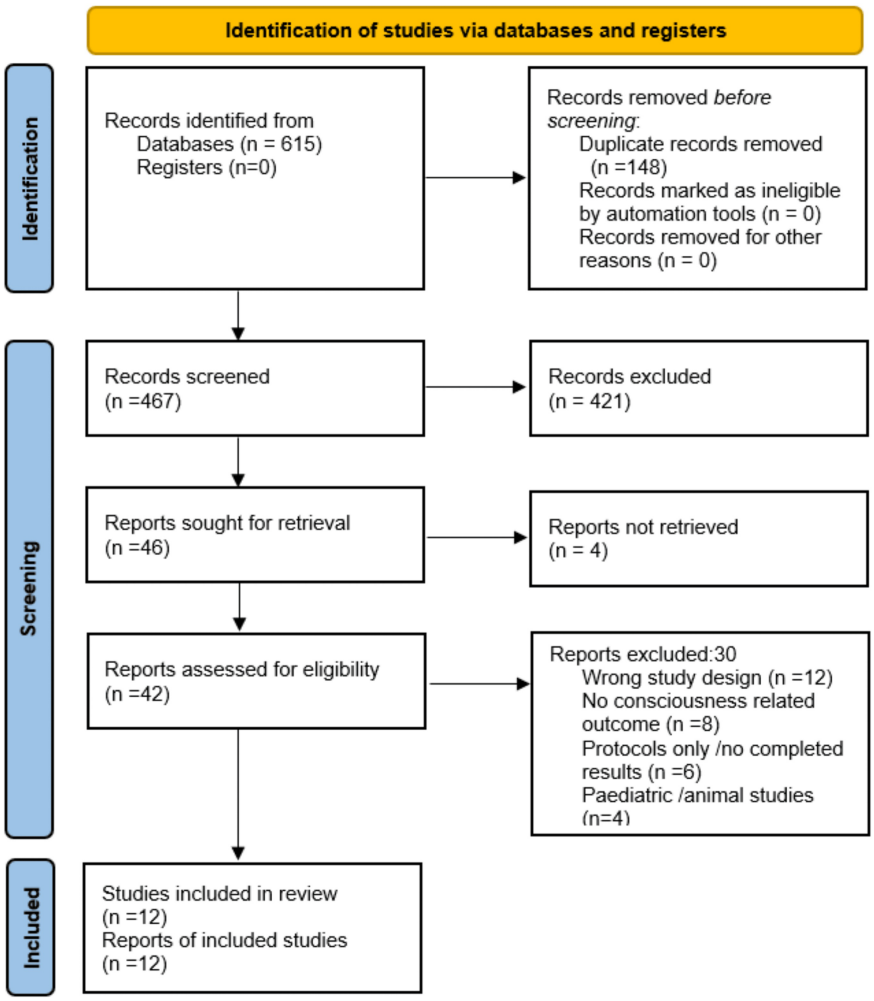


FIGURE 1: PRISMA flowchart.

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

The included studies reported findings across different outcome domains. The ICH-specific randomized trial directly assessed changes in GCS and FOUR scores, whereas other randomized studies evaluated consciousness-related, behavioral, physiological, or functional outcomes. Observational studies primarily provided contextual evidence regarding the measurement and prognostic relevance of consciousness. The characteristics and findings of the included RCTs are summarized in Table *1*.

Author (Year)	Study design	N	Population/Intervention	Outcome measures	Main results	Conclusion
Killedar & Kanase (2026) [14]	Randomized controlled parallel-group trial	36	Adult ICH patients in neuro-ICU; graded vestibular stimulation (head/trunk movement, positioning, rocking, wheelchair mobilization, gaze stabilization, optokinetic stimulation) added to conventional multisensory stimulation vs. multisensory stimulation alone	GCS and FOUR score at day 1, 7, and 14	Both groups improved by day 14 ($p<0.001$). Experimental group had significantly higher GCS and FOUR scores at day 7 and day 14 than control (e.g., day 14 GCS 11.3±1.4 vs. 10.1±1.3, $p=0.010$)	Add-on graded vestibular stimulation was associated with greater LOC improvement, though total treatment exposure also differed between groups
Salmani et al. (2017) [15]	Three-group double-blind RCT	90	TBI patients with GCS 5–8; family-centered affective stimulation vs. placebo vs. standard care, twice daily for 7 days	Level of consciousness (GCS-based)	Affective stimulation group showed significantly greater improvement in LOC than placebo and control groups	Early family-centered affective stimulation is more effective than routine sensory stimulation in improving LOC in

						comatose brain-injured patients
Moattari et al. (2016) [16]	Randomized controlled trial	44	Comatose patients with severe TBI; sensory stimulation delivered by nurses and trained family members vs. routine care	Level of cognitive function; basic cognitive-sensory recovery	Sensory stimulation group demonstrated significantly greater recovery of cognitive function and sensory responsiveness than controls	Structured multisensory stimulation by nurses and family supports earlier cognitive-sensory recovery in comatose TBI patients
Tramontano et al. (2022) [17]	Two-arm single-blind RCT	30	Severe TBI inpatients in post-acute neurorehabilitation; 8-week vestibular rehabilitation program vs. conventional rehabilitation program	Gait quality (inertial sensors); activities of daily living (ADL)	Vestibular rehabilitation group showed earlier and greater improvement in ADL scores and significant gains in gait smoothness on curvilinear walking versus conventional rehabilitation	Vestibular rehabilitation is feasible in TBI and improves gait quality and daily function, supporting a physiological rationale for vestibular input after brain injury
Puggina et al. (2011) [18]	Single-blind randomized controlled trial	30	Patients with disorders of consciousness in two ICUs; music and voice (message) stimulus sessions over 3 consecutive days vs. control	GCS; Ramsay Sedation Scale; vital signs and facial expression	Significant alterations in vital signs and facial expression during stimulation sessions; the voice message was a stronger stimulus than music	Organized auditory stimulation (voice/message) elicits measurable behavioral and physiological responses in patients with disorders of consciousness
Çevik & Namik (2018) [19]	Randomized controlled trial	60	Comatose patients in anesthesia/reanimation and internal medicine ICUs; organized voice stimulation by a nurse, twice daily for 10 days, vs. no auditory intervention	GCS scores recorded before and after auditory stimulation	GCS improved progressively across the intervention period in the auditory-stimulation group relative to control	Nurse-delivered organized auditory (voice) stimulation is a feasible, low-cost adjunct that may support LOC recovery in comatose ICU patients
Mohammadi et al. (2019) [20]	Single-blind randomized controlled trial	60	Comatose ICU patients with head trauma; familiar-voice auditory stimulation for 3 consecutive days vs. control	Level of consciousness (GCS)	A significant increase was found in mean LOC in the intervention group after each daily auditory stimulation session ($p<0.05$)	Familiar-voice auditory stimulation is associated with measurable short-term gains in LOC among comatose brain-injured patients
Li et al. (2026) [21]	Randomized controlled trial	116	Patients with disorders of consciousness (GCS 4–8) after acquired brain injury; standard care + median nerve electrical stimulation (MNES) + auricular intradermal needling vs. standard care + MNES	Coma Recovery Scale-Revised (CRS-R) at 4 weeks and 3 months; GCS; awakening rate; GOS; family satisfaction	Intention-to-treat analysis showed significantly greater CRS-R improvement in the combined-stimulation group at 4 weeks (mean difference: 1.62, $p=0.022$) and 3 months (mean difference: 2.05, $p=0.006$)	Adding auricular sensory stimulation to median nerve stimulation is associated with greater consciousness recovery in acquired brain injury

TABLE 1: Randomized controlled trial evidence on vestibular and related sensory stimulation for level of consciousness in ICH and closely related severe brain injury.

ICH: intracerebral hemorrhage; ICU: intensive care unit; GCS: Glasgow Coma Scale; FOUR: Full Outline of UnResponsiveness; LOC: level of consciousness; RCT: randomized controlled trial; TBI: traumatic brain injury; ADL: activities of daily living; CRS-R: Coma Recovery Scale–Revised; MNES: median nerve electrical stimulation; GOS: Glasgow Outcome Scale; N: number of participants.

A total of four observational studies involving 2,320 participants evaluated the assessment of LOC using the GCS and the FOUR score in neurocritical care populations. These studies included patients with ICH, hemorrhagic stroke, and mixed ICU populations. Overall, both GCS and FOUR were found to be reliable and

valid bedside tools for assessing LOC. However, the FOUR score demonstrated better inter-rater reliability, stronger prognostic accuracy, and greater usefulness in intubated or sedated patients due to its assessment of brainstem reflexes and respiratory patterns. These findings support the inclusion of both GCS and FOUR score as appropriate outcome measures for evaluating consciousness in studies involving patients with ICH and other severe brain injuries. The characteristics and findings of the included observational studies are summarized in Table *2*.

Author (Year)	Study design	N	Population	Outcome measures	Main results	Conclusion
Omar et al. (2024) [22]	Prospective cross-sectional study	84	Adult neurological ICU patients across three hospitals in the West Bank; hemorrhagic stroke was the most common diagnosis (46.4%)	GCS and FOUR score at admission, 48 hours, and discharge	Mean GCS rose from 11.2 at admission to 12.2 at discharge; mean FOUR score rose from 12.2 to 12.5; FOUR showed stronger predictive value than GCS, particularly in sedated/intubated patients	Both GCS and FOUR are valid bedside tools for tracking LOC in neuro-ICU populations that include ICH; FOUR offers advantages in ventilated or sedated patients
Fischer et al. (2010) [23]	Prospective observational study	267 patients/437 paired ratings	Unselected critically ill ICU patients scored independently by neurologists and ICU staff	Inter-rater reliability of GCS and FOUR score	Exact inter-rater agreement was 71% for GCS and 82% for FOUR (p=0.0016); agreement within ±1 point was 90% (GCS) and 92% (FOUR, ns)	FOUR score shows a modest inter-rater reliability advantage over GCS, but not sufficient to replace a tool with a long track record in critical care
Braksick et al. (2018) [24]	Retrospective cross-sectional cohort	274	Consecutive patients with spontaneous ICH; FOUR score incorporated into the existing ICH Score (ICH ScoreFS) as a substitute for GCS	30-day mortality prediction (ICH Score vs. ICH ScoreFS)	The FOUR-based ICH ScoreFS provided accuracy for 30-day mortality comparable to the standard GCS-based ICH Score, with additional neurological detail	The FOUR score is a viable alternative to GCS within existing ICH prognostic models, supporting its use as an LOC outcome in ICH research
Wijdicks et al. (2015) [25]	Prospective multicenter observational study	1,695	Consecutive unselected ICU admissions across 13 ICUs at 5 US hospitals	GCS and FOUR score within 1 hour of admission; in-hospital mortality	FOUR score was a stronger predictor of ICU mortality than GCS, attributed to its inclusion of brainstem reflexes and respiratory pattern	FOUR score may outperform GCS as a prognostic tool in unselected critically ill patients, reinforcing its value alongside GCS in neuro-critical LOC assessment

TABLE 2: Cross-sectional and prospective observational evidence on level-of-consciousness assessment tools in ICH and neurocritical populations.

ICH: intracerebral hemorrhage; GCS: Glasgow Coma Scale; FOUR: Full Outline of UnResponsiveness; ICU: intensive care unit; LOC: level of consciousness.

Assessment of risk of bias

Randomized Trials (RoB 2)

The trial was judged as having some concerns overall: randomization and blinded outcome assessment were strengths, but the experimental group received additional treatment time by design, since vestibular exercises were delivered as an add-on rather than a time-matched alternative, introducing a cointervention/exposure confound [14]. The trial described in reference [15] used permuted block randomization with double-blinding and was judged low risk overall. The trials reported in references [16-21] were each judged as having some concerns, principally reflecting single or unclear blinding of an inherently difficult-to-blind sensory intervention, convenience or unreported allocation procedures, and small-to-moderate single-center samples. The detailed risk-of-bias judgments for the eight RCTs are presented in Table *3*.

Study	Randomization process	Deviations from intended intervention	Missing outcome data	Outcome measurement	Selective reporting	Overall RoB 2
Killedar & Kanase (2026) [14]	Low risk	Some concerns (unequal treatment exposure)	Low risk	Low risk (blinded assessor)	Low risk	Some concerns
Salmani et al. (2017) [15]	Low risk	Low risk	Low risk	Low risk (double-blind)	Low risk	Low risk
Moattari et al. (2016) [16]	Some concerns	Some concerns	Some concerns	Some concerns	Low risk	Some concerns
Tramontano et al. (2022) [17]	Some concerns	Some concerns (single-blind, small n)	Low risk	Some concerns	Low risk	Some concerns
Puggina et al. (2011) [18]	Some concerns	Some concerns (single-blind, small n=30)	Low risk	Some concerns	Low risk	Some concerns
Çevik & Namik (2018) [19]	Some concerns	Some concerns (blinding of assessment unclear)	Low risk	Some concerns	Low risk	Some concerns
Mohammadi et al. (2019) [20]	Some concerns (convenience sampling)	Some concerns (single-blind)	Low risk	Some concerns	Low risk	Some concerns
Li et al. (2026) [21]	Some concerns (allocation concealment underreported)	Some concerns (open-label sensory add-on)	Low risk	Low risk (ITT analysis)	Low risk	Some concerns

TABLE 3: Risk of bias assessment for eight included RCTs using RoB 2 tool (Cochrane Collaboration).

RCT: randomized controlled trial; RoB 2: Revised Cochrane Risk of Bias 2; ITT: intent-to-treat.

Cross-Sectional and Observational Studies (AXIS)

The study in reference [22] clearly defined its aims, setting, and sampling frame across three ICUs and used validated instruments, including the GCS and FOUR score, prospectively. However, sample-size justification and formal non-response bias analysis were not reported, and the single-region setting limits generalizability. The studies in references [23] and [25] were large, multi-rater or multicenter prospective designs with validated outcome tools and were judged moderate-to-good and good, respectively, although neither formally addressed non-response bias. The retrospective cohort study in reference [24] used validated tools within a single center and consecutive series sampling and was judged moderate overall owing to its retrospective, single-site design. The quality assessment of the included cross-sectional and observational studies using the AXIS tool is presented in Table *4*.

Study	Clear aims/sampling	Sample size justified	Non-response bias assessed	Reliable measurement tools	Overall AXIS judgment
Omar et al. (2024) [22]	Yes	Not formally reported	Not clearly addressed	Yes (validated GCS/FOUR)	Moderate – limited to single region; non-response bias unreported
Fischer et al. (2010) [23]	Yes	Not formally reported (large pragmatic sample)	Not clearly addressed	Yes (validated GCS/FOUR, dual-rater design)	Moderate-to-good – strong internal design, limited reporting on non-response
Braksick et al. (2018) [24]	Yes	Not formally justified (consecutive series)	Not applicable (retrospective chart review)	Yes (validated ICH Score, GCS, FOUR)	Moderate – single-center, retrospective design limits generalizability
Wijdicks et al. (2015) [25]	Yes	Not formally powered a priori	Not clearly addressed	Yes (validated GCS/FOUR, multicenter)	Good – large multicenter sample strengthens external validity

TABLE 4: Quality assessment of included cross-sectional studies using the AXIS tool.

AXIS: Appraisal Tool for Cross-Sectional Studies; ICH: intracerebral hemorrhage; GCS: Glasgow Coma Scale; FOUR: Full Outline of UnResponsiveness.

Discussion

This review asked whether vestibular stimulation exercises improve the LOC in patients with ICH. The central finding, consistent with the limited direct literature, is that this question has been tested in only one small randomized trial, but the findings of that trial align with, and are biologically supported by, a wider body of sensory-stimulation research in comatose and severely brain-injured populations, as well as by observational evidence supporting the validity of the outcome measures used.

The only study testing vestibular stimulation directly in ICH found that adding a graded vestibular protocol to conventional multisensory stimulation produced significantly greater GCS and FOUR score gains at day 7 and day 14 than multisensory stimulation alone [14]. This is an encouraging early signal, particularly because the FOUR score does not depend on a verbal response and is therefore informative even for intubated or aphasic patients with ICH. However, because the vestibular exercises were delivered as an add-on rather than a time-matched alternative, the experimental group received more total therapeutic contact than the control group. This makes it difficult to isolate the specific physiological contribution of vestibular input from the general effect of additional structured sensory input, a limitation reflected in the study's "some concerns" RoB 2 rating [14].

The remaining seven randomized trials, although none evaluated vestibular input specifically, strengthen the plausibility of a stimulation-related arousal effect through convergent findings across different sensory channels. Family-centered affective stimulation produced significantly greater improvement in LOC than placebo or standard care [15], while nurse- and family-delivered multisensory stimulation accelerated cognitive-sensory recovery compared with routine care [16]. Three further trials targeted the auditory channel specifically: organized voice and music stimulation elicited measurable behavioral and physiological responses in patients with disorders of consciousness [18]; nurse-delivered organized voice stimulation was associated with progressive improvement in GCS scores among comatose ICU patients [19]; and familiar-voice stimulation was associated with a significant daily increase in LOC in comatose patients with head trauma [20]. In the largest included trial, adding auricular sensory stimulation to median nerve electrical stimulation produced significantly greater Coma Recovery Scale-Revised gains than median nerve stimulation alone in a mixed acquired-brain-injury cohort [21]. Taken together, these trials support the broader premise underlying the ICH vestibular trial: structured, repeated sensory input delivered after severe brain injury may influence the trajectory of consciousness recovery, although the specific sensory channel, dose, and population vary considerably across studies.

The more recent literature from 2020 to 2026 provides additional context for these findings. Contemporary evidence continues to support the investigation of sensory and multimodal stimulation for disorders of consciousness, while also emphasizing substantial heterogeneity in intervention protocols and outcome measures. Recent systematic evidence on coma arousal therapy has examined multiple stimulation approaches and suggests potential benefits for consciousness-related outcomes, although the certainty and consistency of effects differ across modalities. More recent reviews of tactile and multimodal sensory stimulation similarly suggest short-term changes in behavioral and physiological indicators of consciousness, while emphasizing the need for standardized protocols and longer-term follow-up. These findings support continued investigation of sensory-based approaches while reinforcing the need to distinguish the effects of vestibular stimulation specifically from those of general multisensory stimulation.

A further randomized trial provides complementary, indirect evidence regarding vestibular rehabilitation [17]. Although consciousness was not measured directly, a structured vestibular rehabilitation program was feasible and produced measurable functional gains, improved gait smoothness, and faster recovery of activities of daily living in patients with severe TBI during post-acute neurorehabilitation [17]. These findings support the physiological premise that the vestibular system remains a responsive rehabilitation target after severe brain injury and provide indirect support for investigating vestibular input earlier in the recovery trajectory while consciousness is still impaired.

The four observational studies were considered primarily as contextual evidence regarding the assessment and prognostic relevance of LOC rather than as evidence of the effectiveness of vestibular stimulation. In a neuro-ICU population in which hemorrhagic stroke was the most common diagnosis, both GCS and FOUR scores tracked meaningful changes in consciousness from admission to discharge, with the FOUR score performing particularly well in sedated or intubated patients [22]. Large multi-rater and multicenter critically ill cohorts similarly demonstrated that the FOUR score offers modest reliability and prognostic advantages over the GCS without fully replacing it [23,25]. In an ICH-specific cohort, substituting the FOUR score for the GCS within the established ICH Score preserved accuracy for 30-day mortality while providing additional neurological information [24]. Collectively, this evidence supports the use of GCS and FOUR scores as primary outcome measures in ICH-specific vestibular stimulation research and reinforces their validity and prognostic relevance across neuro-critical populations [22-25].

For clinicians, the available evidence supports the use of GCS and FOUR scores as responsive, low-cost bedside tools for monitoring the trajectory of LOC in ICH [22-25]. Graded vestibular stimulation may be considered a potential adjunct to conventional multisensory stimulation when delivered under appropriate clinical supervision, although the current ICH-specific evidence remains limited [14]. For researchers, the findings indicate a clear need for larger, multicenter, time-matched RCTs in ICH populations, incorporating blinded outcome assessment, standardized vestibular stimulation protocols, and pre-specified safety monitoring to isolate the specific contribution of vestibular input from the general effects of increased sensory or therapeutic contact time [14-21].

Recommendations and clinical implications

Clinical Implications

The findings suggest that graded vestibular stimulation may be considered as an adjunct to conventional multisensory stimulation in selected patients with ICH and impaired consciousness when clinically appropriate and when delivered by trained healthcare professionals. Because the available ICH-specific evidence is limited and the intervention was delivered as an add-on with greater total treatment exposure, the findings should not be interpreted as evidence that vestibular stimulation alone is responsible for the observed improvement. GCS and FOUR scores may be used together to monitor changes in LOC, with FOUR providing additional information in patients who are intubated or unable to provide a verbal response.

Recommendations for Clinical Practice

Vestibular stimulation should be individualized according to the patient's neurological status, medical stability, LOC, and tolerance to positional and movement-based stimulation. Clinical monitoring should include neurological status and relevant physiological responses during treatment. Standardized protocols describing the type, intensity, frequency, duration, and progression of vestibular stimulation are required to improve reproducibility between studies and clinical settings.

Recommendations for Future Research

Future studies should use adequately powered multicenter randomized controlled designs with time-matched control interventions so that the specific contribution of vestibular stimulation can be distinguished from the effects of additional therapist contact or sensory exposure. Studies should use blinded outcome assessment, standardized vestibular stimulation protocols, predefined safety criteria, and validated consciousness measures such as GCS, FOUR, and, where appropriate, the Coma Recovery Scale-Revised. Longer-term follow-up should also be incorporated to determine whether improvements in consciousness are sustained and translate into meaningful functional recovery.

Limitations

This systematic review has several limitations. First, only one RCT specifically evaluated vestibular stimulation in patients with ICH, limiting the strength of evidence for this population. Second, most included intervention studies were conducted in patients with TBI, acquired brain injury, or disorders of consciousness, which may reduce the generalizability of the findings to ICH. Third, considerable heterogeneity existed in the type, intensity, duration, and delivery of sensory stimulation interventions, making direct comparison across studies difficult and precluding meta-analysis. Fourth, several randomized trials had some concerns regarding risk of bias, mainly due to limited blinding, small sample sizes, and

incomplete reporting of allocation procedures. Finally, the review included only English-language publications from 2010 to 2026, which may have introduced language and publication bias.

Conclusions

Recent evidence from 2020 to 2026 continues to support investigation of structured sensory stimulation as an approach for promoting arousal and behavioral responsiveness in disorders of consciousness. However, evidence specific to vestibular stimulation in ICH remains limited. The available ICH-specific randomized trial suggests that graded vestibular stimulation added to conventional multisensory stimulation is associated with greater improvement in GCS and FOUR scores, but the unequal treatment exposure between groups limits attribution of the effect specifically to vestibular stimulation. Evidence from related neurological populations provides biological and clinical support but cannot be assumed to be directly equivalent to ICH. Therefore, vestibular stimulation should currently be regarded as a potential adjunct rather than an established standard intervention for impaired consciousness after ICH. Larger multicenter RCTs using time-matched interventions, standardized vestibular protocols, blinded outcome assessment, and predefined safety monitoring are required to determine its independent therapeutic effect.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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