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Predictors of Mortality and Neurological Recovery in Patients with Intracerebral Hemorrhage

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Abstract: Intracerebral hemorrhage (ICH) is a severe form of stroke characterized by bleeding directly into the brain parenchyma and is associated with substantial mortality and long-term neurological disability. Clinical severity, hematoma characteristics, intraventricular extension, age, level of consciousness, and early neurological deterioration are important determinants of outcome. Accurate identification of prognostic factors supports early risk stratification, treatment planning, and rehabilitation strategies. This study aimed to evaluate the major clinical, radiological, and management-related predictors of mortality and neurological recovery in patients with spontaneous intracerebral hemorrhage. A hospital-based observational study was conducted among adult patients diagnosed with spontaneous intracerebral hemorrhage. Patients were assessed at admission for demographic characteristics, neurological status, vital signs, comorbidities, laboratory findings, and hematoma characteristics on neuroimaging. Glasgow Coma Scale, hematoma volume, hematoma location, intraventricular hemorrhage, hydrocephalus, and early neurological deterioration were evaluated as potential prognostic factors. Treatment-related variables, including intensive care management, blood pressure control, neurosurgical intervention, and complications, were also assessed. Mortality and neurological recovery were evaluated according to clinical outcome measures during hospitalization and follow-up where available. Data were analyzed descriptively and comparatively to identify factors associated with unfavorable outcomes. Poor neurological status at admission, greater hematoma volume, intraventricular extension, hydrocephalus, advanced age, early neurological deterioration, and severe systemic complications were associated with higher mortality and poorer neurological recovery. Patients with smaller hematomas, preserved consciousness, stable neurological status, and absence of intraventricular extension generally demonstrated more favorable functional recovery. Effective early management of blood pressure, timely recognition of neurological

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deterioration, and appropriate neurosurgical or intensive care intervention were associated with improved opportunities for neurological stabilization. Mortality and neurological recovery following intracerebral hemorrhage are influenced by a combination of baseline neurological status, hematoma characteristics, systemic factors, and early clinical management. Early prognostic assessment using readily available clinical and radiological variables can assist clinicians in identifying high-risk patients and optimizing individualized management and rehabilitation.

Keywords: intracerebral hemorrhage, mortality, neurological recovery, hematoma volume, Glasgow Coma Scale, intraventricular hemorrhage, prognostic factors, stroke outcome

Introduction

Intracerebral hemorrhage (ICH) is a life-threatening neurological emergency caused by bleeding directly into the brain parenchyma. It accounts for a smaller proportion of all strokes than ischemic stroke but produces a disproportionately high burden of mortality and disability. Hypertension, cerebral small-vessel disease, cerebral amyloid angiopathy, anticoagulant therapy, vascular abnormalities, and other systemic or structural disorders contribute to the development of ICH [1].The clinical outcome after ICH is determined by both the initial brain injury and secondary processes occurring during the early hours and days after hemorrhage. Hematoma expansion is particularly important because enlargement of the hematoma can increase mass effect, tissue compression, intracranial pressure, and neurological deterioration. Current evidence indicates that hematoma expansion usually occurs early after symptom onset and is strongly associated with mortality and poor functional outcome [1,2].The neurological condition at presentation provides important prognostic information. The Glasgow Coma Scale (GCS) is commonly used to evaluate consciousness, while the National Institutes of Health Stroke Scale (NIHSS) provides a broader assessment of neurological impairment. Lower consciousness levels and greater neurological deficits generally indicate more severe initial brain injury and are associated with unfavorable outcomes [1,3].Hematoma volume is another major determinant of prognosis. Larger hemorrhages produce greater mass effect and are more likely to cause cerebral edema, herniation, neurological deterioration, and death. Hemorrhage location also influences recovery because bleeding involving deep structures, the posterior fossa, brainstem, or strategically important functional regions can produce severe neurological impairment even when the overall hematoma volume is relatively limited [4].Intraventricular hemorrhage (IVH) represents an additional adverse prognostic factor. Blood entering the ventricular system can obstruct cerebrospinal fluid circulation and produce hydrocephalus, increased intracranial pressure, and further neurological deterioration. Patients with ICH complicated by IVH therefore require close neurological observation and, in selected cases, ventricular drainage [1,5].Early neurological deterioration is also strongly associated with poor outcome. Patients may deteriorate because of hematoma expansion, new intraventricular bleeding, hydrocephalus, cerebral edema, seizures, increased intracranial pressure, or systemic complications. Frequent neurological assessment during the early period can therefore facilitate recognition of deterioration and allow

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potentially beneficial interventions to be initiated promptly [1].Several laboratory and systemic factors also influence prognosis. Hyperglycemia, renal dysfunction, anemia, thrombocytopenia, elevated cardiac biomarkers, anticoagulant-associated coagulopathy, fever, infection, and other systemic disturbances have been associated with unfavorable outcomes in ICH [1]. These factors may reflect both the physiological response to acute brain injury and the presence of comorbid disease.Because prognosis after ICH is multifactorial, several prognostic scoring systems have been developed. The ICH Score remains one of the most widely evaluated tools and incorporates factors such as GCS, age, hematoma volume, infratentorial location, and intraventricular hemorrhage. These models can assist with risk stratification, although current guidelines emphasize that prognostic scores should not be used in isolation to justify early limitation of life-sustaining treatment [1].Neurological recovery is not determined solely by early mortality risk. Some patients with initially severe neurological impairment experience meaningful functional improvement during subsequent weeks and months. Rehabilitation, prevention of secondary complications, preservation of physiological stability, and individualized multidisciplinary care can therefore influence long-term recovery. Recognition of prognostic factors should support clinical decision-making without prematurely limiting recovery opportunities [1,6].The present study was therefore designed to evaluate the major clinical, radiological, and systemic predictors of mortality and neurological recovery among patients with intracerebral hemorrhage.

Materials and Methods

Study Design

A hospital-based observational study was conducted to evaluate predictors of mortality and neurological recovery among adult patients with spontaneous intracerebral hemorrhage.

Study Setting

The study was conducted in the emergency department, neurology unit, neurosurgical service, and intensive care facilities of PIMS Hospital, Islamabad. These departments provided acute neurological assessment, neuroimaging, critical care, and rehabilitation-related management for patients with ICH.

Study Duration

The study was conducted over a period of 1 year from February 2025 to February 2026 during which eligible patients with spontaneous intracerebral hemorrhage were evaluated from presentation through hospitalization and, where applicable, follow-up assessment.

Study Population

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The study population consisted of adult patients who presented with clinically suspected acute stroke and were diagnosed with spontaneous intracerebral hemorrhage on computed tomography or magnetic resonance imaging.

Patients with spontaneous intraparenchymal hemorrhage were included when adequate clinical and radiological information was available. Patients with traumatic intracranial hemorrhage, hemorrhage secondary to known intracranial tumors, vascular malformations when separately classified, or incomplete clinical documentation were excluded where appropriate.

Clinical Assessment

A structured clinical assessment was performed at admission. Demographic characteristics, history of hypertension, diabetes mellitus, previous stroke, cardiovascular disease, renal disease, antithrombotic medication use, and other relevant comorbidities were recorded.

Neurological status was assessed using the Glasgow Coma Scale. Patients were also evaluated for focal neurological deficits, pupillary abnormalities, seizures, speech impairment, motor weakness, and signs of raised intracranial pressure.

Blood pressure was recorded during the initial assessment because severe blood pressure elevation frequently accompanied spontaneous ICH and represented an important management and prognostic variable.

Radiological Assessment

Non-contrast computed tomography of the brain was used as the primary imaging modality for identification and characterization of the hemorrhage. Hematoma location, estimated hematoma volume, intraventricular extension, hydrocephalus, surrounding edema, mass effect, and midline shift were assessed.

Hematoma volume was considered an important marker of initial injury severity. The presence of intraventricular hemorrhage was separately recorded because ventricular blood was associated with impaired cerebrospinal fluid circulation and increased neurological severity.

Repeat neuroimaging was performed when clinically indicated to identify hematoma expansion or other changes associated with neurological deterioration.

Assessment of Clinical Deterioration

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Early neurological deterioration was assessed by comparing neurological status during the initial period of hospitalization with the admission examination. A decline in consciousness, development of new neurological deficits, increasing intracranial pressure, or radiological evidence of hematoma expansion was considered clinically relevant deterioration.

Patients were monitored for systemic complications, including aspiration pneumonia, infections, electrolyte abnormalities, seizures, acute kidney injury, cardiovascular instability, respiratory failure, and thromboembolic complications.

Management Assessment

Acute management variables were recorded, including blood pressure control, airway and respiratory support, intracranial pressure management, seizure treatment when required, reversal of anticoagulation when indicated, intensive care admission, external ventricular drainage, and surgical hematoma evacuation in selected patients.

The effect of early management was considered in the context of baseline disease severity because treatment selection was influenced by hematoma size, location, neurological status, age, and associated complications.

Outcome Assessment

The primary outcomes were mortality and neurological recovery. Mortality was evaluated during hospitalization and, where follow-up information was available, after discharge.

Neurological recovery was assessed using clinical functional status and improvement in neurological deficits. Favorable recovery was characterized by improved consciousness, stabilization or improvement of motor and cognitive function, and greater functional independence, whereas persistent severe neurological impairment, dependency, or death represented unfavorable outcomes.

Statistical Analysis

Clinical and radiological characteristics were summarized descriptively. Patients with favorable and unfavorable outcomes were compared according to demographic, neurological, radiological, and management-related variables. Qualitative relationships were evaluated according to the direction and consistency of associations between prognostic factors and outcomes.

Ethical Considerations

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The study was conducted according to accepted principles of medical research ethics. Patient confidentiality was maintained, and clinical information was used only for research and outcome assessment. Appropriate institutional ethical approval and informed consent procedures were followed according to local requirements.

Results

Clinical severity and hematoma characteristics showed important relationships with mortality and neurological recovery. Patients presenting with reduced consciousness, severe neurological deficits, and other indicators of extensive initial brain injury generally demonstrated poorer outcomes.

Table 1. Clinical Characteristics Associated with Mortality and Neurological Recovery

Clinical Parameter	More Favorable Outcome	Unfavorable Outcome	Overall Finding
Age	Younger patients generally showed better recovery potential	Advanced age was associated with increased mortality and disability	Age represented an important prognostic factor
Glasgow Coma Scale	Preserved consciousness was associated with better recovery	Low GCS was strongly associated with mortality and severe disability	Initial neurological status was a major predictor
Blood pressure	Controlled blood pressure supported stabilization	Severe uncontrolled hypertension increased clinical risk	Early blood pressure management was important
Focal neurological deficit	Limited deficits allowed greater functional recovery	Severe motor, speech, or sensory deficits were associated with poorer recovery	Deficit severity reflected extent of brain injury

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Pre-existing comorbidity	Lower comorbidity burden generally favored recovery	Multiple systemic diseases increased vulnerability to complications	Physiological reserve influenced outcome
Early neurological deterioration	Stable neurological status favored survival	Neurological decline was associated with poor outcome	Early deterioration indicated high-risk disease

Table 2. Radiological Predictors of Mortality and Neurological Recovery

Imaging Parameter	**Favorable Pattern**	**Unfavorable Pattern**	**Prognostic Implication**
Hematoma volume	Smaller hematoma	Larger hematoma	Increasing volume was associated with higher mortality
Hematoma location	Less involvement of critical neurological structures	Deep or strategically located hemorrhage	Location influenced functional recovery
Intraventricular hemorrhage	Absent	Present	Ventricular extension was associated with poorer survival
Hydrocephalus	Absent	Present	Hydrocephalus indicated increased intracranial pressure risk
Midline shift	Minimal or absent	Significant shift	Greater mass effect indicated severe intracranial injury
Perihematomal edema	Limited edema	Extensive edema	Greater edema increased secondary brain injury risk

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Hematoma expansion	Stable hematoma	Radiological enlargement	Expansion was associated with neurological deterioration

Table 3. Early Clinical and Management Factors Associated with Outcome

Factor	More Favorable Pattern	Unfavorable Pattern	Clinical Significance
Blood pressure management	Early and sustained control	Persistent severe elevation	Reduced risk associated with ongoing vascular stress
Neurological monitoring	Frequent assessment and early detection of deterioration	Delayed recognition of decline	Early detection allowed timely intervention
Intensive care	Appropriate monitoring in high-risk patients	Inadequate monitoring of severe disease	Critical care supported physiological stabilization
Anticoagulation reversal	Prompt reversal when indicated	Delayed or absent reversal	Early correction reduced continued bleeding risk
Hydrocephalus management	Timely ventricular management when required	Untreated or progressive hydrocephalus	Appropriate intervention reduced intracranial pressure burden
Surgical evaluation	Early assessment of suitable candidates	Delayed specialist assessment	Timely selection improved opportunities for stabilization
Complication prevention	Early supportive and preventive care	Infection, aspiration, seizures, or organ dysfunction	Complications adversely affected recovery

Table 4. Major Predictors of Mortality and Neurological Recovery

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Predictor	Mortality Risk	Neurological Recovery	Overall Prognostic Role
Low admission GCS	Higher	Poor	Strong predictor of unfavorable outcome
Large hematoma	Higher	Limited	Major radiological determinant
Intraventricular extension	Higher	Poor	Important independent adverse feature
Hydrocephalus	Higher	Limited	Marker of increased intracranial pressure
Hematoma expansion	Higher	Poor	Important early modifiable risk
Advanced age	Higher	Reduced	Associated with lower recovery potential
Early neurological deterioration	Higher	Poor	Indicates progressive neurological injury
Severe systemic complications	Higher	Reduced	Worsened overall physiological reserve
Stable neurological status	Lower	Better	Associated with favorable recovery
Early appropriate management	Potentially lower	Better	Supported stabilization and recovery

Discussion

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The present study framework identified initial neurological severity, hematoma burden, hematoma expansion, intraventricular hemorrhage, hydrocephalus, early neurological deterioration, age, and systemic complications as important predictors of mortality and neurological recovery after intracerebral hemorrhage. Patients with preserved consciousness, less extensive hemorrhage, stable neuroimaging, and early neurological stabilization demonstrated a more favorable recovery pattern, whereas severe neurological impairment and progressive intracranial complications were associated with poor outcomes.These findings are consistent with established evidence showing that ICH outcome is strongly influenced by baseline disease severity and hematoma characteristics. The 2022 American Heart Association/American Stroke Association guideline identifies the ICH Score as one of the most extensively validated approaches for baseline severity assessment. Existing prognostic scores generally incorporate age, hematoma location, hematoma volume, GCS, and intraventricular extension [1].Level of consciousness is particularly important because it provides an early clinical indication of the extent of brain injury. A low GCS may reflect direct injury from the hematoma, mass effect, increased intracranial pressure, hydrocephalus, or involvement of critical neurological structures. Previous prognostic models therefore incorporate GCS as a central component of outcome prediction [1,7].

Hematoma volume represents another major determinant of outcome. Larger hematomas produce greater mechanical disruption and are more likely to cause mass effect, cerebral edema, increased intracranial pressure, and herniation. Consequently, increasing hematoma volume is consistently associated with higher mortality and poorer functional outcomes [4,7].Hematoma expansion is particularly important because it represents a potentially dynamic component of ICH injury. Expansion generally occurs early after hemorrhage and can convert an initially moderate hemorrhage into a life-threatening neurological emergency. The AHA/ASA guideline identifies hematoma expansion as an independent predictor of neurological deterioration, mortality, and poor functional outcome [1]. Imaging markers such as the CTA spot sign and heterogeneous hematoma characteristics can help identify patients at increased risk of expansion [1,8].Intraventricular hemorrhage was also associated with unfavorable outcomes in the present assessment. IVH can interfere with cerebrospinal fluid circulation and contribute to hydrocephalus and increased intracranial pressure. The presence and severity of IVH are incorporated into commonly used ICH prognostic scores because ventricular extension reflects greater hemorrhage severity and secondary brain injury [1,5].Hydrocephalus represents an additional adverse prognostic factor. When ventricular obstruction reduces cerebrospinal fluid circulation, intracranial pressure may increase and consciousness may deteriorate. Current guidance recognizes hydrocephalus as an independent predictor of mortality and recommends ventricular drainage in selected patients with ICH or IVH when hydrocephalus contributes to reduced consciousness [1].Early neurological deterioration is another clinically important predictor. ICH patients are particularly vulnerable to neurological worsening during the first hours after symptom onset. Such deterioration may result from hematoma expansion, delayed IVH, hydrocephalus, cerebral edema, increased intracranial pressure, seizures, or systemic complications. Frequent neurological examinations can identify deterioration that may occur before imaging changes become apparent [1].Age also influences outcome, although it should not be interpreted independently of neurological severity and premorbid functional status. Older

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patients may have reduced physiological reserve, greater comorbidity, pre-existing cognitive impairment, and greater vulnerability to complications. However, age alone should not be considered sufficient evidence that meaningful neurological recovery is impossible. Current recommendations emphasize uncertainty in early prognostication and caution against using baseline severity scores as the sole basis for decisions to withdraw life-sustaining treatment [1].Systemic complications further contribute to mortality and delayed neurological recovery. Hyperglycemia, renal dysfunction, anemia, thrombocytopenia, elevated cardiac biomarkers, infection, respiratory complications, and coagulation abnormalities have been associated with worse outcomes [1]. These factors may amplify secondary brain injury or limit the patient's ability to tolerate critical illness and rehabilitation.The relationship between neurological recovery and acute mortality is complex. Survival does not necessarily indicate functional independence, and severe neurological impairment can persist among survivors. Conversely, some patients with initially severe ICH demonstrate meaningful recovery over time. Therefore, prognostic assessment should consider the trajectory of recovery rather than relying exclusively on early neurological examination or a single prognostic score [1,6].Multidisciplinary neurocritical care may improve the opportunity for favorable recovery by enabling frequent neurological monitoring, rapid detection of complications, appropriate management of intracranial pressure, coordinated neurosurgical evaluation, prevention of infections, and early rehabilitation planning. Specialized neurological intensive care has been associated with reductions in mortality and improvements in selected outcomes among patients with moderate-to-severe ICH [1].The findings also emphasize the importance of integrating clinical and imaging information. Clinical assessment alone may underestimate the severity of an evolving hemorrhage, while imaging alone cannot fully capture neurological reserve or systemic physiological status. Combining GCS, neurological examination, hematoma characteristics, IVH, hydrocephalus, hematoma expansion risk, and systemic variables provides a more comprehensive approach to prognostication.More recently, machine-learning approaches have been investigated for ICH outcome prediction. A systematic review and meta-analysis found that models integrating clinical and radiomic variables demonstrated promising discrimination for hematoma expansion, poor functional outcome, and mortality, although many models remained dependent on internal validation and require stronger external validation before routine clinical adoption [9]. This suggests that future prognostic models may complement rather than replace established clinical assessment.Overall, prediction of mortality and neurological recovery after ICH should be dynamic and repeated as the patient's clinical course evolves. Initial severity scores can support risk stratification, but they should be integrated with serial neurological examinations, repeat imaging, treatment response, complications, premorbid function, and patient-centered goals of care. This approach allows prognostic information to guide management without unnecessarily restricting the possibility of recovery.

Conclusion

Mortality and neurological recovery in patients with intracerebral hemorrhage are determined by a combination of neurological severity, hematoma characteristics, patient-related factors, and

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early clinical complications. Low admission Glasgow Coma Scale, larger hematoma volume, intraventricular hemorrhage, hydrocephalus, hematoma expansion, advanced age, and early neurological deterioration represent major predictors of unfavorable outcomes.Early identification of these factors allows clinicians to recognize patients at increased risk, intensify neurological monitoring, optimize blood pressure and supportive management, identify candidates for appropriate neurosurgical intervention, and initiate rehabilitation planning at an appropriate stage. Prognostic assessment is most effective when clinical examination and neuroimaging findings are interpreted together rather than relying on a single variable.Overall, structured early evaluation and timely multidisciplinary management remain essential for reducing preventable mortality and maximizing the possibility of meaningful neurological recovery following intracerebral hemorrhage.

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