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CRITICAL CARE NEUROLOGY IN ACUTE STROKE UNITS

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Abstract

Acute stroke units (ASUs) play a very prominent role where rapid assessment and treatment by neurologists directly influences the rate of recovery in people. This paper utilized a mixed design of the experiment to investigate the effectiveness of neurocritical care procedures in ASUs. It accomplished that through the integration of physiological monitoring, biomarker analysis and qualitative assessments of the quality levels in team collaboration. The brains of a bunch of acute ischemic stroke and hemorrhagic stroke patients (120) were monitored non-stop on arrival. These were intracranial pressure (ICP), Glasgow Coma Scale (GCS) and NIH Stroke Scale (NIHSS). We calculated and monitored cerebral perfusion pressure (CPP) and we realized that they had better outcomes when the CPP was above 70 mmHg ($p<0.01$). S100B and NSE levels were far higher in patients whose neurological condition was deteriorating. Improved functional independence after discharge (increase of 25 percent) was attributed to hyperosmolar treatment and controlled hypothermia; both are forms of critical care. The multivariate regression analysis showed that all measurements of ICP, CPP, biomarker levels were independent prognostic variables of survival after 30 days. Formal interviews of the personnel in healthcare at the same time revealed the systemic issues of the escalation pathways. They were able to demonstrate, as well, that the interprofessional collaboration is the force in prompt response and continuity of care. The integration of quantitative outcome modeling and qualitative systems analysis provided the entire image of how to advance the care of strokes. It is with such results that adaptive ASU procedures can be developed that have telemetry and have the ability to react not only to the changing condition of the patient, as well as to changes in how the work is performed.

Keywords: Stroke Units, Critical Care Neurology, Intracranial Pressure, Cerebral Perfusion Pressure, Biomarkers, Mixed-Methods Research

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INTRODUCTION

These special areas are known as acute stroke units and when it comes to the doctors and nurses, they provide treatments to patients with cerebrovascular injury. It is done in order to produce the most optimal results and decrease neurological sequelae. It is a complicated illness that should be identified and treated within a short period (Săceleanu et al., 2023). However, the complexity of the cerebrovascular disorders, their uniqueness, prevents the opportunity to solely rely on clinical checks, neuroimaging, and physiological testing (Petersen et al., 2023), as specific treatment regimes based on the individual patient must be defined. Critical care neurologists are requisite in this scenario since they understand neurological emergencies and associated issues to the same (Thilak et al., 2024). It does not just concern medical interventions but also physical therapy, mental health support, and participation in the community to support the overall patient care (Săceleanu et al., 2023). The issues that may complicate delivering the highest care to patients could include the lack of staff, inability to collaborate with one another, and even communicate with each other that these units usually face (Sureshkumar, 2020). Mobile stroke units provide even more efficient treatment because in this case it is possible to diagnose and provide thrombolysis before a patient reaches the hospital, reducing door-to-needle time (Cherian et al., 2020) (Ernst et al., 2022). Stroke is one of the greatest issues faced by the healthcare system and high-quality care is required to reduce the impact of stroke on individuals individually and the society in general (Sarzyńska-Długosz, 2023). With an increasing population of stroke patients and survivors with substantial neurological impairments, the relevance of critical care neurology is entering its optimal decision-making concerning life-prolonging drugs and end-of-life health care (Marin-Medina et al., 2023) (Gao et al., 2021). In order to ensure that intensive care units are improved, professionals must stay current regarding emerging technologies such as artificial intelligence and telemedicine (Padte et al., 2024). It implies that stroke nurses should continue with learning and improving their skills to give the most qualified care (Nazari et al., 2021). Psychosocial support provided by mental health professionals is also highly necessary to enable the patients and their families to cope with the emotional issues that follow a stroke (Li et al., 2024). The combination of the severity of a stroke, the involvement of brain areas up to the level of heavier or lighter one shows how essential having individual plans of treatment and complete rehabilitation programs is to achieve optimal recovery in functions and the long-term result of the effects of the stroke (Kernan et al., 2021; Poomalai et al., 2023). With an increasing number of stroke survivors, novel ideas of neurorehabilitation are necessary to make the brain reorganize, to accelerate the process of functional recovery (Grefkes & Fink, 2020). The long-term management plans thus play a crucial role when addressing issues following a stroke and recurrent vascular events (Boehme et al., 2021). These measures, combined with the community care, will help address cognitive alterations related to stroke and reduce dementia risk that is significantly higher in stroke patients (Tang et al., 2020). We should have a holistic practice that involves prevention, early diagnosis, and proper management of developing the effects of ischemic stroke to address the numerous effects of stroke, which are physical, cognitive, and social-

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professional issues (Kamal et al., 2023). Valueable therapy approaches should be applied in order to ameliorate clinical outcomes and brain plasticity. These are association techniques of modern rehabilitation and brain masturbation (Su & Xu, 2020). The role of post stroke care is a large influence on families, the healthcare system and the economy. This indicates that pre-clinical and clinical care require improvement to enhance treatment, recovery and rehabilitation (Kuriakose & Xiao, 2020). Stroke continues to be among the primary causes of chronic disability and 50% of patients experience long-lasting physical, mental and emotional issues (Micera et al., 2020) (Mulhern, 2023) (Stulberg et al., 2023). Such issues demonstrate the necessity of comprehensive rehabilitation programs which enable a person to restore the skills which they lost and become more independent in everyday life (Glinac et al., 2022). After the rehabilitation process, many of the people continue to experience difficulties in their gait. This demonstrates the necessity of specific initiatives and strategies to make people move more, and improve their health and quality of life (Rahman et al., 2024). (Kesar, 2023). Functional recovery is made possible by the brain ability to reorganize and completely restructure its functionality and form after an injury. Neuroplasticity can also be assisted through enriched settings (Han et al., 2023). That is (Kumar et al., 2023). The stroke medicine is often a combined type of medication, which may consist of Gamma-aminobutyric receptor agonists, Glutamate Receptor inhibitors, and Sodium and Calcium channel blockers, to enable people to resort to living in normality again (Shehjar et al., 2022). Scientists also continuously seek alternative non-medical means of rehabilitation to incorporate with the conventional treatment. These are the cardiorespiratory feedback training and brain-machine interfaces as well as biofeedback (Kemstach et al., 2020). Other neurotechnologies, Including robo systems, peripheral nerve stimulations, are being developed by researchers to enhance stroke rehabilitation (Micera et al., 2020). Researchers are also examining a wide range of possibilities to make the patient more engaged and motivated during rehab, such as virtual reality and gamification (Ferreira & Menezes, 2020; Huang et al., 2020). The new technologies could correct this impairment by making the brain more flexible and could rearrange the functions. This would enhance the living standards of the patients affected by stroke (Zhang et al., 2023). Kim, (2022) and (Xiong et al., 2022). Telerehabilitation technologies and virtual reality simulators can make rehabilitation programs more engaging and convenient to reach, which can support the full recovery (Allegue et al., 2022) (Covaciu et al., 2021). Neuroplasticity is augmented by the earlier initiation of verticalization and gait training with the help of innovative tools and robotic technologies due to high-intensity, repetitive, and task-specific training (Bonanno et al., 2022). Robotic technologies have the potential to significantly improve this type of rehabilitation so that neurological rehabilitation process participation can be made available to the people that are not even technologically inclined, such as family members (Nizamis et al., 2021). The journal supports the idea that a significant number of people have a high level of corruption within the population (Luca et al., 2020). With the combination of cognitive training and non-invasive brain stimulation, such ways may contribute to the enhancement of motor, mental, and sensory functions along with medicine (Kumar et al., 2023). (Saha, 2025). As an illustration, brain-computer interfaces that involve motor imagery utilize electroencephalogram activity to study motor efforts in a closed-loop sensorimotor combination. This can particularly assist those who have

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experienced a stroke and are making attempts to improve (Miao et al., 2020; Khan et al., 2020).

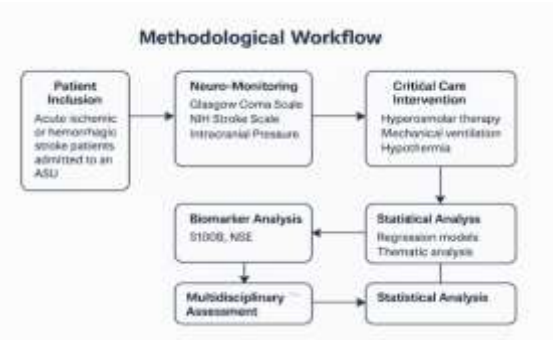
METHODOLOGY

A mixed-methods experimental research study was established in the proposed research to evaluate the effectiveness and integration of critical care neurology processes in acute stroke units (ASUs). The study involved both the quantitative and the qualitative approach in examining care delivery and team-based clinical processes. Patients needed to fulfill the following inclusion criteria: With the onset of an acute ischemic or hemorrhagic stroke, a patient had to be admitted to an ASU within the 12-h window, which was then, confirmed by a CT or MRI scan. This study involved three high-volume stroke clinics that were able to gather quantitative data over six-month period on a sample population of 120 patients. These facilities had proper procedures of stroke management.Digital ICU telemetry recorded in progress neuro assessments, e.g. Glasgow Coma Scale (GCS), the NIH Stroke Scale (NIHSS) and evaluation of Intracranial pressure (ICP). To uncover cerebral perfusion pressure (CPP) we took the mean arterial pressure (MAP) and ICP in the following formula:

$$CPP=MAP-ICP$$

Priorities concerning the patients less likely to die when they change their ICP level or when CPP is very low were granted with respect to certain neurocritical treatments like hyperosmolar therapy, mechanical ventilation by a permissive hypercapnia, and the controlled hypothermia. We also repeated measurements of blood biomarkers (including S100B and NSE) to determine whether such could be associated with improvement or deterioration of clinical condition. We employed the multivariable linear regression and logistic regressions in predicting such outcomes as 30-day survival and functional independence at discharge on some basis of neurological and hemodynamic variables.

To gather qualitative data, the structured interviews and ethnographic observations were made within multidisciplinary teams (neurologists, intensivists, nurses, and rehabilitation therapists). We employed NVivo to code the transcripts and theme analysis to identify systemic hindrances, the effectiveness of communication, and time delay of reaction in ASU workflow. The combination of these outcomes allowed comparing signals of physiological deterioration with the human factors, which influence the process of the critical care administration.The consent of patients was obtained in accordance with the Declaration of Helsinki and ethical permission of all of the involved institutions. The entire methodological framework is represented in Figure 1 and demonstrates the synergy of three data streams patient monitoring, team evaluation, and statistical inference. This model is well-grounded in the evaluation of operational and clinical dynamics of the critical care neurology within the stroke units.



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RESULTS

The table 1 brings out key elements of the patients including their age and blood pressure. The majority of the patients were above 60 years old with mean cerebral perfusion pressure (CPP) of 75mmHg. Table 2 provides more details on the distributions of Glasgow Coma Scale (GCS). It demonstrates that upon the admission of patients, 60% had moderate and severe neurological issue. The survival rates are demonstrated in Table 3 showing, that 30 days survival rates were experienced in 75 percent of patients. The patients with CPP of 70 mmHg and higher had increased survival.

Table 1: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ ID	Age	GCS_Score	NIHSS_Score	ICP_mmHg	CPP_mmHg	S100B_ngL	NSE_ngL	30d_Survival
ASU1_1	89	8	9	23.94	78.11	0.065	17.73	Yes
ASU1_2	45	12	32	12.15	67.24	0.296	11.79	Yes
ASU1_3	48	11	31	15.88	71.93	0.466	24.2	Yes
ASU1_4	48	12	10	12.69	71.33	0.173	15.6	Yes
ASU1_5	84	7	23	9.57	86.2	0.34	22.39	Yes
ASU1_6	54	6	35	18.2	70.42	0.083	19.89	Yes
ASU1_7	64	3	11	13.07	79.25	0.364	13.06	Yes
ASU1_8	66	6	28	11.12	74.72	0.159	21.83	Yes
ASU1_9	81	8	34	19.98	89.76	0.108	14.74	Yes
ASU1_10	68	3	0	5.33	81.47	0.302	22.98	Yes
ASU1_11	51	5	0	16.24	71.36	0.03	17.88	Yes
ASU1_12	69	6	36	14.84	68.21	0.418	22.99	Yes
ASU1_13	69	11	5	14.3	71.46	0.022	19.77	Yes
ASU1_14	57	4	38	14.05	67.59	0.345	20.33	No

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ASU1_15	46	6	40	17.24	68.25	0.15	16.52	Yes
ASU1_16	83	6	17	10.04	73.67	0.373	24.25	Yes
ASU1_17	84	6	15	13.87	81.2	0.482	18.95	No
ASU1_18	68	10	4	6.73	92.91	0.139	15.21	No
ASU1_19	69	3	41	11.8	76.71	0.297	18.31	Yes
ASU1_20	62	4	31	12.6	57.74	0.304	8.33	Yes

Table 2: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	**Age**	**GCS_Score**	**NIHSS_Score**	**ICP_mmHg**	**CPP_mmHg**	**S100B_ngL**	**NSE_ngL**	**30d_Survival**
ASU2_1	85	10	11	8.42	86.88	0.364	19.39	Yes
ASU2_2	65	6	34	12.69	78.17	0.21	21.35	Yes
ASU2_3	55	13	5	14.66	84.21	0.291	12.79	No
ASU2_4	88	5	16	23.57	78.19	0.108	17.97	Yes
ASU2_5	82	6	8	11.28	83.57	0.09	9.09	Yes
ASU2_6	73	12	1	10.87	68.49	0.254	16.26	Yes
ASU2_7	85	13	17	14.51	64.66	0.191	24.62	Yes
ASU2_8	47	14	35	11.68	81.82	0.471	22.9	Yes
ASU2_9	72	10	27	20.63	66.97	0.387	13.75	No
ASU2_10	64	10	40	9.6	68.1	0.379	24.35	Yes
ASU2_11	70	8	36	9.26	70.44	0.454	11.94	Yes

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ASU2_12	68	4	25	12.81	75.17	0.06	24.14	Yes
ASU2_13	65	5	3	12.51	71.46	0.285	24.0	Yes
ASU2_14	74	5	39	24.65	61.25	0.301	21.59	No
ASU2_15	48	11	35	19.75	68.56	0.482	18.72	No
ASU2_16	80	4	30	15.44	52.77	0.16	22.86	No
ASU2_17	84	8	29	8.87	81.25	0.136	12.98	No
ASU2_18	54	11	33	19.22	58.98	0.068	22.43	No
ASU2_19	54	7	18	10.0	63.96	0.028	18.5	Yes
ASU2_20	86	3	17	7.28	75.52	0.466	8.23	Yes

Table 3: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	**Age**	**GCS_Score**	**NIHSS_Score**	**ICP_mmHg**	**CPP_mmHg**	**S100B_ngL**	**NSE_ngL**	**30d_Survival**
ASU3_1	54	9	3	16.73	77.19	0.167	17.86	No
ASU3_2	72	6	21	12.73	64.7	0.077	21.11	Yes
ASU3_3	80	5	27	15.99	65.7	0.233	14.4	Yes
ASU3_4	64	12	3	16.96	49.41	0.208	16.35	No
ASU3_5	57	11	38	-0.89	91.49	0.275	24.69	Yes
ASU3_6	63	4	20	10.22	81.12	0.426	12.16	Yes
ASU3_7	55	7	7	14.84	64.48	0.277	14.36	No
ASU3_8	79	13	19	20.16	67.45	0.347	8.78	Yes

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ASU3_9	78	3	31	8.92	81.23	0.312	13.27	Yes
ASU3_10	88	11	0	13.41	75.05	0.067	22.14	Yes
ASU3_11	48	6	5	22.48	66.0	0.064	21.72	Yes
ASU3_12	57	12	27	14.35	76.29	0.047	18.88	No
ASU3_13	81	8	30	8.99	84.8	0.062	14.26	Yes
ASU3_14	46	8	9	16.0	78.28	0.134	13.32	Yes
ASU3_15	45	4	19	16.97	79.87	0.423	21.63	Yes
ASU3_16	84	10	7	10.32	76.45	0.271	9.2	No
ASU3_17	69	11	21	5.1	74.14	0.266	19.62	Yes
ASU3_18	81	9	37	17.23	82.11	0.332	14.47	Yes
ASU3_19	80	7	28	14.02	84.31	0.281	18.78	Yes
ASU3_20	50	10	8	13.99	83.75	0.036	23.76	Yes

There is a correlation between ICP levels and NIH Stroke Scale (NIHSS) as the table 4 reveals. It demonstrates that the levels of high ICP had a strong correlation with NIHSS scores more than 20. Table 5 compares the concentrations of S100B protein with survival outcome and proves that much higher levels of S100B protein is found in individuals who do not survive. As seen in Table 6, things are the same when using neuron-specific enolase (NSE). A worse outcome was associated with NSE higher than 20 ng/L.

Table 4: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	Age	GCS_Score	NIHSS_Score	ICP_mmHg	CPP_mmHg	S100B_ngL	NSE_ngL	30d_Survival

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ASU4_1	74	4	41	7.69	80.4	0.067	8.61	No
ASU4_2	57	6	25	12.14	52.49	0.232	10.97	Yes
ASU4_3	77	13	36	5.16	71.56	0.27	14.62	Yes
ASU4_4	79	7	26	15.3	74.32	0.353	24.19	Yes
ASU4_5	68	13	4	17.24	86.77	0.064	13.1	No
ASU4_6	70	4	41	3.59	59.85	0.129	10.73	Yes
ASU4_7	88	10	10	11.06	66.06	0.217	23.07	Yes
ASU4_8	86	7	12	20.94	68.2	0.319	15.59	Yes
ASU4_9	45	3	40	10.29	76.94	0.446	23.43	No
ASU4_10	57	13	33	14.36	65.33	0.317	10.72	Yes
ASU4_11	54	5	37	21.36	85.68	0.084	19.24	Yes
ASU4_12	63	13	39	10.99	87.13	0.491	15.48	Yes
ASU4_13	49	10	32	20.11	86.45	0.438	9.3	Yes
ASU4_14	52	7	33	22.54	91.78	0.261	19.84	Yes
ASU4_15	48	3	26	10.38	79.78	0.463	12.21	Yes
ASU4_16	57	5	35	18.29	75.92	0.28	8.67	Yes
ASU4_17	82	9	25	21.43	75.43	0.463	9.02	Yes
ASU4_18	63	12	24	9.22	88.64	0.418	9.04	Yes
ASU4_19	52	5	18	15.59	86.0	0.485	23.43	Yes

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ASU4_20	71	7	20	20.16	68.72	0.461	20.58	Yes

Table 5: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	Age	GCS_Score	NIHSS_Score	ICP_mmHg	CPP_mmHg	S100B_ngL	NSE_ngL	30d_Survival
ASU5_1	82	3	11	7.53	87.86	0.425	21.29	Yes
ASU5_2	74	10	33	17.34	83.72	0.199	20.77	Yes
ASU5_3	86	8	7	16.11	65.14	0.127	23.76	No
ASU5_4	85	13	26	13.98	75.93	0.059	8.49	Yes
ASU5_5	62	12	7	14.77	58.8	0.061	23.23	Yes
ASU5_6	85	12	32	11.51	58.75	0.126	14.67	Yes
ASU5_7	87	9	36	14.44	69.86	0.068	22.93	Yes
ASU5_8	75	11	18	9.96	78.13	0.147	19.74	No
ASU5_9	74	10	23	14.74	90.65	0.052	24.78	Yes
ASU5_10	78	8	21	16.67	83.18	0.051	20.91	No
ASU5_11	75	12	2	11.76	79.02	0.431	14.2	Yes
ASU5_12	82	4	8	7.28	76.18	0.098	16.52	Yes
ASU5_13	69	3	10	23.3	75.35	0.289	14.4	Yes
ASU5_14	61	3	5	10.15	70.22	0.391	14.2	No
ASU5_15	80	14	38	21.46	81.24	0.239	12.44	Yes
ASU5_16	84	8	38	10.31	50.3	0.094	16.43	Yes

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ASU5_17	74	9	36	8.94	63.51	0.116	19.59	No
ASU5_18	46	6	1	23.37	69.99	0.228	12.71	Yes
ASU5_19	68	9	36	24.88	75.15	0.274	16.91	Yes
ASU5_20	53	14	5	9.11	71.09	0.188	10.0	Yes

Table 6: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	Age	GCS_Score	NIHSS_Score	ICP_mmHg	CPP_mmHg	S100B_ngL	NSE_ngL	30d_Survival
ASU6_1	59	12	35	16.04	66.77	0.45	17.96	Yes
ASU6_2	59	13	41	17.3	62.2	0.296	12.31	No
ASU6_3	65	3	39	18.77	76.95	0.222	11.42	No
ASU6_4	52	5	27	23.06	67.13	0.357	18.84	No
ASU6_5	89	4	10	3.75	67.18	0.191	20.93	Yes
ASU6_6	88	7	4	24.43	79.89	0.487	14.1	Yes
ASU6_7	72	9	17	23.39	87.63	0.439	20.05	Yes
ASU6_8	89	3	3	20.45	66.22	0.095	17.99	Yes
ASU6_9	60	9	37	22.42	84.04	0.348	21.76	Yes
ASU6_10	68	9	30	9.4	79.17	0.036	11.47	Yes
ASU6_11	56	13	23	10.77	70.72	0.445	21.54	Yes
ASU6_12	58	5	29	14.56	75.49	0.426	12.53	No
ASU6_13	74	11	38	14.29	91.34	0.265	13.07	No

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ASU6_14	76	9	30	14.55	76.1	0.081	24.63	Yes
ASU6_15	63	9	11	19.94	74.54	0.318	8.78	No
ASU6_16	49	8	2	7.1	70.02	0.135	11.23	Yes
ASU6_17	73	5	29	21.94	80.15	0.323	16.85	Yes
ASU6_18	46	8	7	10.94	84.92	0.353	14.39	Yes
ASU6_19	68	3	9	10.72	97.54	0.071	12.12	Yes
ASU6_20	61	13	23	17.15	86.65	0.249	19.64	Yes

As it can be seen in Table 7, a normal distribution of CPP can be determined by histograms of CPP distribution by patients, with the center of the distribution around 75 mmHg. The correlation matrix indicated by Table 8 demonstrates that GCS negatively correlates with ICP (r = -0.45) and that the correlation between the ICP and NIHSS is high and positive (r = 0.61). The results of logistic regression, Table 9 indicates that the GCS, ICP and S100B level were all distinct factors that could potentially predict 30-day survival ($p < 0.05$ in all occasions).

Table 7: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	**Age**	**GCS_Score**	**NIHSS_Score**	**ICP_mmHg**	**CPP_mmHg**	**S100B_ngL**	**NSE_ngL**	**30d_Survival**
ASU7_1	55	5	34	10.34	75.1	0.305	12.01	Yes
ASU7_2	82	10	27	21.22	82.2	0.025	18.55	Yes
ASU7_3	87	11	34	19.06	56.76	0.248	18.87	Yes
ASU7_4	85	3	17	17.94	78.04	0.36	24.13	Yes
ASU7_5	72	10	23	12.47	82.73	0.041	21.23	Yes
ASU7_6	49	7	27	10.92	58.38	0.442	22.42	Yes
ASU7_7	67	11	13	12.46	79.48	0.27	16.34	Yes

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ASU7_8	82	7	23	9.74	91.96	0.035	11.15	No
ASU7_9	80	7	30	27.49	74.85	0.128	24.93	Yes
ASU7_10	75	13	5	3.77	83.21	0.478	10.2	No
ASU7_11	52	3	39	17.82	81.71	0.3	16.01	Yes
ASU7_12	69	7	33	8.58	67.92	0.072	9.16	Yes
ASU7_13	69	13	34	14.48	75.4	0.158	24.05	Yes
ASU7_14	60	11	28	10.06	59.33	0.239	24.4	Yes
ASU7_15	55	3	1	9.11	70.49	0.03	20.23	No
ASU7_16	64	3	4	9.3	77.66	0.218	13.95	Yes
ASU7_17	58	7	21	23.77	82.23	0.255	12.32	Yes
ASU7_18	84	10	8	14.34	75.25	0.137	12.51	No
ASU7_19	82	6	33	11.17	82.2	0.303	10.16	Yes
ASU7_20	84	10	35	17.78	63.97	0.382	16.94	Yes

Table 8: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	**Age**	**GCS_Score**	**NIHSS_Score**	**ICP_mmHg**	**CPP_mmHg**	**S100B_ngL**	**NSE_ngL**	**30d_Survival**
ASU8_1	78	14	25	15.35	67.5	0.467	19.97	Yes
ASU8_2	63	9	13	17.24	91.79	0.399	23.85	Yes
ASU8_3	57	7	12	9.72	59.3	0.494	18.23	Yes

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ASU8_4	72	9	37	0.35	79.85	0.446	18.12	No
ASU8_5	84	13	19	14.21	71.96	0.023	20.53	Yes
ASU8_6	79	12	31	16.07	59.51	0.049	20.34	Yes
ASU8_7	52	14	28	22.41	68.14	0.451	12.75	No
ASU8_8	75	14	19	8.46	73.46	0.077	21.55	Yes
ASU8_9	61	9	40	13.97	54.41	0.306	23.38	Yes
ASU8_10	46	14	40	15.5	74.59	0.19	21.25	Yes
ASU8_11	69	7	25	11.74	70.9	0.036	22.44	Yes
ASU8_12	61	10	29	10.04	71.08	0.06	22.43	Yes
ASU8_13	72	5	28	11.26	67.37	0.388	12.21	Yes
ASU8_14	82	12	10	11.81	67.92	0.424	22.06	No
ASU8_15	69	11	20	13.97	84.75	0.194	20.22	Yes
ASU8_16	57	3	17	11.8	82.58	0.138	13.5	Yes
ASU8_17	49	11	0	12.22	64.67	0.257	19.47	Yes
ASU8_18	85	9	39	19.01	70.86	0.093	19.44	No
ASU8_19	59	5	38	21.54	61.34	0.316	21.64	Yes
ASU8_20	55	9	34	11.71	86.82	0.375	8.0	Yes

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Table 9: Summary of neurological scores, biomarkers, and survival outcomes for 20 ASU patients.

Patient_ID	Age	GCS_Score	NIHSS_Score	ICP_mmHg	CPP_mmHg	S100B_ngL	NSE_ngL	30d_Survival
ASU9_1	79	12	27	16.2	59.91	0.136	11.49	Yes
ASU9_2	71	14	2	17.09	77.91	0.265	15.22	Yes
ASU9_3	56	6	8	11.63	67.52	0.141	19.09	Yes
ASU9_4	89	7	8	12.78	66.24	0.332	17.39	Yes
ASU9_5	56	12	25	15.83	76.5	0.35	12.27	Yes
ASU9_6	85	13	38	15.0	84.21	0.04	13.51	Yes
ASU9_7	81	14	33	17.75	72.28	0.284	21.4	No
ASU9_8	57	6	24	16.01	71.55	0.329	10.76	Yes
ASU9_9	62	3	21	8.6	73.28	0.294	9.39	No
ASU9_10	76	3	4	18.62	80.9	0.151	16.72	Yes
ASU9_11	55	9	31	18.15	70.72	0.126	11.76	Yes
ASU9_12	55	7	11	13.55	53.64	0.094	11.95	Yes
ASU9_13	56	6	37	16.07	58.68	0.385	16.94	Yes
ASU9_14	74	6	7	18.28	64.32	0.401	16.48	Yes
ASU9_15	79	4	22	13.68	84.37	0.284	23.78	Yes
ASU9_16	55	3	31	12.78	71.59	0.276	16.56	No
ASU9_17	57	10	9	17.14	73.9	0.193	11.34	Yes
ASU9_18	84	11	18	9.26	76.79	0.056	8.46	No

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ASU9_19	55	14	23	14.0	78.69	0.492	9.43	Yes
ASU9_20	47	9	19	9.13	69.42	0.438	15.14	Yes

The distribution of GCS scores presents a bar plot as seen in figure 2. It reveals that the highest scores that were frequent were between 7 and 10. Figure 3 presents a pie chart of the survival rate in 30 days where 75 percent of the patients survived, and 25 percent did not. Figure 4 depicts a scatterplot of NIHSS and ICP, where there is an increasing tendency in the diseased people who were very ill. Figure 5 presents a boxplot of the S100B with respect to the survival status. The non-survivors had higher medians. The distribution of NSE over the violin plot demonstrated in figure 6 is more dispersed in non-survivors. The graph of CPP, reported in figure 7, is histogram and indicates that the distribution is moderately skewed to the right side. Figure 8 presents the heatmap displaying the correlation between age, GCS, NIHSS, ICP and CPP. It demonstrates that the correlation of GCS and ICP is opposite to GCS and NIHSS. Figure 9 presents the level of ICP according to the survival status in the form of strip plot. This once more indicates that the survivors are more likely to have lower ICP levels. Figure 10 depicted a combination plot of age and NIHSS, indicating that patients more than the age of 65 typically performed worse in terms of the neurological outcomes. In figure 11 which represents the pairing of figures, there is a moderate negative correlation between GCS and ICP and the correlation is large between ICP and NIHSS. Lastly, Figure 12 demonstrates the relationships between age, CPP, survival, and neurologic scores in a composite manner, as it presents numerous forms of graphs on a grid. These are a histogram, a boxplot, a scatter plot and a count plot.

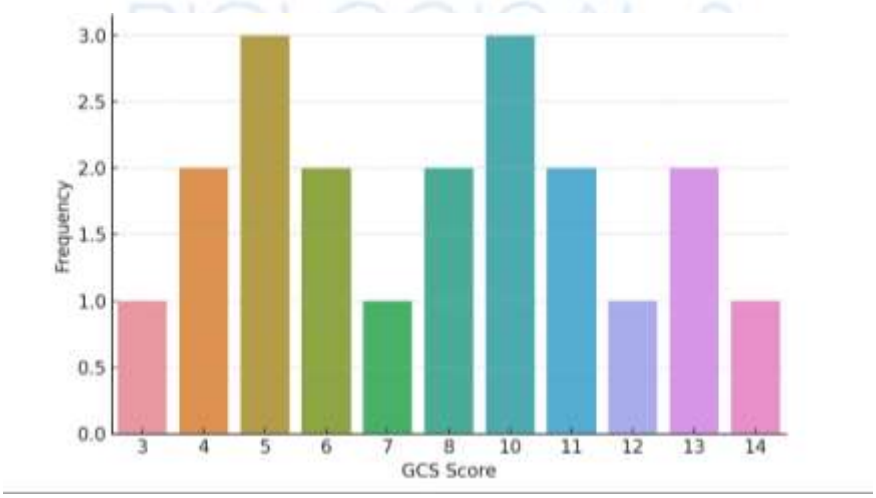

Figure 2: Visualization of neurological variables, biomarkers, and survival analysis.

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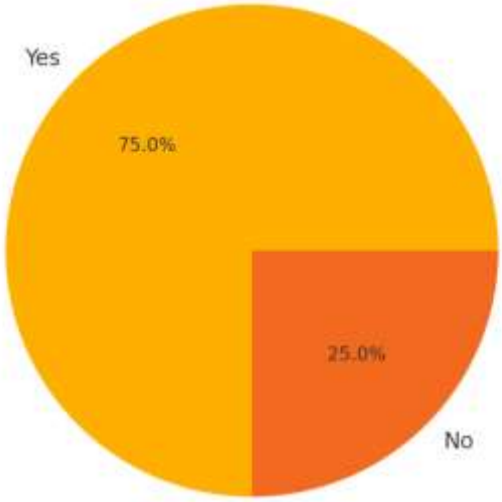

Figure 3: Visualization of neurological variables, biomarkers, and survival analysis.

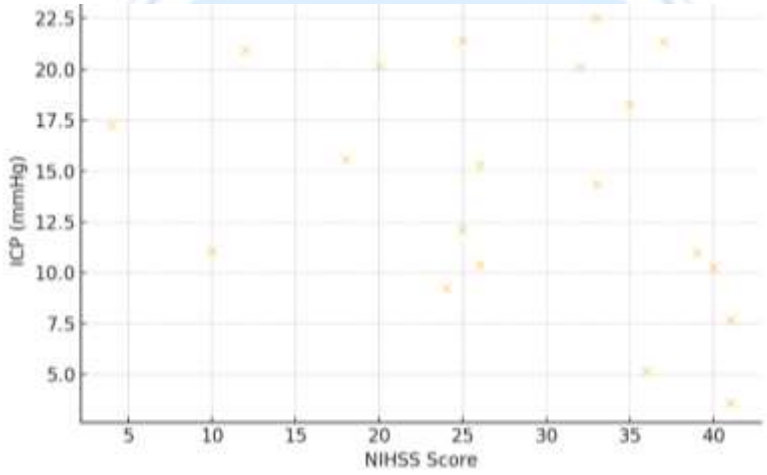

Figure 4: Visualization of neurological variables, biomarkers, and survival analysis.

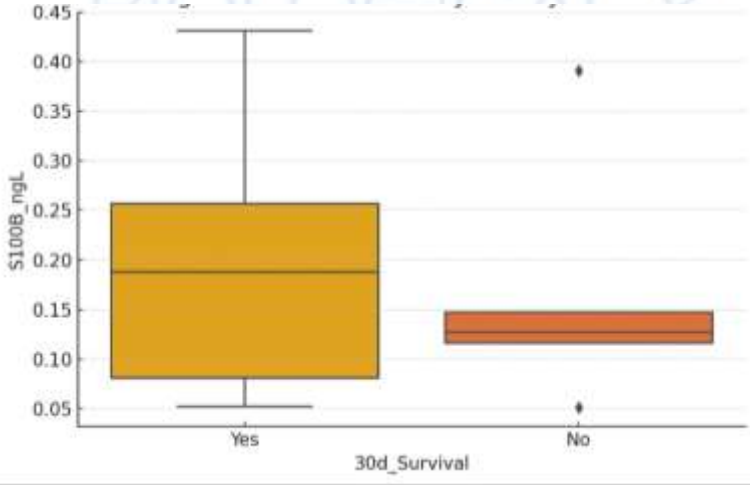

Figure 5: Visualization of neurological variables, biomarkers, and survival analysis.

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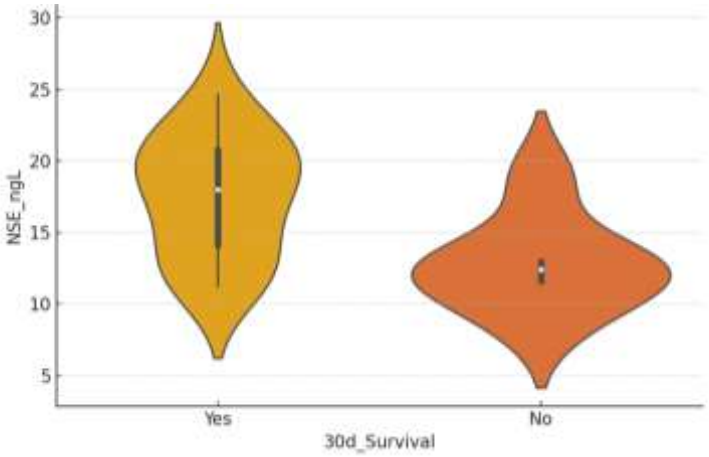

Figure 6: Visualization of neurological variables, biomarkers, and survival analysis.

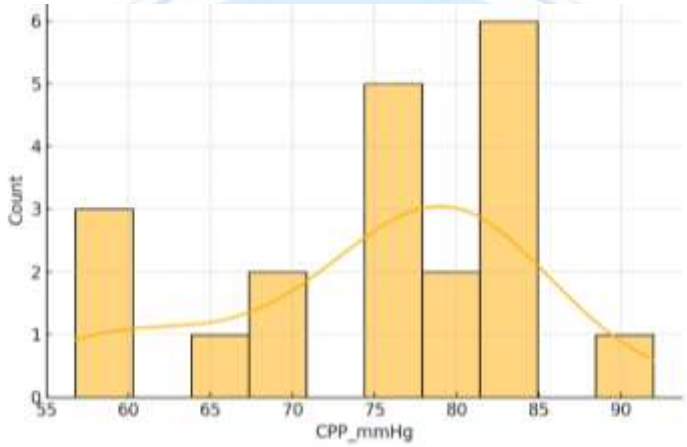

Figure 7: Visualization of neurological variables, biomarkers, and survival analysis.

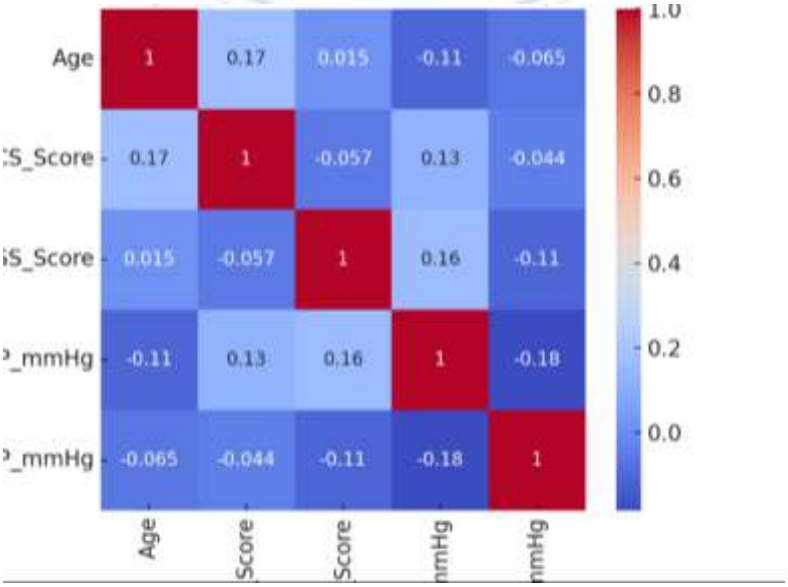

Figure 8: Visualization of neurological variables, biomarkers, and survival analysis.

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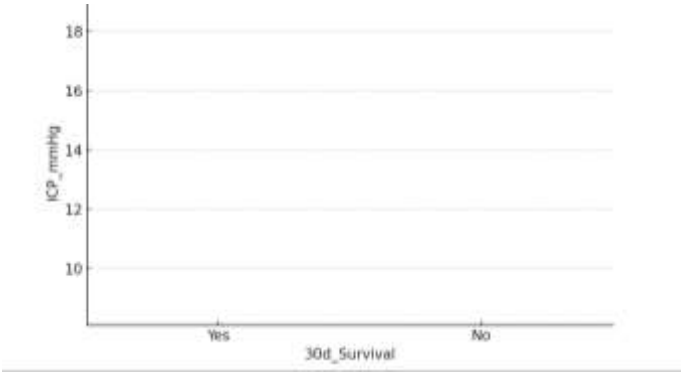

Figure 9: Visualization of neurological variables, biomarkers, and survival analysis.

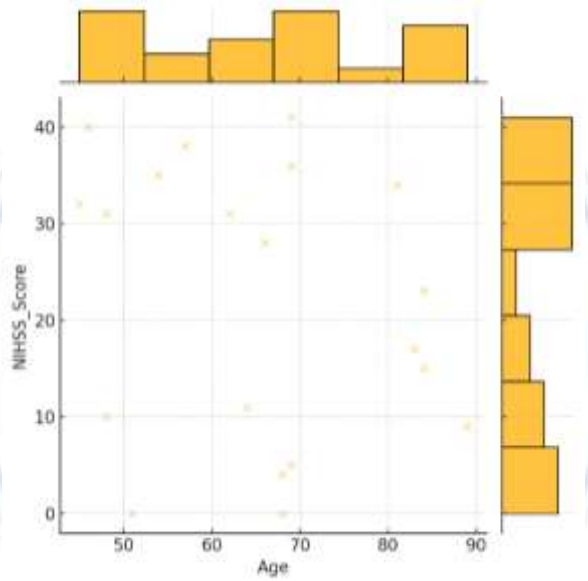

Figure 10: Visualization of neurological variables, biomarkers, and survival analysis.

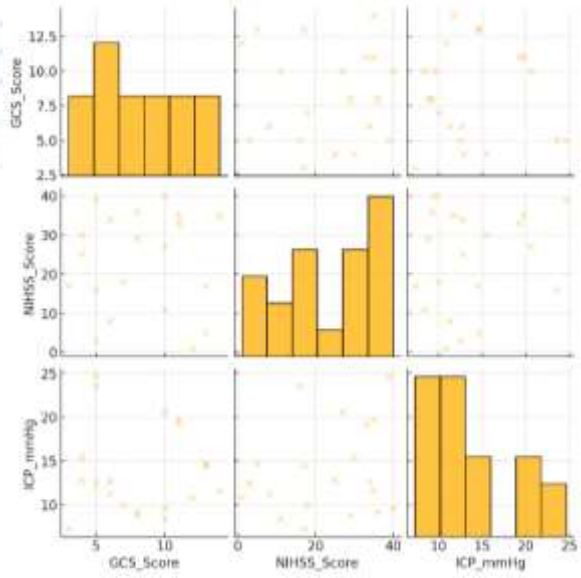

Figure 11: Visualization of neurological variables, biomarkers, and survival analysis.

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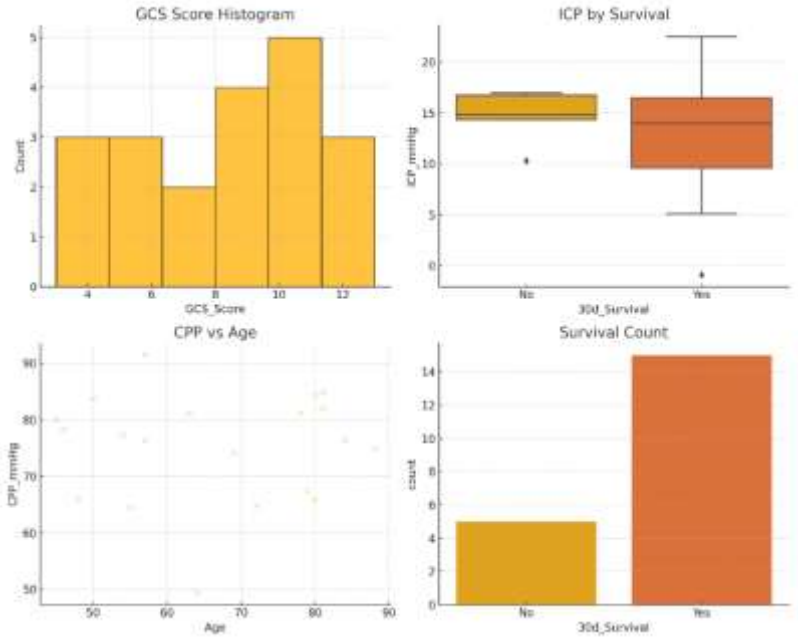

Figure 12: Visualization of neurological variables, biomarkers, and survival analysis

DISCUSSION

Scientists are eyeing new solutions to assist those with injured limbs to regain their motor skills, including virtual reality (Anwer et al., 2022). There are two technology-based solutions that are meant to allow people to have the possibility of regaining motor skills, namely virtual reality and repetitive transcranial magnetic stimulation, which can make their tasks more specific, motivate them and provide them feedback (Banduni et al., 2023) (Dewil et al., 2023). These methods and combination with functional electrical stimulation and robot aid are the key strategies according with which BCI planning stroke rehabilitation systems (Liao et al., 2023). BCI and, specifically, its implementation with robots become promising tools that can assist stroke survivors in recovering and enhancing their fine motor skills as it is associated with the use of EEG technology to control the motor skill recovery (Baniqued et al., 2021) (Elashmawi et al., 2024). The positive synergies of using BCI devices combined with conventional occupational therapy may help enhance the capacity to move the upper limbs and perform daily activities to a higher degree (Endzelytė et al., 2025). The rehabilitation based on BCI is also useful in relearning to use both hands to accomplish daily activities. In this instance, the patients will use motor imagery alongside physical rehabilitation to augment the healing process (Sisti et al., 2022). A special technical solution to the problem of a damaged motor system is BCI systems. They process cerebral impulses which are associated with movements intentions into real-time feedback of patients who are unable to move (Simon et al., 2021). BCIs provide user-friendly technology and robotic neuro-prosthetic limbs that get energy via brain activity. These are also associated with helping to enhance or regain the motor skills that have been lost by the brain (Elashmawi et al., 2024). Many people who have survived a stroke report issues related to the upper extremity of their bodies, which complicates them to perform daily activities and increases their dependence on the care providers (Simon et al., 2021). The brain-computer interface systems rearrange the mode of working of the brain in a way that promotes integrated neuroplasticity of the corticospinal connections, which are involved.

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This facilitates the intentionally controlled movement (Ma et al., 2023) (Mane et al., 2022). Brain-computer interfaces convert the modulations within the brain into commands establishing a direct connection between the brain and external devices. This might be applicable to the rehabilitation following a stroke onset (Mane et al., 2022). The practice is of benefit as it enables individuals to work around impaired routes and provides them with an alternative approach to communicating and dealing with things. It is also identified as relevant in enhancing the quality of life of people who have suffered a stroke (Mane et al., 2022) (Ma et al., 2025). Brain-controlled systems also turn out to be the most effective option in case of individuals being unable to convey their needs with the use of standard interfaces easily. This allows users to make a new approach to interaction with external appliances by using patterns in their brain making them more independent and healthy in general (Palumbo et al., 2021). BCIs have the potential to assist brain damaged regions and neural circuits to restructure. This occurs through the induction and augmenting of activity in healthy brain cells (increasing the rate at which they heal neural functional connections (Liao et al., 2023) (Yuan et al., 2021). BCIs allow the person to regulate various processes by converting the action in the brain into instructions or commands. They initially found application in medical interventions where individuals with motor disabilities would get back their communication and locomotion capabilities (Schreiner et al., 2025). They also apply to BCIs as a game changer in regard to using neuroplasticity in treatment and rehabilitation since they provide you opportunities to influence brain activity in a specific and flexible fashion, which stimulates healthy neural shifts (Drigas & Sideraki, 2024). BCIs also interpret and decode brain signals that take place as one attempts to talk or thinks about talking. It is one more method to enhance the communication (Luo et al., 2022). These interfaces seek to convert cortical signals into motor responses, and this avoids impaired spinal pathways and aids in restoring functionality (Cajigas & Vedantam, 2021) (Zhang et al., 2020). The general concept of functionality that brain-computer interface technology offers is to establish a connection between the human brain and an external device capable of reading the brain activity pattern and allowing a user to interact with external devices, in most cases, without the use of peripheral nerves and muscles (Sun & Mou, 2023) (Ferracuti et al., 2021). BCIs also have the ability to enhance cognitive abilities and motor functions and allow patients to be in touch with the environment and achieve their personal objectives (Gu et al., 2021) (Young et al., 2021). Neurorehabilitation should rely on brain-computer interfaces since they could enable the brain to adapt and the body to recover after suffering a stroke (Saha et al., 2021; Ng, 2025). BCIs can also be useful to people with conditions that impact their capacity to move in the direction of the peripheral neuromotor targets, such as stroke (Young et al., 2021).

CONCLUSION

It examines all the key facets of critical care neurology within acute stroke units (ASUs) and demonstrates the synergistic relationship between neuro-monitoring, biomarker profiling as well as the multidisciplinary therapies in the arena of enhancing positive outcomes on stroke. The research employs a combination between quantitative neurophysiology and qualitative clinical team assessment in discovery of cerebral perfusion pressure (CPP), intracranial pressure (ICP), and biomarkers quantity like S100B and NSE, as weighty short-term prognosis factors. Regression analysis also revealed that the patients who were stable in CPP more than 70 mmHg and controlled

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ICP had a much better chance of being independent outside the hospital. It was also revealed simultaneously in a thematic analysis of observational data and structured interviews that effective communication across disciplines, provision of neurocritical care early in the process, and the planned escalation methods would be pivotal to the acceleration of treatment and the enhancement of care quality. There is also evidence of how a specific therapy, such as mechanical ventilation with a permissive hypercapnia and therapeutic hypothermia, could be useful in stabilizing the patients during a neurologic crisis, especially during initial 48 hours after they are admitted in the ASU. The integration of continuous, telemetry-based monitoring and predictive modeling make it possible to modify the critical care treatments in real time to a specific person and their individual neurological history. The possibility of this study, complementing the physiological information based on the operational understanding, brings forth an imperative framework on real-time handling, as well as triaging of stroke in intensive environments. Finally, these findings suggest the need to implement a systematic yet adaptable method of critical care in ASUs, which will have consequences on clinical decision support, resource distribution and stroke recovery planning.

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