Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.journals.elsevier.com/journal-of-clinical-neuroscience

Aneurysmal subarachnoid hemorrhage care in a middle-income public healthcare system: A real-world neurocritical care cohort

Thire Baggio Machado Marazzi [a,1,*], Brunna Pileggi Rimoli [a,2], Ricardo Santos de Oliveira [b,3], Daniel Giansante Abud [c,4], Octávio Marques Pontes-Neto [a,5]

[a] *Department of Neurosciences and Behavioral Sciences, Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, Brazil*
[b] *Division of Neurosurgery, Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, Brazil*
[c] *Department of Radiology, Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, Brazil*

A R T I C L E I N F O

Keywords:
Subarachnoid Hemorrhage
Critical Care
Developing countries
Neurocritical care
Health systems

A B S T R A C T

Background and Purpose: Although aneurysm treatment capacity has expanded worldwide, outcomes after aneurysmal subarachnoid hemorrhage (aSAH) remain strongly influenced by neurocritical care (NCC) delivery, referral pathways, and access to specialized treatment. Contemporary data describing real-world aSAH care in resource-limited healthcare systems remain scarce. We aimed to characterize treatment patterns, NCC delivery, complications, and outcomes in a large Brazilian public referral center.

Methods: This retrospective cohort study included consecutive adults with confirmed aSAH admitted between June 2018 and March 2022 to a high-volume Brazilian tertiary referral center. Only patients admitted within five days of symptom onset were included. Demographic, clinical, radiological, treatment, complication, and outcome data were extracted from institutional records. Primary outcomes were in-hospital mortality and 3-month functional outcome assessed by the modified Rankin Scale (mRS).

Results: Seventy-four patients were included. Disease severity was high, with 45% presenting WFNS grades 4–5, 73% modified Fisher grade 4 hemorrhage, and 64% hydrocephalus. Endovascular treatment was performed in 73% of cases, and median time from admission to aneurysm treatment was 1 day. Despite early treatment capability, only 28% of patients were admitted to an ICU within 48 h, while 38% never received ICU care. Delayed cerebral ischemia occurred in 43%, radiologic vasospasm in 58%, ventriculitis in 22%, and infectious complications in 57%. External ventricular drainage was required in 42%, and vasoactive drugs were used in 85%. In-hospital mortality was 42%, and 66% had unfavorable 3-month outcomes (mRS 4–6).

Conclusions: This real-world cohort highlights the substantial neurocritical care burden of aSAH in a middle-income public healthcare system. Despite timely access to definitive aneurysm treatment, patients experienced frequent neurological and systemic complications, emphasizing that contemporary aSAH care extends well beyond aneurysm occlusion.

1. Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) remains one of the deadliest neurologic emergencies worldwide despite substantial advances in aneurysm occlusion techniques and neurocritical care (NCC) medicine [1–8]. While major efforts over recent decades have focused on improving aneurysm treatment, less attention has been directed toward how NCC itself is delivered after rupture, particularly in middle-income healthcare systems [9,10].

Contemporary aSAH management extends far beyond aneurysm

* Corresponding author at: Emergency Unit, Hospital das Clínicas, Ribeirão Preto Medical School, University of São Paulo Adress: Avenida Bandeirantes, 3900 Vila Monte Alegre Ribeirão Preto, SP Postal Code: 14049-900, Brazil.
E-mail address: tbmmarazzi@hcrp.usp.br (T.B. Machado Marazzi).
[1] Thire Baggio Machado Marazzi 0000-0002-2613-490X.
[2] Brunna Pileggi Rimoli 0000-0001-7434-3127.
[3] Ricardo Santos de Oliveira 0000-0003-0390-5553.
[4] Daniel Giansante Abud 0000-0002-6171-669X.
[5] Octávio Marques Pontes-Neto MD PhD 0000-0003-0317-843X.

https://doi.org/10.1016/j.jocn.2026.112225
Received 29 June 2026; Accepted 29 July 2026
Available online 5 August 2026

exclusion. Survival and long-term recovery frequently depend on prolonged NCC, including management of intracranial hypertension, hydrocephalus, delayed cerebral ischemia (DCI), systemic complications, and high-intensity neurologic monitoring [11–14]. Although timely access to specialized aneurysm treatment remains a major challenge in many healthcare systems, outcomes after rupture may also be strongly influenced by how NCC is delivered throughout the acute phase of care [15–18]. In this context, limitations in referral pathways, intensive care availability, and multidisciplinary NCC infrastructure may substantially affect real-world aSAH outcomes, particularly in middle-income settings [9].

This question may be particularly relevant in middle-income countries, where highly specialized neurovascular expertise often coexists with heterogeneous access to intensive care resources, organization, and advanced monitoring. In these settings, tertiary referral centers may concentrate disproportionately severe cases while simultaneously operating under constrained critical care infrastructure [19,20]. However, contemporary data describing how aSAH care is delivered in these environments remain scarce.

Brazil provides a unique setting to explore these challenges. The country has one of the largest universal public healthcare systems worldwide, with progressive expansion of endovascular capability and specialized stroke care over recent decades [9]. Nevertheless, marked disparities persist in access to intensive care beds and specialized multidisciplinary infrastructure. Most available Brazilian aSAH studies have focused on clinical outcomes or prognostic factors, while detailed characterization of real-world NCC delivery remains limited.

In this study, we aimed to characterize aSAH care in a high-volume Brazilian public tertiary referral center, focusing on treatment patterns, NCC delivery, complication burden, and clinical outcomes in a contemporary real-world cohort.

2. Methods

2.1. Study design and setting

This retrospective observational cohort study included consecutive adult patients with aSAH admitted between June 2018 and March 2022 to Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (HCFMRP-USP), a high-volume public tertiary referral center in southeastern Brazil.

Ribeirão Preto is a city with approximately 750,000 inhabitants [21] located nearly 300 km from São Paulo city, the country's largest metropolitan area. HCFMRP-USP is part of the Brazilian Unified Health System (Sistema Único de Saúde [SUS]), a publicly funded universal healthcare system that provides exclusive healthcare coverage for a substantial proportion of the Brazilian population [22]. The institution functions as a regional referral center for neurovascular emergencies, serving an estimated catchment population of nearly 3 million individuals dependent on public healthcare services [21].

The study period was defined based on two institutional milestones: the digitization of the Registro de Acidente Vascular Encefálico de Ribeirão Preto (REAVER) platform in 2018 and the implementation of standardized institutional care protocols for aSAH in 2022. Since 2014, the REAVER registry has prospectively recorded demographic, clinical, radiological, and functional outcome data from patients admitted with cerebrovascular diseases, independently of the attending specialty teams.

The center provides both microsurgical and endovascular aneurysm treatment, including 24-hour emergency neurointerventional capability. During the study period, patients with aSAH were managed through a multidisciplinary model involving neurology, neurosurgery, neurointerventional radiology, intensive care, and rehabilitation teams. Although the hospital did not operate a dedicated NCC unit, many patients requiring NCC were managed in the stroke unit or ED, where continuous cardiac monitoring, invasive arterial pressure monitoring, and MV were available. Within these units, nurse staffing averaged approximately one registered nurse per 10 patients and one nursing technician per three patients. Patients requiring additional organ support or advanced monitoring were admitted to two general ICUs according to clinical needs and bed availability.

Clinical, radiological, NCC, treatment, and outcome variables were retrospectively extracted from institutional electronic medical records and stored in a secure research database with restricted investigator access.

The study period partially overlapped with the COVID-19 pandemic [23]. However, the institution maintained its role as a regional emergency and neurovascular referral center throughout the study period and was not primarily converted into a dedicated COVID-19 admission unit. Therefore, the observed patterns of ICU utilization and NCC delivery likely reflect broader structural and organizational characteristics of the local healthcare system rather than exclusively pandemic-related resource reallocation. This potential pandemic effect was considered during data interpretation and contextual analysis of the study findings.

The study was approved by the local institutional ethics committee (CAAE: 63926022.9.0000.5440). Due to the retrospective nature of the study and prior institutional consent procedures associated with the REAVER registry, the requirement for additional informed consent was waived. All procedures were conducted in accordance with the Declaration of Helsinki and Brazilian national data protection regulations (Lei Geral de Proteção de Dados Pessoais [LGPD]).

2.2. Patient selection and data collection

Adult patients ($\geq$18 years) with confirmed admission during the study period were consecutively screened through the REAVER registry and institutional electronic medical records.

aSAH was confirmed by cranial computed tomography or lumbar puncture, and aneurysmal etiology was established through computed tomography angiography or digital subtraction angiography. Patients were included only if they were admitted within five days of symptom onset and remained hospitalized at HCFMRP-USP during the acute phase of treatment, allowing adequate assessment of NCC delivery and in-hospital complications. Patients transferred exclusively for aneurysm occlusion procedures or lacking sufficient clinical documentation were excluded.

Demographic variables, vascular risk factors, pre-admission functional status, clinical presentation, radiological findings, aneurysm characteristics, treatment modality and timing, NCC interventions, neurological and systemic complications, and in-hospital outcomes were retrospectively extracted from institutional records.

Radiological evaluation included modified Fisher classification [24], presence of intraventricular hemorrhage, hydrocephalus, intracerebral hemorrhage, and radiological signs suggesting intracranial hypertension on admission imaging (defined by cerebral herniation, midline shift $>$ 5 mm, or moderate-to-severe hydrocephalus, as evidenced by dilation of the temporal horns, basal cistern effacement, or transependymal edema, with imaging findings independently assessed by two examiners and disagreements resolved by consensus). Clinical severity was assessed using the World Federation of Neurosurgical Societies (WFNS) grading scale [25].

NCC variables included intensive care unit admission, external ventricular drain placement, intracranial pressure monitoring, transcranial Doppler surveillance [26], diagnosis of DCI [27] and associated rescue therapies, vasospasm-directed interventions, hypertensive therapy, mechanical ventilation, tracheostomy, and major systemic complications during hospitalization.

Radiological vasospasm was assessed using transcranial Doppler ultrasonography, computed tomography angiography, or digital subtraction angiography according to institutional availability and clinical indication. Diagnostic criteria were based on the recommendations of Alexandrov et al [26]. for transcranial Doppler ultrasonography and

Khawaja et al [28]. for angiographic imaging. Because a substantial proportion of patients presented with poor-grade aSAH, impaired consciousness, or required mechanical ventilation and sedation during the acute phase, the diagnosis of symptomatic vasospasm was considered unreliable in many cases. Therefore, vasospasm and delayed cerebral ischemia (DCI) were analyzed as distinct entities. DCI was defined according to the consensus criteria proposed by Vergouwen et al. [27] and also included cases in which the treating multidisciplinary team initiated rescue therapies after exclusion of alternative causes, primarily in the presence of severe or critical angiographic vasospasm involving a defined cerebral vascular territory. Although recent studies have proposed multimodal approaches incorporating brain tissue oxygen (PbO_2) monitoring, cerebral microdialysis, perfusion imaging, and other advanced neuromonitoring techniques to improve DCI detection, these modalities were not routinely available at our institution [29,30]. Therefore, in poor-grade patients or those with unreliable neurological examinations, rescue therapies were primarily guided by the presence of severe or critical angiographic vasospasm in conjunction with the overall clinical assessment.

Functional outcome at 3 months was assessed using the modified Rankin Scale [31] (mRS) through structured telephone interviews conducted by trained REAVER investigators.

Patient selection is summarized in Fig. 1.

2.3. Outcomes

The primary outcomes were in-hospital mortality and functional outcome 3 months after discharge. Poor functional outcome was defined as a mRS score of 4 to 6.

Secondary outcomes included frequency of neurological and systemic complications, NCC interventions, timing of aneurysm treatment, and patterns of intensive care utilization.

2.4. Statistical analysis

Descriptive statistics were used to characterize demographic, clinical, radiological, treatment, NCC, and outcome variables. Continuous variables were reported as mean ± standard deviation or median and interquartile range according to distribution characteristics, while categorical variables were expressed as absolute numbers and percentages.

Exploratory analyses evaluating associations between selected clinical, radiological, treatment, and neurocritical care variables and clinical outcomes were performed primarily using univariable analyses. Given the relatively limited sample size and substantial overlap among severity-related variables, multivariable modeling was interpreted cautiously and considered exploratory.

Statistical analyses were performed using IBM SPSS Statistics for Windows version 21.0 (IBM Corp.) and Python libraries (Scikit-learn and NumPy). Statistical significance was defined as $p < 0.05$.

3. Results

3.1. Cohort characteristics and severity profile

A total of 5,185 patients with cerebrovascular diseases were identified in the REAVER registry between 2014 and March 2022. During the study period, 140 patients were initially screened with a diagnosis of subarachnoid hemorrhage. After exclusion of non-aneurysmal etiologies, late admissions, transfers exclusively for aneurysm treatment, and incomplete clinical documentation, 74 patients with confirmed aSAH-were included in the final cohort (Fig. 2.).

The mean age was 56.6 ± 14.5 years, and most patients were women (72%). Smoking and hypertension were the most frequent vascular risk factors, present in 61% and 47% of patients, respectively. Most individuals were functionally independent before admission, with 93%

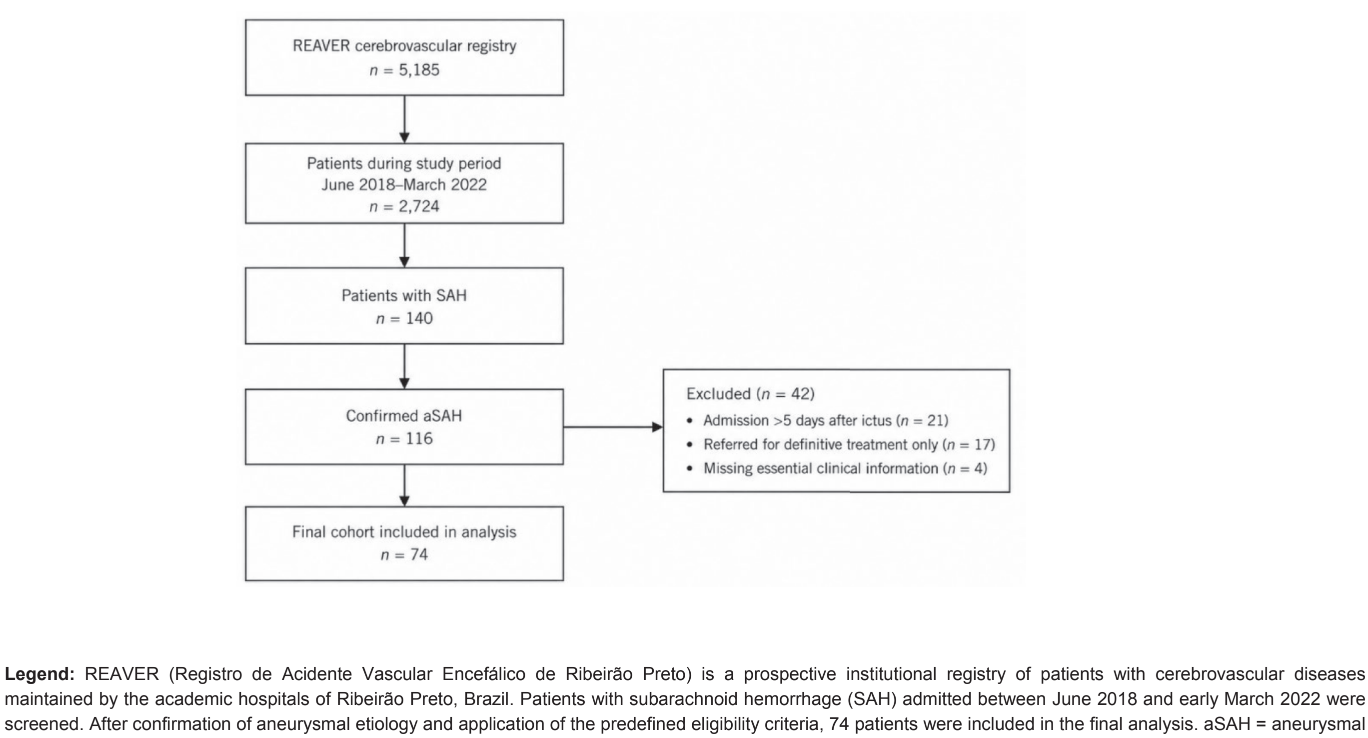

Fig. 1. Flow diagram of patient selection for the aneurysmal subarachnoid hemorrhage (aSAH) cohort from the REAVER registry. **Legend:** REAVER (Registro de Acidente Vascular Encefálico de Ribeirão Preto) is a prospective institutional registry of patients with cerebrovascular diseases maintained by the academic hospitals of Ribeirão Preto, Brazil. Patients with subarachnoid hemorrhage (SAH) admitted between June 2018 and early March 2022 were screened. After confirmation of aneurysmal etiology and application of the predefined eligibility criteria, 74 patients were included in the final analysis. aSAH = aneurysmal subarachnoid hemorrhage; SAH = subarachnoid hemorrhage.

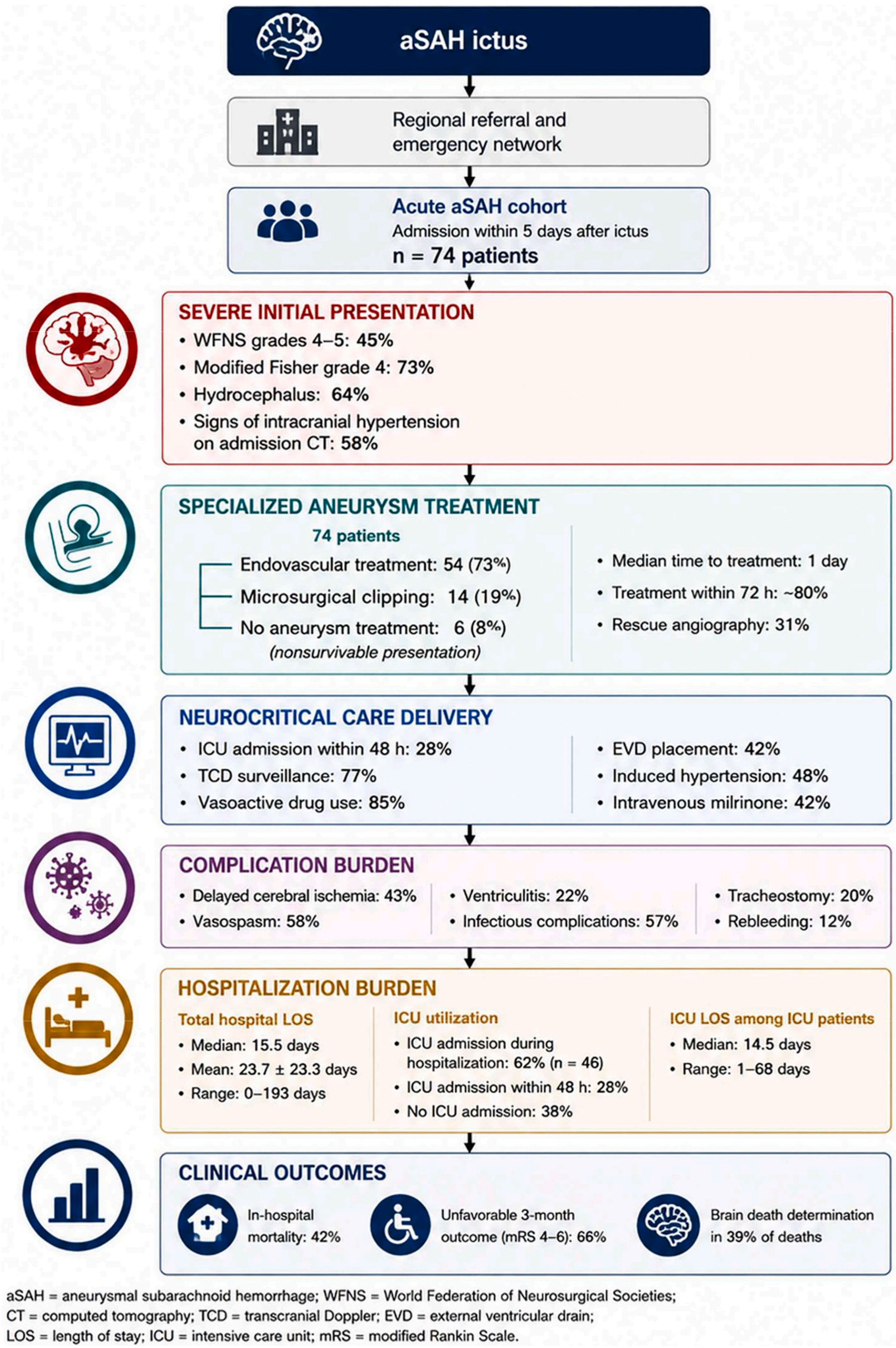

Fig. 2. Real-world care pathway, neurocritical care delivery, complication burden, and clinical outcomes in patients with aneurysmal subarachnoid hemorrhage (aSAH).

presenting a pre-admission mRS score of 0.

The cohort was characterized by a markedly severe clinical and radiological presentation. Nearly half of patients (45%) were classified as poor-grade aSAH (WFNS 4–5) at admission, while 73% were classified as modified Fisher grade 4. Hydrocephalus was present in 64% of cases, intraventricular hemorrhage in 42%, and radiological signs suggestive of intracranial hypertension in 58%.

Only one patient experienced in-hospital symptom onset. All remaining patients were initially evaluated either at the institution's emergency department or at secondary hospitals within the regional referral network before transfer for specialized neurovascular care.

Baseline demographic, clinical, radiological, and aneurysm-related characteristics are summarized in Table 1.

3.2. Aneurysm characteristics and treatment patterns

Most ruptured aneurysms involved the anterior circulation, although posterior circulation aneurysms represented 16% of the cohort. Multiple aneurysms were identified in 40% of patients.

Endovascular embolization was the predominant treatment modality, performed in 73% of cases, whereas microsurgical clipping was performed in 19%. Six patients did not undergo aneurysm treatment because they presented with catastrophic neurological injury considered incompatible with meaningful recovery.

The median interval between hospital admission and aneurysm treatment was 1 day, with nearly 80% of treated patients undergoing aneurysm occlusion within the first 72 h after admission.

Detailed aneurysm characteristics, treatment patterns, and NCC interventions are summarized in Tables 1 and 2.

Table 1
Demographic, Clinical, Radiological, Treatment, and Functional Outcome Characteristics of Patients With Aneurysmal Subarachnoid Hemorrhage (n = 74).

Variable	Value
Demographic characteristics	
Age (years)	Mean: 56.6; SD: 14.3; Range: 21–87
Female sex	54 (73%)
Baseline modified Rankin Scale	mRS 0: 69 (93%) mRS 1–3: 5 (7%)
Clinical severity and early neurological injury	
Focal neurological deficits	25 (34%)
Acute hydrocephalus	47 (64%)
Pupillary abnormalities	12 (16%)
Pre-admission rebleeding	9 (12%)
Early cerebral ischemia	4 (5%)
Signs of intracranial hypertension on admission CT	43 (58%)
WFNS score on admission	I: 15 (20%) II: 19 (26%) III: 7 (9%) IV: 11 (15%) V: 22 (30%)
Hunt–Hess scale on admission	I: 8 (11%) II: 17 (23%) III: 18 (24%) IV: 9 (12%) V: 22 (30%)
Use of antiplatelet agents	10 (14%)
Radiological findings	
Modified Fisher scale	0: 1 (1%) 1: 3 (4%) 2: 4 (5%) 3: 12 (16%) 4: 54 (73%)
Maximum subarachnoid clot thickness (mm)	Mean: 8.0; SD: 7.1; Range: 0–32
Intraventricular hemorrhage	31 (42%)
Aneurysm management	
Microsurgical clipping	14 (19%)
Endovascular coiling	54 (73%)
No aneurysm treatment	6 (8%)
Three-month functional outcome (mRS)	
mRS 0–2 (independent)	22 (30%)
mRS 3	3 (4%)
mRS 4–5	18 (24%)
mRS 6 (death)	31 (42%)

Data are presented as n (%) unless otherwise indicated. SD = standard deviation; mRS = modified Rankin Scale; WFNS = World Federation of Neurosurgical Societies; CT = computed tomography; SAH = subarachnoid hemorrhage; ICU = intensive care unit.

Table 2
Neurocritical care management, neurological complications, and systemic complications among patients with aneurysmal subarachnoid hemorrhage.

Variable	Total N = 74	Survivors N = 43	Non-survivors N = 31
Early neurological injury and acute complications			
Hydrocephalus	47 (63)	21 (49)	26 (84)
Rebleeding	9 (12)	2 (5)	7 (23)
Early cerebral ischemia	4 (5)	1 (2)	3 (10)
Seizures	48 (65)	26 (60)	22 (71)
Signs of intracranial hypertension on admission CT	43 (58)	16 (37)	27 (87)
Delayed neurological complications			
Delayed cerebral ischemia (DCI)	32 (43)	20 (47)	12 (39)
Radiological vasospasm (TCD/CTA/DSA)	42 (58)	28 (65)	14 (45)
Neurocritical care interventions			
External ventricular drainage	31 (42)	13 (30)	18 (58)
Decompressive craniectomy	7 (9)	3 (7)	4 (13)
Induced hypertension therapy	36 (49)	22 (51)	14 (45)
Milrinone use	31 (42)	20 (47)	11 (35)
Vasopressor use	63 (85)	32 (74)	31 (100)
Tracheostomy	15 (20)	12 (28)	3 (10)
ICU admission within 48 h	21 (28)	11 (26)	10 (32)
Systemic complications			
Sodium disturbances	49 (66)	31 (72)	18 (58)
Pneumonia	25 (34)	13 (30)	12 (39)
Ventriculitis	16 (22)	9 (21)	7 (23)
Cardiomyopathy associated with aSAH	10 (13)	4 (9)	6 (19)

DCI = delayed cerebral ischemia; ICU = intensive care unit; aSAH = aneurysmal subarachnoid hemorrhage.

3.3. Care pathway time Metrics

To characterize the referral pathway and early hospital care, the median time from symptom onset to admission at the tertiary referral center was 9.1 h (IQR, 2.8–19.9). After arrival, the median time to admission CT was 0.5 h (IQR, 0.2–1.6), and the median time from admission to definitive aneurysm treatment was 22.3 h (IQR, 10.6–40.9). Patients with poor-grade aSAH (WFNS IV–V) reached the referral center earlier than those with good-grade aSAH (median 3.6 vs. 13.4 h), underwent admission CT sooner (median 0.3 vs. 0.6 h), and received definitive aneurysm treatment earlier after admission (median 18.2 vs. 25.2 h), consistent with prioritization of the most critically ill patients within the regional referral network.

3.4. Neurocritical care delivery

All patients were initially stabilized in the emergency department before transferring to monitored stroke unit beds, general wards, or intensive care units according to institutional availability and clinical prioritization. During the study period, the institution operated two general intensive care units and one coronary care unit, without dedicated NCC beds. Consequently, NCC was delivered across multiple hospital settings, including the emergency department, monitored stroke unit beds, and specialized neurological wards.

Only 21 patients (28%) were admitted to an intensive care unit within the first 48 h after hospital admission. Among patients admitted to ICU, the interval between hospital admission and ICU transfer ranged from 0 to 13 days, with a median delay of 3 days. Among patients with poor-grade aSAH (WFNS 4–5), only 30% were admitted to ICU during this period. Overall, 38% of the cohort were never admitted to an ICU at any point during hospitalization. Early ICU admission was not significantly associated with in-hospital mortality (47.6% vs. 38.5%; OR, 1.45; $p = 0.600$) or poor functional outcome at 3 months, defined as mRS 4–6 (81.0% vs. 59.6%; OR, 2.88; $p = 0.106$). These unadjusted comparisons should be interpreted cautiously because ICU admission was determined by clinical severity and bed availability, resulting in substantial confounding by indication.

All patients received nimodipine prophylaxis for DCI. Daily transcranial Doppler surveillance was performed in 77% of patients. Radiological vasoespasm (VSP) [26,28] was documented in 58% of patients (by TCD, CTA, or DSA).

DCI [27] was diagnosed in 43% of patients, typically between days 3 and 14 after symptom onset. Induced hypertension protocols were implemented in 46% of the cohort. Intravenous milrinone was administered in 42% of patients, while 30% underwent intra-arterial milrinone infusion during rescue angiography procedures [32,33]. Rescue angiography for refractory VSP evaluation was required in 31% of patients.

Hydrocephalus occurred in 64% of patients, and 31 patients (42%) required external ventricular drainage. Seven patients (9%) subsequently required ventriculoperitoneal shunt placement. Although 58% of patients presented radiological signs suggesting intracranial hypertension at admission, invasive intracranial pressure monitoring was performed in only 7 patients (9%).

Vasoactive drugs were administered in 85% of patients during hospitalization and were frequently used outside traditional ICU environments, including the emergency department and monitored stroke unit settings. Tracheostomy was required in 20% of the cohort, and decompressive craniectomy was performed in 9%.

A comprehensive summary of neurocritical care interventions, monitoring practices, and treatment-related variables is presented in Table 2.

3.5. Neurological complications

Neurological complications were highly prevalent throughout hospitalization. Rebleeding occurred in 12% of patients and was significantly associated with in-hospital mortality. Notably, two patients experienced hemorrhagic expansion despite early aneurysm treatment, including one patient requiring repeat surgical intervention.

DCI was diagnosed in 43% of the cohort, whereas radiological vasospasm (VSP), diagnosed by TCD, CTA, or DSA according to clinical indication, was documented in 58% of patients. Serial TCD monitoring was performed in 57 patients (77%), with VSP identified in 36, whereas additional cases were diagnosed by CTA or DSA. Middle cerebral artery VSP was the most frequent pattern identified. Rescue angiography for refractory VSP evaluation was required in nearly one-third of patients, including repeated rescue procedures in selected cases.

Clinical seizures occurred in 65% of patients during hospitalization, with 45% presenting seizures at admission. Antiseizure medications were administered in 80% of the cohort, predominantly within the first 24 h after symptom onset. Eleven patients received antiseizure medication despite the absence of documented seizures during hospitalization, consistent with primary seizure prophylaxis. Documented indications included intraparenchymal hematoma, cortical surgical manipulation, and infarction involving eloquent cortex. Status epilepticus was diagnosed in one patient.

Hydrocephalus was diagnosed with 64% of patients during hospitalization. External ventricular drainage was required in 42% of cases, and approximately one-quarter of drained patients subsequently required ventriculoperitoneal shunt placement.

Radiological signs suggestive of intracranial hypertension were identified in 58% of admission computed tomography scans. Seven patients underwent decompressive craniectomy because of refractory intracranial hypertension.

Ventriculitis occurred in 22% of the cohort and affected more than half of patients requiring ventricular diversion procedures.

3.6. Systemic complications

Systemic complications were also frequent during hospitalization. Infectious complications occurred in approximately 57% of patients, and more than one infectious focus was identified in 27% of the cohort. Pulmonary infections, including hospital-acquired pneumonia and ventilator-associated pneumonia, were the most frequent infectious events, affecting 34% of patients. Bloodstream infections occurred in 18%, urinary tract infections in 14%, and ventriculitis in 22% of the cohort.

Sodium disturbances were highly prevalent. Hypernatremia developed in 46% of patients, whereas hyponatremia occurred in 54%. Cerebral salt wasting syndrome was diagnosed in 24% of the cohort, and all affected patients received fludrocortisone therapy. Diabetes insipidus was diagnosed in 7% of patients.

Cardiovascular complications were documented in 14% of the cohort, including electrocardiographic abnormalities, elevated troponin levels, arrhythmias, and echocardiographic dysfunction. Troponin elevation was identified in 60% of tested patients. One patient developed refractory cardiogenic shock associated with severe ventricular dysfunction.

Vasoactive drugs were administered in 85% of patients during hospitalization. Thromboembolic complications included deep venous thrombosis in 5% and pulmonary embolism in 3% of patients. One patient died from complications associated with COVID-19 infection.

3.7. Clinical outcomes

Hospital length of stay ranged from 0 to 193 days, with a median duration of 15.5 days (mean 23.7 ± 28.3 days). Among the 46 patients admitted to the intensive care unit, ICU length of stay ranged from 1 to 68 days, with a median duration of 14.5 days.

In-hospital mortality was 42% (31 patients). Death occurred early during hospitalization, with a median interval of 6 days between admission and death, and approximately one-quarter of deaths occurring within the first 48 h after hospital admission. Most nonsurvivors presented with severe neurological injury at admission, with nearly three-quarters of deaths occurring among patients classified as WFNS 4–5.

Older age altered the level of consciousness at admission, hydrocephalus, rebleeding, radiological signs suggesting intracranial hypertension, external ventricular drainage requirement, and vasoactive drug use were associated with in-hospital mortality in univariate analyses.

At hospital discharge, only 28% of patients achieved a favorable functional outcome (mRS 0–3), whereas 23% remained severely dependent (mRS 4–5). Functional recovery remained limited at 3-month follow-up, with favorable functional outcome observed in 34% of the cohort (Fig. 3). Exploratory multivariable analyses suggested associations between older age, radiological signs suggestive of intracranial hypertension, and worse clinical outcomes; however, these findings should be interpreted cautiously given the relatively limited sample size and overlap among severity-related variables.

Similarly, unfavorable functional outcome at 3 months was associated with admission severity markers, hydrocephalus, rebleeding, pneumonia, and septic shock in univariate analyses. After multivariable adjustment, older age and radiological signs suggestive of intracranial hypertension remained independently associated with poor functional recovery. Neither aneurysm treatment modality nor treatment timing demonstrated independent association with mortality or functional outcomes. These findings should be interpreted cautiously, as treatment selection was individualized according to aneurysm characteristics, anatomical considerations, and clinical presentation.

Among patients who died during hospitalization, 39% fulfilled institutional criteria for brain death determination.

Exploratory univariable analyses evaluating variables associated with mortality and unfavorable functional outcomes are presented in **Supplementary Table S1**.

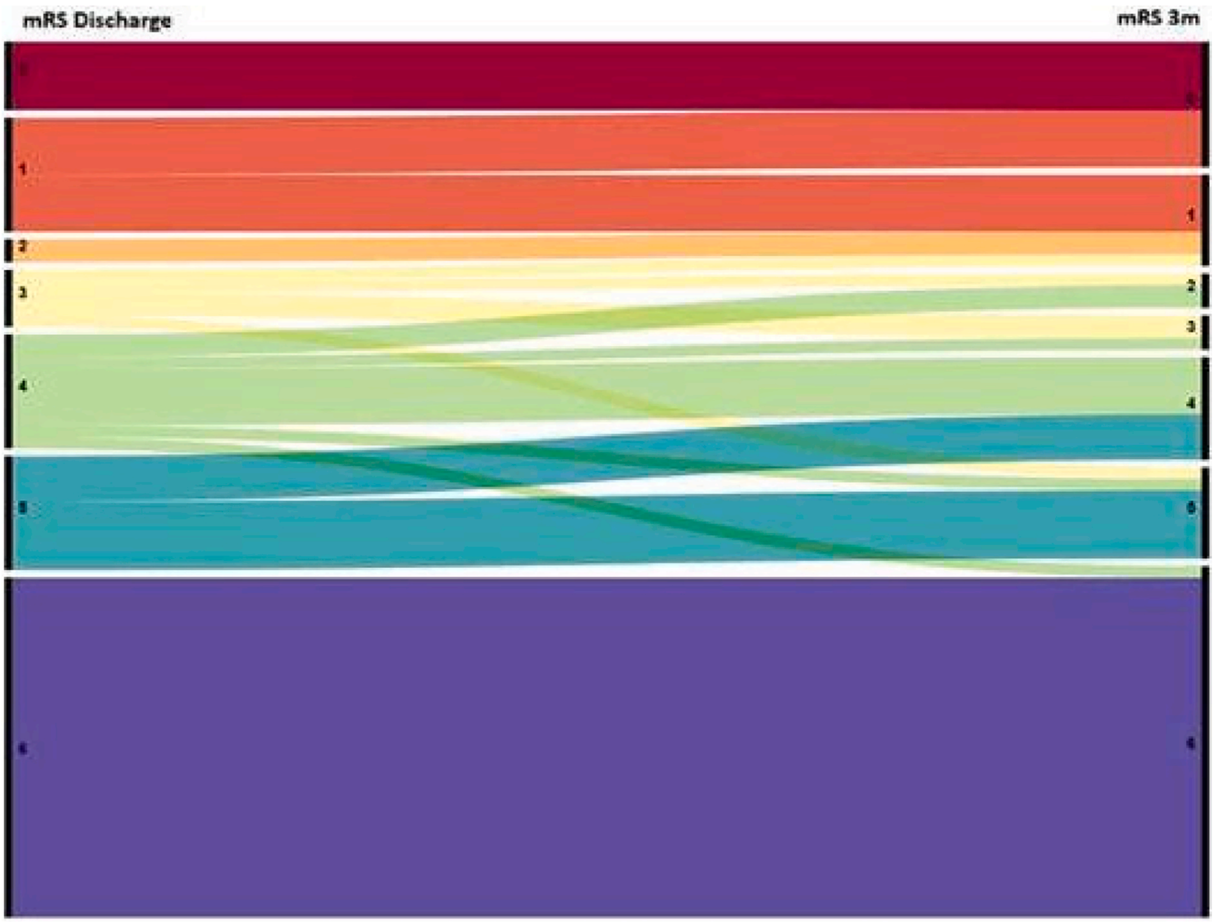

Fig. 3. Functional clinical outcomes of patients with aneurysmal subarachnoid hemorrhage 3 months after hospital discharge according to the modified Rankin Scale (mRS).

4. Discussion

Contemporary international guidelines and an expanding body of observational evidence recognize that comprehensive aSAH care extends beyond aneurysm occlusion and includes the organization and delivery of specialized neurocritical care after rupture [13,14,34,35]. Although a substantial proportion of the global burden of aSAH occurs in low- and middle-income countries [1,36], relatively few studies from these settings have characterized the neurocritical care demands of patients with aSAH or described how specialized care is organized and delivered in routine clinical practice [19,36]. The present study, based on a retrospective observational cohort, contributes to this perspective by providing a real-world description of how this continuum of care is delivered within a public tertiary referral center in Brazil.

Previous Brazilian administrative [9,23] and hospital-based studies [10,36–46] suggested that access to specialized aSAH care remained challenging. National SUS administrative data documented approximately 10,000 hospital admissions for aSAH annually during the study period, with only 18.8% of patients undergoing definitive aneurysm treatment [9]. Moreover, comparisons with Global Burden of Disease (GBD) [47] incidence estimates suggest that the number of hospitalized patients was substantially lower than expected, indicating important losses throughout the diagnostic and referral pathway. Additionally, the few available Brazilian hospital-based cohorts were conducted in large tertiary referral centers, predominantly located in the country's most economically developed states. Despite being generated in these resource-advantaged regions, these studies consistently reported cohorts composed of patients with severe neurological injury and persistently high in-hospital mortality, suggesting that referral and admission biases toward patients with advanced clinical severity remain a characteristic of hospital-based aSAH series in Brazil.

Our cohort reflects the experience of the only comprehensive neurovascular referral center serving approximately three million inhabitants in northeastern São Paulo state. As such, the study population represents patients who successfully reached specialized care after a complex process of diagnosis, stabilization, and interhospital transfer. One possible explanation for this clinical profile is referral and survivor selection occurring across multiple stages of the care continuum, including underrecognition or delayed diagnosis of aSAH, early prehospital mortality, delays in interhospital referral, and limited access to specialized neurovascular treatment, all of which have previously been suggested as potential contributors to disparities in aSAH care in Brazil [9]. This interpretation is consistent with the substantially higher proportion of poor-grade aSAH observed in the present cohort compared with previous Brazilian hospital-based series, making this the most clinically severe cohort reported in the national literature.

Despite the high clinical complexity of the present cohort, definitive aneurysm treatment was achieved in 94% of patients, with a median admission-to-treatment interval of one day and more than 80% of patients undergoing aneurysm occlusion within 48 h of tertiary admission. Endovascular treatment accounted for 73% of all procedures, representing the first Brazilian hospital-based cohort to report endovascular therapy as the predominant treatment modality. These findings contrast with previous national administrative data [9], indicating that, among patients who reached a specialized neurovascular referral center, timely and effective aneurysm treatment was consistently delivered.

Following aneurysm occlusion, our cohort demonstrated a substantial burden of neurological and systemic complications, including hydrocephalus, DCI, intracranial hypertension, ventriculitis, prolonged vasoactive drug use, and infectious complications, all of which required sustained multidisciplinary management throughout the acute phase. The overall frequency and coexistence of these complications indicate a neurocritical care burden higher than that generally reported in contemporary international aSAH cohorts [48–56].

Dedicated neurocritical care units (NCCUs) have been associated with greater adherence to evidence-based practices, earlier recognition and treatment of secondary neurological complications, more coordinated multidisciplinary care, shorter ICU and hospital length of stay, lower healthcare costs, and, in observational studies, improved clinical outcomes [13,15–18,57–62]. However, establishing dedicated NCCUs remains challenging in many low- and middle-income countries because of financial, infrastructural, and workforce constraints [19,63–65]. In Brazil, this structural gap has previously been highlighted in nationwide studies of neurocritical care, which demonstrated substantial heterogeneity in the availability of specialized infrastructure, trained personnel, and organized neurocritical care services across institutions [66,67]. Consequently, many tertiary referral centers rely on alternative organizational models in which specialized neurocritical care is delivered across stroke units, emergency departments, and general ICUs rather than within a dedicated unit. In our institution, despite the absence of a dedicated NCCU and limited ICU availability, patients had access to multiple components of contemporary neurocritical care, including advanced neuromonitoring, rescue endovascular therapies, cerebrospinal fluid diversion, decompressive surgery, and protocolized management of secondary neurological complications.

Importantly, the present findings should not be interpreted as evidence that the organizational model adopted at our institution directly influenced patient outcomes. Consistent with this interpretation, the univariate analyses did not demonstrate a statistically significant association between ICU-related variables and in-hospital mortality. Interpretation of these findings is inherently complex, as the ability to detect meaningful associations depends on the underlying effect size, sample size, and adequate control of bias and confounding, factors that cannot be fully addressed within the design of the present observational study.

Nevertheless, whether these alternative organizational models are inferior, equivalent, or comparable to dedicated NCCUs remains uncertain because they have rarely been systematically characterized, particularly with respect to care processes, resource utilization, and the delivery of specialized neurocritical care in resource-constrained healthcare systems.

Beyond the organization of tertiary neurovascular care, our findings also highlight additional opportunities for intervention across earlier stages of the aSAH care continuum. Compared with contemporary cohorts from high-income healthcare systems [1,56,68,69], the high prevalence of modifiable vascular risk factors observed in our population, particularly hypertension and smoking, underscores the persistent need for more effective primary prevention strategies to reduce aneurysm formation and rupture risk. Likewise, the markedly severe clinical presentation at tertiary admission suggests that important opportunities may still exist to improve the organization of prehospital and interhospital care, including earlier recognition, timely diagnosis, initial stabilization, and efficient referral to specialized neurovascular centers.

At the opposite end of the care continuum, functional recovery also remained limited after hospital discharge, with only modest improvement in favorable outcomes at 3-month follow-up. Although recovery after aSAH is strongly influenced by the severity of the initial brain injury, these findings also emphasize the importance of structured post-acute rehabilitation and long-term multidisciplinary follow-up. Previous analyses from our group have similarly demonstrated that admission severity remains a major determinant of mortality and functional recovery in this population [10]. Together, these observations reinforce that improving outcomes after aSAH requires coordinated interventions extending from primary prevention and timely access to specialized care through rehabilitation and long-term recovery.

5. Limitations

This study has several limitations that should be considered when interpreting its findings. First, its retrospective, single-center observational design precludes causal inference and may limit the generalizability of the results to healthcare systems with different referral structures and resource availability. Second, as a tertiary referral center cohort, the study is inherently subject to referral and survivor selection biases, since only patients who survived the initial hemorrhage, were recognized, stabilized, and successfully transferred to specialized care were included. Consequently, the cohort is more representative of patients who ultimately reached definitive treatment than of the overall regional population affected by aSAH.

Third, a substantial portion of the study period overlapped with the COVID-19 pandemic. Although contemporary Brazilian studies did not demonstrate major changes in aSAH admissions, aneurysm treatment rates, or in-hospital mortality during this period, the pandemic likely imposed additional pressure on ICU capacity, interhospital transfers, and healthcare resource allocation [9,39,70,71]. These factors may have influenced aspects of care delivery and should be considered when interpreting the organizational model described.

Finally, because this study was designed to characterize care rather than compare models of care delivery, future investigations should evaluate how different organizational structures influence each stage of the aSAH care continuum, from early diagnosis and referral to aneurysm treatment, neurocritical care, rehabilitation, and long-term recovery.

6. Conclusion

This study provides a comprehensive real-world description of contemporary aneurysmal subarachnoid hemorrhage care delivered within a public tertiary referral center in a middle-income healthcare system. The combination of severe neurological presentation, timely definitive aneurysm treatment, and a substantial neurocritical care burden illustrates the complexity of specialized aSAH care in routine clinical practice. Rather than focusing exclusively on individual interventions or hospital outcomes, these findings emphasize the importance of understanding how specialized care is organized across the entire patient journey. Characterizing how specialized aSAH care is organized may represent an essential first step toward informing future studies designed to identify which components of the care continuum are associated with improved patient outcomes across diverse healthcare settings.

CRediT authorship contribution statement

Thire Baggio Machado Marazzi: Writing – original draft, Validation, Supervision, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Brunna Pileggi Rimoli:** Writing – review & editing, Data curation. **Ricardo Santos de Oliveira:** Writing – review & editing, Supervision. **Daniel Giansante Abud:** Writing – review & editing, Supervision. **Octávio Marques Pontes-Neto:** Writing – review & editing.

Funding

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Finance Code 001.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation Process

During the preparation of this work, generative artificial intelligence tools were used to assist with language editing and manuscript organization. The authors critically reviewed and edited all AI-generated content, take full responsibility for the content of this publication, and approve its final version.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jocn.2026.112225.

References

[1] Etminan N, Chang HS, Hackenberg K, et al. Worldwide incidence of aneurysmal subarachnoid hemorrhage according to region, time period, blood pressure, and smoking prevalence in the population. JAMA Neurol 2019;76(5):588. https://doi.org/10.1001/jamaneurol.2019.0006.

[2] van Gijn J, Kerr RS, Rinkel GJ. Subarachnoid haemorrhage. Lancet 2007;369(9558):306–18. https://doi.org/10.1016/S0140-6736(07)60153-6.

[3] Seule M, Oswald D, Muroi C, Brandi G, Keller E. Outcome, return to work and health-related costs after aneurysmal subarachnoid hemorrhage. Neurocrit Care 2020;33(1):49–57. https://doi.org/10.1007/s12028-019-00905-2.

[4] le Roux AA, Wallace MC. Outcome and cost of aneurysmal subarachnoid hemorrhage. Neurosurg Clin N Am 2010;21(2):235–46. https://doi.org/10.1016/j.nec.2009.10.014.

[5] Lovelock CE, Rinkel GJE, Rothwell PM. Time trends in outcome of subarachnoid hemorrhage: population-based study and systematic review. Neurology 2010;74(19):1494–501. https://doi.org/10.1212/WNL.0b013e3181dd42b3.

[6] Marazzi TBM, Mendes PV. Updates on aneurysmal subarachnoid hemorrhage: is there anything really new? Arq Neuropsiquiatr 2022;80:80–7. https://doi.org/10.1590/0004-282X-ANP-2022-S101.

[7] Nieuwkamp DJ, Setz LE, Algra A, Linn FH, de Rooij NK, Rinkel GJ. Changes in case fatality of aneurysmal subarachnoid haemorrhage over time, according to age, sex, and region: a meta-analysis. Lancet Neurol 2009;8(7):635–42. https://doi.org/10.1016/S1474-4422(09)70126-7.

[8] Lee HS, Sohn MK, Lee J, et al. Five-year functional outcomes among patients surviving aneurysmal subarachnoid hemorrhage. JAMA Netw Open 2025;8(3):e251678. https://doi.org/10.1001/jamanetworkopen.2025.1678.

[9] Goulart TO, Marazzi TBM, Monteiro RA, Perdoná G da SC, Camilo MR, Pontes-Neto OM. Nationwide epidemiological study of subarachnoid hemorrhage: trends in admissions, mortality, seasonality, costs, clipping, embolization, and the impact of COVID-19. *Front Neurol*.

[10] Marazzi TBM, Goulart TO, Rimoli BP, Pontes-Neto OM. Prognostic value of aneurysmal subarachnoid hemorrhage scores on mortality and disability in a Brazilian tertiary center. 84(4).

[11] Suarez JI. *Diagnosis and Management of Subarachnoid Hemorrhage*. Vol 21. 2015: 1263-1287. www.ContinuumJournal.com.

[12] Addis A, Baggiani M, Citerio G. Intracranial pressure monitoring and management in aneurysmal subarachnoid hemorrhage. Neurocrit Care 2023;39(1):59–69. https://doi.org/10.1007/s12028-023-01752-y.

[13] Treggiari MM, Rabinstein AA, Busl KM, et al. Guidelines for the Neurocritical Care Management of Aneurysmal Subarachnoid Hemorrhage. Neurocrit Care 2023;39(1):1–28. https://doi.org/10.1007/s12028-023-01713-5.

[14] Connolly ES, Rabinstein AA, Carhuapoma JR, et al. Guidelines for the management of aneurysmal subarachnoid hemorrhage. Stroke 2012;43(6):1711–37. https://doi.org/10.1161/STR.0b013e3182587839.

[15] Diringer MN, Edwards DF. Admission to a neurologic/neurosurgical intensive care unit is associated with reduced mortality rate after intracerebral hemorrhage. Crit Care Med 2001;29(3):635–40. https://doi.org/10.1097/00003246-200103000-00031.

[16] Egawa S, Hifumi T, Kawakita K, et al. Impact of neurointensivist-managed intensive care unit implementation on patient outcomes after aneurysmal subarachnoid hemorrhage. J Crit Care 2016;32:52–5. https://doi.org/10.1016/j.jcrc.2015.11.008.

[17] Josephson SA, Douglas VC, Lawton MT, English JD, Smith WS, Ko NU. Improvement in intensive care unit outcomes in patients with subarachnoid hemorrhage after initiation of neurointensivist co-management. J Neurosurg 2010;112(3):626–30. https://doi.org/10.3171/2009.8.JNS09441.

[18] Samuels O, Webb A, Culler S, Martin K, Barrow D. Impact of a dedicated neurocritical care team in treating patients with aneurysmal subarachnoid hemorrhage. Neurocrit Care 2011;14(3):334–40. https://doi.org/10.1007/s12028-011-9505-z.

[19] Prabhakar H, Lele AV, Kapoor I, et al. Neurocritical care organization in the low-income and middle-income countries. Neurocrit Care 2025;43(1):141–56. https://doi.org/10.1007/s12028-025-02210-7.

[20] Barkley AS, Spece LJ, Barros LM, et al. A mixed-methods needs assessment of traumatic brain injury care in a low- and middle-income country setting: building neurocritical care capacity at two major hospitals in Cambodia. J Neurosurg 2021;134(1):244–50. https://doi.org/10.3171/2019.10.JNS192118.

[21] INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Censo Demográfico 2022: resultados do universo. Rio de Janeiro: IBGE, 2023. Disponível em: https://www.ibge.gov.br/estatisticas/sociais/populacao/22827-censo-demografico-2022.html. Acesso em: 14 maio 2024.

[22] Coletiva S, Basílio da Gama R, Paim J. Series the Brazilian health system: history, advances, and challenges. Lancet 2011;377:1778–97. https://doi.org/10.1016/S0140.

[23] Goulart TO, Marazzi TBM, Monteiro RA, Camilo MR, Pontes-Neto OM. Spontaneous Intracranial Hemorrhage in Brazil: trends, Seasonality, Pandemic Disruption, and cost Burden. World Neurosurg 2026;207:124793. https://doi.org/10.1016/j.wneu.2026.124793.

[24] Lindvall P, Runnerstam M, Birgander R, Koskinen LOD. The Fisher grading correlated to outcome in patients with subarachnoid haemorrhage. Br J Neurosurg 2009;23(2):188–92. https://doi.org/10.1080/02688690802710668.

[25] Rosen DS, Loch Macdonald R, Macdonald RL. Subarachnoid hemorrhage grading scales a systematic review. Published online 2005. https://doi.org/10.1385/Neurocrit.

[26] Alexandrov AV, Sloan MA, Tegeler CH, et al. Practice standards for transcranial doppler (TCD) ultrasound. Part II. clinical indications and expected outcomes. J Neuroimaging 2012;22(3):215–24. https://doi.org/10.1111/j.1552-6569.2010.00523.x.

[27] Vergouwen MDI, Vermeulen M, van Gijn J, et al. Definition of delayed cerebral ischemia after aneurysmal subarachnoid hemorrhage as an outcome event in clinical trials and observational studies. Stroke 2010;41(10):2391–5. https://doi.org/10.1161/STROKEAHA.110.589275.

[28] Khawaja AM, McNulty J, Thakur UV, et al. Transcranial Doppler and computed tomography angiography for detecting cerebral vasospasm post-aneurysmal subarachnoid hemorrhage. Neurosurg Rev 2022;46(1):3. https://doi.org/10.1007/s10143-022-01913-1.

[29] Veldeman M, Albanna W, Weiss M, et al. Invasive neuromonitoring with an extended definition of delayed cerebral ischemia is associated with improved outcome after poor-grade subarachnoid hemorrhage. J Neurosurg 2021;134(5):1527–34. https://doi.org/10.3171/2020.3.JNS20375.

[30] Veldeman M, Bögli SY, Olakorede I, et al. The metabolic and autoregulatory profile of reversible delayed cerebral ischemia in unconscious patients after aneurysmal subarachnoid hemorrhage: a prospective multimodal neuromonitoring cohort study. Crit Care 2025;29(1):228. https://doi.org/10.1186/s13054-025-05460-1.

[31] Banks JL, Marotta CA. Outcomes validity and reliability of the modified rankin scale: implications for stroke clinical trials. Stroke 2007;38(3):1091–6. https://doi.org/10.1161/01.STR.0000258355.23810.c6.

[32] Lannes M, Zeiler F, Guichon C, Teitelbaum J. The use of Milrinone in patients with delayed cerebral ischemia following subarachnoid hemorrhage: a systematic review. Can J Neurol Sci J Can Sci Neurol 2017;44(2):152–60. https://doi.org/10.1017/cjn.2016.316.

[33] Lannes M, Teitelbaum J, del Pilar CM, Cardoso M, Angle M. Milrinone and homeostasis to treat cerebral vasospasm associated with subarachnoid hemorrhage: the montreal neurological hospital protocol. Neurocrit Care 2012;16(3):354–62. https://doi.org/10.1007/s12028-012-9701-5.

[34] Chou SHY. Subarachnoid Hemorrhage. Contin Lifelong Learn Neurol 2021;27(5):1201–45. https://doi.org/10.1212/CON.0000000000001052.

[35] Hoh BL, Ko NU, Amin-Hanjani S, et al. 2023 guideline for the management of patients with aneurysmal subarachnoid hemorrhage: a guideline from the american heart association/american stroke association. Stroke 2023;54(7). https://doi.org/10.1161/STR.0000000000000436.

[36] de Oliveira V, Souza N, Rouanet C, Fontoura Solla DJ, et al. Impact of medical and neurologic complications on the outcome of patients with aneurysmal subarachnoid hemorrhage in a middle-income country. World Neurosurg 2024;183:e250–60. https://doi.org/10.1016/j.wneu.2023.12.068.

[37] Oliveira Souza NV de, Rouanet C, Solla DJF, et al. The Role of VASOGRADE as a Simple Grading Scale to Predict Delayed Cerebral Ischemia and Functional Outcome After Aneurysmal Subarachnoid Hemorrhage. *Neurocrit Care*. 2023;38(1):96-104. doi:10.1007/s12028-022-01577-1.

[38] Kurtz P, Taccone FS, Bozza FA, et al. Systemic severity and organ dysfunction in subarachnoid hemorrhage: a large retrospective multicenter cohort study. Neurocrit Care 2021;35(1):56–61. https://doi.org/10.1007/s12028-020-01139-3.

[39] Marazzi TBMM. *Perfil Dos Pacientes Com Hemorragia Subaracnóide Aberuismática Atendidos Entre 2018-2022 Em Hospital Terciário de Referência No Brasil.* Ribeirão Preto Medical School: University of São Paulo; 2025.

[40] Gonçalves B, Rynkowski C, Turon R, et al. Clinical Characteristics and Outcomes of Patients with Aneurysmal Subarachnoid Hemorrhage: A Prospective Multicenter Study in a Middle-Income Country. *Neurocrit Care*. Published online April 1, 2022. doi:10.1007/s12028-022-01629-6.

[41] Gonçalves B, Kurtz P, Turon R, et al. Incidence and impact of sepsis on long-term outcomes after subarachnoid hemorrhage: a prospective observational study. Ann Intensive Care 2019;9(1):94. https://doi.org/10.1186/s13613-019-0562-3.

[42] Turon R, Kurtz P, Rynkowski C, et al. Ventriculitis incidence and outcomes in patients with aneurysmal subarachnoid hemorrhage: a prospective observational study. Crit Care Sci 2025;37:doi:10.62675/2965-2774.20250076.

[43] Rynkowski CB, Hegele V, Soares PHR, et al. Effects of tranexamic acid in patients with subarachnoid hemorrhage in brazil: a prospective observational study with propensity score analysis. Neurocrit Care 2023;39(1):191–7. https://doi.org/10.1007/s12028-023-01732-2.

[44] Kus WP, Pereira Furtado F, De França Y, et al. Analysis of delayed cerebral ischemia incidence after treatment for aneurysmal subarachnoid hemorrhage in young adults: a cohort study. Surg Neurol Int 2024;15:449. https://doi.org/10.25259/SNI_648_2024.

[45] Ballestero M, Saraiva TS, Pongeluppi RI, De Oliveira RS. Epidemiological and Clinical Profile of Patients With Non-traumatic Subarachnoid Hemorrhage in a Brazilian Referral Hospital. *Cureus*. Published online December 26, 2025. doi: 10.7759/cureus.100142.
[46] Yoshikawa MH, Rabelo NN, Telles JPM, et al. Microsurgery versus embolization: different risk factors for short- and longterm outcomes of patients with ruptured aneurysms. Acta Cirúrgica Bras 2022;37(8):e370806. https://doi.org/10.1590/acb370806.
[47] Rautalin I, Volovici V, Stark BA, et al. Global, Regional, and National Burden of Nontraumatic Subarachnoid Hemorrhage. *JAMA Neurol*. Published online May 23, 2025. doi:10.1001/jamaneurol.2025.1522.
[48] Florez WA, García-Ballestas E, Deora H, et al. Intracranial hypertension in patients with aneurysmal subarachnoid hemorrhage: a systematic review and meta-analysis. Neurosurg Rev 2021;44(1):203–11. https://doi.org/10.1007/s10143-020-01248-9.
[49] Claassen J, Peery S, Kreiter KT, et al. Predictors and clinical impact of epilepsy after subarachnoid hemorrhage. Neurology 2003;60(2):208–14. https://doi.org/10.1212/01.WNL.0000038906.71394.DE.
[50] Marigold R, Günther A, Tiwari D, Kwan J. Antiepileptic drugs for the primary and secondary prevention of seizures after subarachnoid haemorrhage. Cochrane Database Syst Rev 2013;2013(6). https://doi.org/10.1002/14651858.CD008710.pub2.
[51] Choi KS, Chun HJ, Yi HJ, Ko Y, Kim YS, Kim JM. Seizures and Epilepsy following Aneurysmal Subarachnoid Hemorrhage : incidence and Risk Factors. J Korean Neurosurg Soc 2009;46(2):93. https://doi.org/10.3340/jkns.2009.46.2.93.
[52] Lantigua H, Ortega-Gutierrez S, Schmidt JM, et al. Subarachnoid hemorrhage: who dies, and why? Crit Care 2015;19(1). https://doi.org/10.1186/s13054-015-1036-0.
[53] Chan V, Lindsay P, McQuiggan J, Zagorski B, Hill MD, O'Kelly C. Declining admission and mortality rates for subarachnoid hemorrhage in canada between 2004 and 2015. Stroke 2019;50(1):181–4. https://doi.org/10.1161/STROKEAHA.118.022332.
[54] Frontera JA, Fernandez A, Schmidt JM, et al. Impact of nosocomial infectious complications after subarachnoid hemorrhage. Neurosurgery 2008;62(1):80–7. https://doi.org/10.1227/01.NEU.0000311064.18368.EA.
[55] Feigin VL, Lawes CM, Bennett DA, Barker-Collo SL, Parag V. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. Lancet Neurol 2009;8(4):355–69. https://doi.org/10.1016/S1474-4422(09)70025-0.
[56] Feigin VL, Rinkel GJE, Lawes CMM, et al. Risk Factors for Subarachnoid Hemorrhage. Stroke 2005;36(12):2773–80. https://doi.org/10.1161/01.STR.0000190838.02954.e8.
[57] Mirski MA, Chang CWJ, Cowan R. Impact of a neuroscience intensive care unit on neurosurgical patient outcomes and cost of care. J Neurosurg Anesthesiol 2001;13(2):83–92. https://doi.org/10.1097/00008506-200104000-00004.
[58] Suarez JI. Outcome in neurocritical care: advances in monitoring and treatment and effect of a specialized neurocritical care team. Crit Care Med 2006;34(Suppl):S232–8. https://doi.org/10.1097/01.CCM.0000231881.29040.25.
[59] Varelas PN, Schultz L, Conti M, Spanaki M, Genarrelli T, Hacein-Bey L. The impact of a neuro-intensivist on patients with stroke admitted to a neurosciences intensive care unit. Neurocrit Care 2008;9(3):293–9. https://doi.org/10.1007/s12028-008-9050-6.
[60] Busl KM, Bleck TP, Varelas PN. Neurocritical care outcomes, research, and technology: a review. JAMA Neurol 2019;76(5):612–8. https://doi.org/10.1001/jamaneurol.2018.4407.
[61] Suarez JI, Zaidat OO, Suri MF, et al. Length of stay and mortality in neurocritically ill patients: impact of a specialized neurocritical care team*. Crit Care Med 2004;32(11):2311–7. https://doi.org/10.1097/01.CCM.0000146132.29042.4C.
[62] Okazaki T, Kuroda Y. Aneurysmal subarachnoid hemorrhage: intensive care for improving neurological outcome. J Intensive Care 2018;6(1). https://doi.org/10.1186/s40560-018-0297-5.
[63] Shrestha GS, Goffi A, Aryal D. Delivering neurocritical care in resource-challenged environments. Curr Opin Crit Care 2016;22(2):100–5. https://doi.org/10.1097/MCC.0000000000000285.
[64] Shrestha GS, Nepal G, Prust ML. Developing systems of emergency and inpatient neurologic care in resource-limited settings. Semin Neurol 2024;44(2):105–18. https://doi.org/10.1055/s-0043-1778638.
[65] Prust ML, Mbonde A, Rubinos C, et al. Providing neurocritical care in resource-limited settings: challenges and opportunities. Neurocrit Care 2022;37(2):583–92. https://doi.org/10.1007/s12028-022-01568-2.
[66] Réa-Neto Á, Bernardelli RS, de Oliveira MC, et al. Epidemiology and disease burden of patients requiring neurocritical care: a Brazilian multicentre cohort study. Sci Rep 2023;13(1). https://doi.org/10.1038/s41598-023-44261-w.
[67] Marazzi TBM, Camilo MR, Goulart TO, et al. Is it time to develop neurocritical care education in Brazil? Analysis of the Brazilian national survey on education in neurocritical care. Arq Neuropsiquiatr 2026;84(02).
[68] Korja M, Lehto H, Juvela S, Kaprio J. Incidence of subarachnoid hemorrhage is decreasing together with decreasing smoking rates. Neurology 2016;87(11):1118–23. https://doi.org/10.1212/WNL.0000000000003091.
[69] Vlak MH, Algra A, Brandenburg R, Rinkel GJ. Prevalence of unruptured intracranial aneurysms, with emphasis on sex, age, comorbidity, country, and time period: a systematic review and meta-analysis. Lancet Neurol 2011;10(7):626–36. https://doi.org/10.1016/S1474-4422(11)70109-0.
[70] dos Reis FI, de Magalhães PSC, Diegoli H, et al. Stroke profile and care during the COVID-19 pandemic: what changed and what did not? a prospective cohort from Joinville, Brazil. Front Neurol 2023;14. https://doi.org/10.3389/fneur.2023.1122875.
[71] de Oliveira MM, Fuller TL, Gabaglia CR, et al. Repercussions of the COVID-19 pandemic on preventive health services in Brazil. Prev Med 2022;155:106914. https://doi.org/10.1016/j.ypmed.2021.106914.