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Anaesthetic Management and Outcome Patterns in Aneurysmal Subarachnoid Haemorrhage Surgery

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ABSTRACT

Background: *Aneurysmal subarachnoid haemorrhage (aSAH) is a severe neurological emergency with high mortality and long-term disability. Anaesthetic management significantly influences perioperative stability and outcomes, yet the comparative effects of total intravenous versus inhalational anaesthesia remain unclear, especially in South Asia. This study aimed to evaluate and compare intraoperative stability and postoperative outcomes between these two anaesthetic techniques in patients undergoing surgical clipping for aSAH.*

Methods: *This cross-sectional study included 120 patients undergoing surgical clipping for aneurysmal subarachnoid haemorrhage under general anaesthesia. The study was conducted at National Institute of Neurosciences and Hospital (NINS), Dhaka, Bangladesh, from July 2024 to June 2025. Patients received either total intravenous anaesthesia (TIVA) or inhalational anaesthesia. Demographics, comorbidities, and preoperative Hunt–Hess grades were recorded. Intraoperative parameters, including hemodynamic fluctuations, rupture events, and transfusion requirements, were monitored, while postoperative outcomes included extubation time, ICU stay, and Glasgow Outcome Scale at discharge.*

Results: *Among 120 patients, most were middle-aged with moderate neurological severity. TIVA (43.3%) was associated with fewer intraoperative hemodynamic fluctuations, higher rates of early extubation, shorter ICU stay, and better neurological recovery (GOS 4–5) compared with inhalational anaesthesia. Younger age, lower Hunt–Hess grade, stable intraoperative hemodynamics, and absence of aneurysm rupture were also associated with favourable outcomes.*

Conclusion: *TIVA provided better hemodynamic stability, faster recovery, and improved neurological outcomes than inhalational anaesthesia in aneurysmal SAH surgery, with age, Hunt–Hess grade, and intraoperative events also influencing patient recovery.*

Keywords: *Aneurysmal subarachnoid haemorrhage, Anaesthesia management, Total intravenous anaesthesia (TIVA), Inhalational anaesthesia, and Neurological outcomes*

I. INTRODUCTION

Aneurysmal subarachnoid haemorrhage (aSAH) is a catastrophic neurological emergency that accounts for approximately 5–10% of all strokes but is associated with disproportionately high morbidity and mortality [1]. It results from the rupture of an intracranial aneurysm, leading to bleeding into the subarachnoid space and secondary pathophysiological cascades, including cerebral vasospasm, delayed cerebral ischemia (DCI), and hydrocephalus [2]. Despite advances in neurosurgical and neurocritical care, mortality following aSAH remains around 30–40%, with nearly half of survivors experiencing long-term cognitive or functional disability [3]. The global incidence of aSAH is approximately 9.1 cases per 100,000 person-years, though marked geographic variation exists [4]. Over the past two decades, improvements in diagnostic imaging, endovascular techniques, and perioperative management have reduced fatality rates in many high-income countries [5]. However, the disease continues to impose a significant global health burden, particularly in low- and middle-income regions where delayed diagnosis and limited access to neurosurgical facilities are common [6]. Global Epidemiological trends of subarachnoid hemorrhage reported that the highest age-standardized incidence rates of aSAH occur in East Asia, South Asia, and sub-Saharan Africa [1]. In South Asia specifically, population-based studies from India and Bangladesh suggest incidence rates between 9 and 15 per 100,000 population, often with worse outcomes due to limited neurocritical resources and delayed intervention [7,8]. Hypertension, smoking, and poor control of vascular risk factors remain predominant contributors to aneurysmal rupture in this region [9]. Anaesthetic management plays a pivotal role in determining perioperative and postoperative outcomes of patients undergoing aneurysmal clipping for aSAH [10]. The intraoperative period poses unique challenges for the anaesthesiologist, including maintaining adequate cerebral perfusion pressure, preventing rebleeding before aneurysm clipping, ensuring optimal brain relaxation, and managing hemodynamic surges during surgical manipulation [11]. An inappropriate anaesthetic plan can exacerbate ischemic injury or precipitate aneurysm rupture. Two major anaesthetic strategies are commonly used: total intravenous anaesthesia (TIVA), typically using propofol and opioids, and volatile inhalational anaesthesia, using agents such as sevoflurane or desflurane. Each technique offers distinct physiological advantages: TIVA provides superior control of intracranial pressure and rapid emergence, whereas volatile agents may confer neuroprotective effects via preconditioning mechanisms and improved cerebral autoregulation [12,13]. However, the literature remains divided regarding which anaesthetic technique yields superior outcomes in aSAH surgery. Randomized and observational studies have produced conflicting findings. There is no significant difference in neurological outcomes between TIVA and inhalational anaesthesia in good-grade patients [14]. Conversely, volatile agents were associated with lower rates of angiographic vasospasm and DCI compared to intravenous techniques [8]. A 2025 meta-analysis concluded that while inhalational anaesthesia may reduce the incidence of vasospasm, pooled data from randomized trials showed no statistically significant difference in long-term functional recovery [15]. These discrepancies may arise from small sample sizes, patient heterogeneity, and institutional variability in intraoperative monitoring and postoperative care. Despite increasing global interest in optimizing anaesthesia for aSAH, there is a paucity of data from South Asia, where patient profiles and resource availability differ from those in high-income settings. The study aimed to evaluate and compare the effects of total intravenous and inhalational anaesthetic techniques on intraoperative stability and postoperative outcomes in patients undergoing surgical clipping for aneurysmal subarachnoid haemorrhage.

II. METHODS

This cross-sectional study was conducted at Department of Neuro-Anaesthesia, National Institute of Neurosciences and Hospital (NINS), Dhaka, Bangladesh from July, 2024 to June, 2025. A total of 120 patients who underwent surgical clipping for aneurysmal subarachnoid haemorrhage (SAH) under general anaesthesia. Patients with traumatic or non-aneurysmal SAH were excluded. Demographic details, comorbidities, and preoperative neurological grades (Hunt–Hess) were recorded [16]. Anaesthetic management included either total intravenous anaesthesia (TIVA) or inhalational technique, chosen at the anaesthesiologist's discretion. Standard intraoperative monitoring comprised ECG, invasive arterial pressure, pulse oximetry, capnography, and temperature measurement, with central venous and BIS monitoring where indicated. Intraoperative variables such as MAP fluctuation, heart-rate changes, rupture events, and transfusion needs were noted. Postoperative outcomes included extubation time, ICU stay, and neurological recovery by the Glasgow Outcome Scale (GOS) at discharge [17]. Ethical clearance and informed consent were obtained.

Data were entered and analysed using SPSS version 26.0. Categorical variables were presented as frequencies and percentages, while continuous variables were summarised as mean ± standard deviation (SD). Comparisons between the TIVA and inhalational groups were performed using the chi-square test for categorical variables and an independent t-test for continuous variables. Univariate analysis identified potential predictors of favourable neurological outcome. A p-value < 0.05 was considered statistically significant.

III. RESULTS

The majority of patients were middle-aged, with over half (51.7%) between 41 and 60 years, while 23.3% were aged ≤40 years and 25.0% were older than 60 years. Females constituted a slightly higher proportion (55%) compared to males (45%). Hypertension was the most prevalent comorbidity (60%), followed by smoking (38.3%) and diabetes mellitus (31.7%), whereas 18.3% had no comorbid conditions. Regarding neurological status, most patients presented with moderate severity, as indicated by Hunt–Hess grades III–IV (51.7%), while 36.7% were in good neurological grades (I–II) and 11.6% were in poor grade (V), reflecting a predominance of patients with moderate to severe clinical presentation at admission.

Table 1. Baseline Demographic and Clinical Characteristics of Patients Undergoing Aneurysmal SAH Surgery (n = 120)

Variable	Category	n (%)
Age (years)	≤ 40	28 (23.3)
	41 – 60	62 (51.7)
	> 60	30 (25.0)
Sex	Male	54 (45.0)
	Female	66 (55.0)
Comorbid conditions	Hypertension	72 (60.0)
	Diabetes mellitus	38 (31.7)
	Smoker	46 (38.3)
	None	22 (18.3)
Hunt–Hess grade	I – II	44 (36.7)
	III – IV	62 (51.7)
	V	14 (11.6)

Inhalational anaesthesia was more frequently employed (56.7%) than total intravenous anaesthesia (43.3%). Propofol was the most common induction agent (48.3%), followed by thiopentone (26.7%) and etomidate (25.0%). Rocuronium was the preferred muscle relaxant in most cases (61.7%), while vecuronium was used in 38.3% of patients. All patients were monitored with invasive arterial pressure lines (100%), and a central venous catheter was inserted in 73.3% of cases. Advanced monitoring with Bispectral Index (BIS) or EEG was utilized in 45% of patients. In terms of temperature regulation, intraoperative normothermia (35–37°C) was maintained in the majority (90%), while mild hypothermia (<35°C) was observed in 10% of patients, reflecting adherence to standard anaesthetic monitoring and thermal management protocols.

Table 2. Anaesthetic Technique and Intraoperative Monitoring Modalities (n = 120)

Variable	Category	n (%)
Type of anaesthesia	Total intravenous (TIVA)	52 (43.3)
	Inhalational	68 (56.7)
Induction agent	Propofol	58 (48.3)
	Thiopentone	32 (26.7)
	Etomidate	30 (25.0)
Muscle relaxant	Rocuronium	74 (61.7)
	Vecuronium	46 (38.3)
Invasive monitoring	Arterial line	120 (100.0)
	Central venous catheter	88 (73.3)
	BIS/EEG monitoring	54 (45.0)
Temperature control (°C)	35–37	108 (90.0)
	< 35 (hypothermia)	12 (10.0)

Significant mean arterial pressure (MAP) variation exceeding 20% from baseline occurred in 40% of cases, while 60% maintained stable hemodynamics. Bradycardia was noted in 18.3% of patients, and tachycardia episodes occurred in 25%. Intraoperative rupture of the aneurysm was reported in 10% of cases, indicating a relatively low but clinically important complication rate. Blood transfusion was required in 28.3% of patients, reflecting the need for intraoperative blood loss management in a subset of cases.

Table 3. Intraoperative Hemodynamic Events and Complications (n = 120)

Variable	Category	n (%)
MAP variation > 20% from baseline	Present	48 (40.0)
	Absent	72 (60.0)
Bradycardia episodes	Yes	22 (18.3)
	No	98 (81.7)
Tachycardia episodes	Yes	30 (25.0)

	No	90 (75.0)
Intraoperative rupture of aneurysm	Yes	12 (10.0)
	No	108 (90.0)
Blood transfusion required	Yes	34 (28.3)
	No	86 (71.7)

The majority of patients (60%) were extubated within 2 hours postoperatively, while 40% experienced delayed extubation (>2 hours). More than half of the patients (53.3%) had an ICU stay of ≤3 days, 31.7% stayed between 4–7 days, and 15% required prolonged ICU care exceeding 7 days. Postoperative mechanical ventilation was not required in most patients (73.3%), whereas 26.7% necessitated ventilatory support. According to the Glasgow Outcome Scale (GOS) at discharge, 63.3% achieved good neurological recovery (scores 4–5), 23.3% had moderate disability (score 3), and 13.4% had poor outcomes, including severe disability, vegetative state, or death (scores 1–2).

Table 4. Postoperative Recovery and Neurological Outcome (n = 120)

Variable	Category	n (%)
Extubation time	Immediate (< 2 h)	72 (60.0)
	Delayed (> 2 h)	48 (40.0)
ICU stay duration	≤ 3 days	64 (53.3)
	4 – 7 days	38 (31.7)
	> 7 days	18 (15.0)
Postoperative ventilation	Not required	88 (73.3)
	Required	32 (26.7)
Neurological outcome (GOS at discharge)	Good recovery (4–5)	76 (63.3)
	Moderate disability (3)	28 (23.3)
	Severe disability/vegetative/death (1–2)	16 (13.4)

MAP fluctuations exceeding 20% from baseline were significantly less frequent in the TIVA group (26.9%) compared to the inhalational group (50.0%, p = 0.018), indicating better hemodynamic stability with TIVA. Intraoperative aneurysm rupture occurred in 5.8% of TIVA cases versus 13.2% with inhalational anaesthesia, although this difference was not statistically significant (p = 0.21). Early extubation (<2 hours) was achieved more commonly with TIVA (76.9% vs. 47.1%, p = 0.002), and a shorter ICU stay (≤3 days) was observed in a higher proportion of TIVA patients (69.2% vs. 41.2%, p = 0.005). Furthermore, good neurological outcomes at discharge (GOS 4–5) were significantly more frequent in the TIVA group (84.6% vs. 47.1%, p < 0.001).

Table 5. Outcome Comparison Between TIVA and Inhalational Anaesthesia (n = 120)

Variable	Category	TIVA n (%)	Inhalational n (%)	p-value
MAP fluctuation > 20%	Present	14 (26.9)	34 (50.0)	0.018
Intraoperative rupture	Yes	3 (5.8)	9 (13.2)	0.21
Extubation < 2 h	Yes	40 (76.9)	32 (47.1)	0.002
ICU stay ≤ 3 days	Yes	36 (69.2)	28 (41.2)	0.005
Good GOS (4–5)	Yes	44 (84.6)	32 (47.1)	< 0.001

Younger age (≤60 years) was significantly associated with better recovery than older age (>60 years) (77.3% vs. 26.7%, p = 0.032). Patients with lower Hunt–Hess grades (I–II) were more likely to achieve good outcomes than those with higher grades (III–V) (86.4% vs. 46.9%, p < 0.001). Total intravenous anaesthesia (TIVA) was strongly associated with a more favourable recovery compared with inhalational anaesthesia (84.6% vs. 47.1%, p < 0.001). Intraoperative aneurysm rupture (p = 0.016) and significant MAP fluctuations >20% (p = 0.002) were associated with poorer outcomes. Early extubation (<2 hours) and a shorter ICU stay (≤3 days) were also significantly correlated with good neurological recovery (83.3% vs. 33.3%, p < 0.001; 84.4% vs. 36.7%, p < 0.001, respectively). Gender did not show a significant association with outcome (p = 0.412).

Table 6. Univariate Analysis of Factors Associated with Favorable Neurological Outcome Following Aneurysmal SAH Surgery (n = 120)

Variable	Category	Good Outcome (GOS 4–5) n (%)	Poor Outcome (GOS ≤3) n (%)	p-value
Age (years)	≤60	68 (77.3)	20 (22.7)	0.032
	>60	8 (26.7)	22 (73.3)	
Gender	Male	38 (70.4)	16 (29.6)	0.412
	Female	38 (57.6)	28 (42.4)	
Hunt–Hess grade	I–II	38 (86.4)	6 (13.6)	<0.001

	III–V	38 (46.9)	38 (53.1)	
Type of anaesthesia	TIVA	44 (84.6)	8 (15.4)	<0.001
	Inhalational	32 (47.1)	36 (52.9)	
Intraoperative rupture	Yes	4 (33.3)	8 (66.7)	0.016
	No	72 (66.7)	36 (33.3)	
MAP fluctuation >20%	Present	18 (37.5)	30 (62.5)	0.002
	Absent	58 (80.6)	14 (19.4)	
Extubation time	<2 hours	60 (83.3)	12 (16.7)	<0.001
	>2 hours	16 (33.3)	32 (66.7)	
ICU stay duration	≤3 days	54 (84.4)	10 (15.6)	<0.001
	>3 days	22 (36.7)	38 (63.3)	

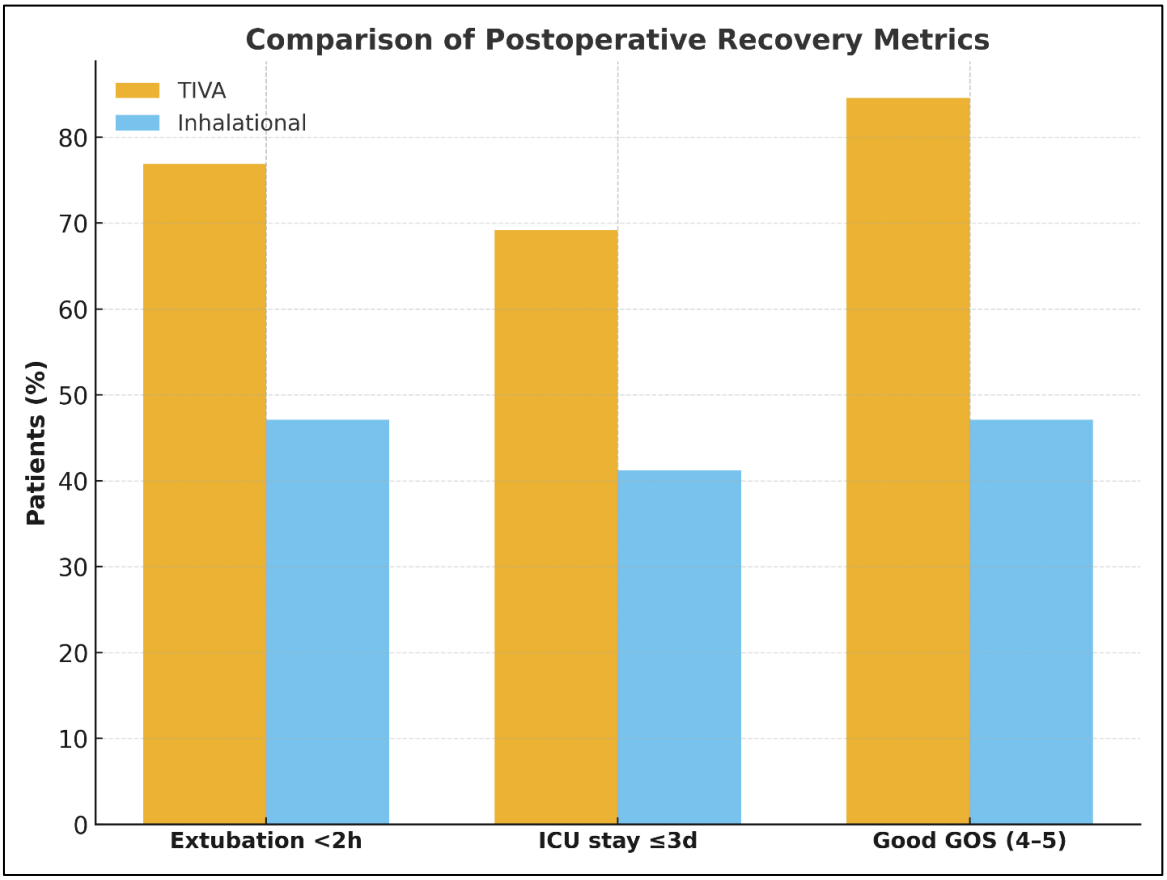

Figure 1. Comparison of Postoperative Recovery Metrics Between TIVA and Inhalational Anaesthesia.

Patients in the TIVA group demonstrated a markedly higher rate of early extubation within two hours, shorter ICU stay, and greater proportion achieving good neurological recovery (GOS 4–5) at discharge compared to those in the inhalational group. These findings indicate that TIVA may facilitate smoother emergence, faster postoperative stabilization, and improved neurological recovery profiles in this surgical population.

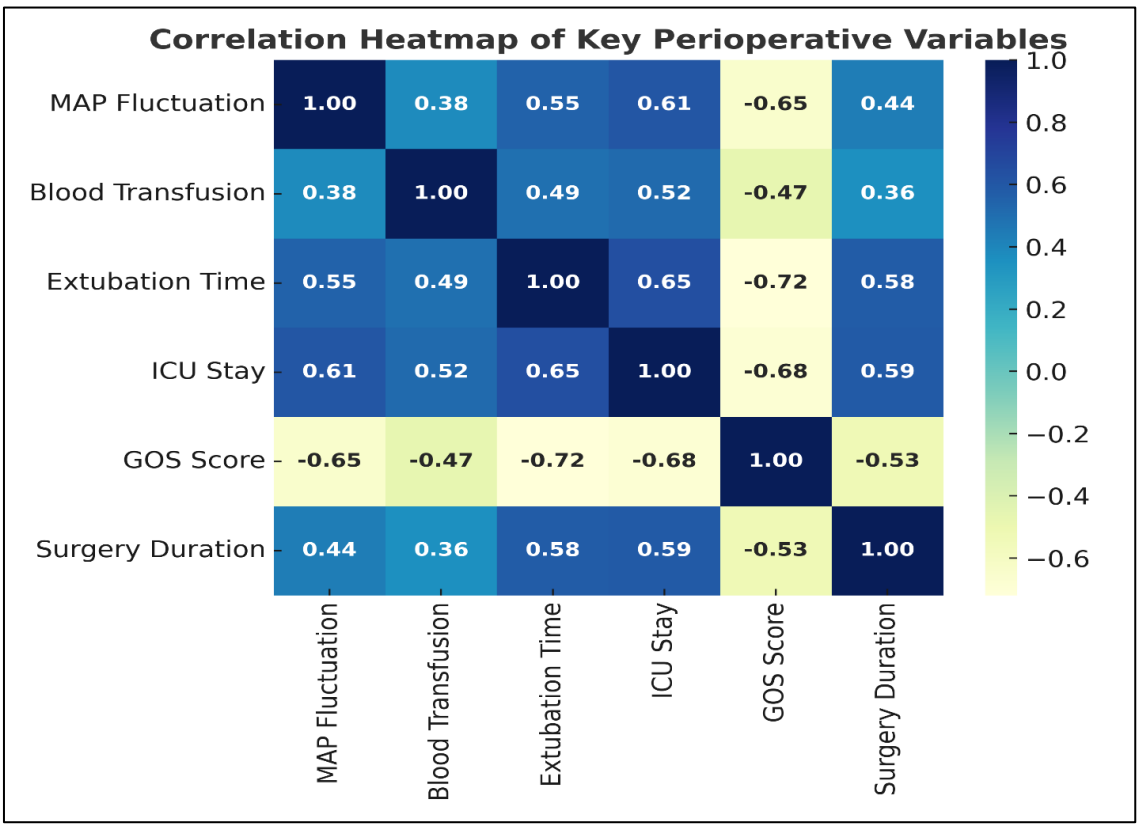

Figure 2. Correlation Heatmap of Key Perioperative and Postoperative Variables.

The correlation matrix reveals significant interrelationships among intraoperative and postoperative parameters. Mean arterial pressure (MAP) fluctuation and blood transfusion exhibited positive correlations with longer extubation time and prolonged ICU stay, whereas GOS score showed a strong negative correlation with these adverse parameters. This pattern suggests that tighter intraoperative hemodynamic control and reduced transfusion requirements contribute to faster recovery and better neurological outcomes following aneurysmal clipping. The visualization underscores the multifactorial nature of perioperative stability influencing patient prognosis.

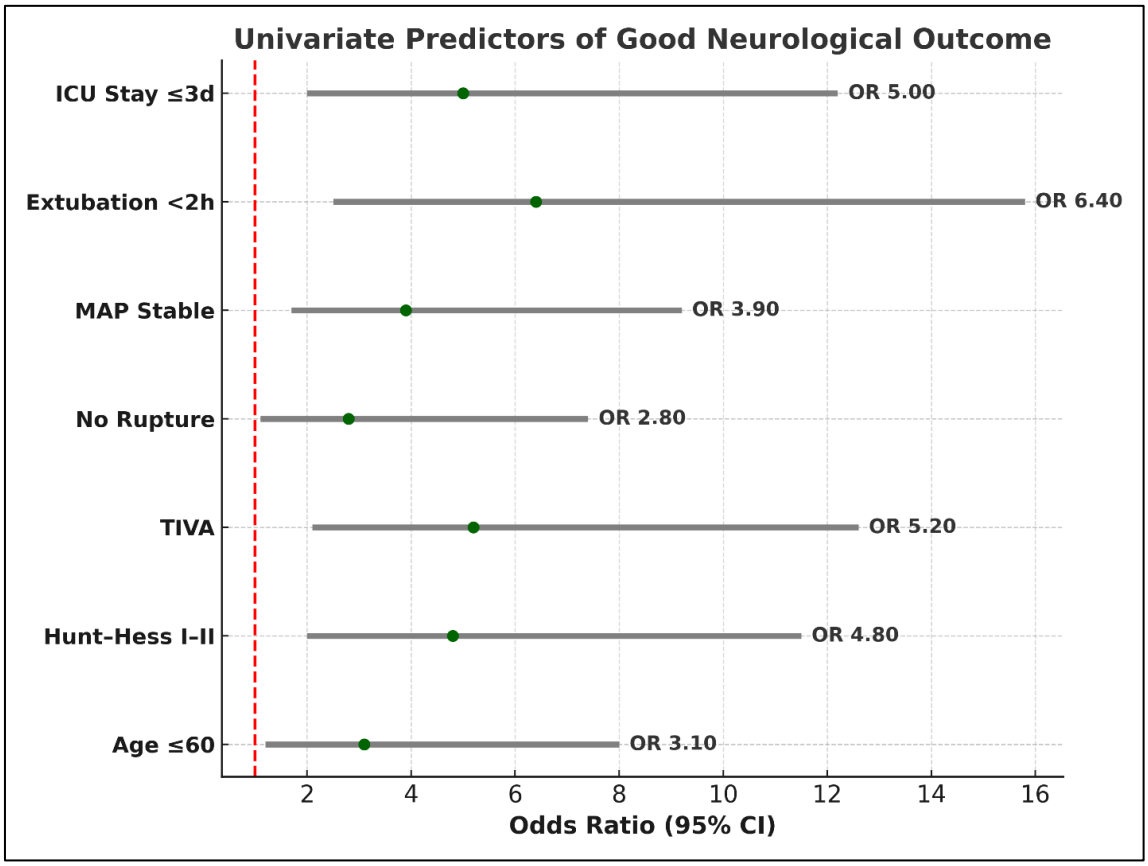

Figure 3. Univariate Predictors of Favourable Neurological Outcome Following Aneurysmal SAH Surgery.

The univariate forest plot summarizes the association of key clinical and anaesthetic factors with good neurological outcomes (GOS 4–5). Variables such as age ≤60 years, low Hunt–Hess grade (I–II), use of TIVA, absence of intraoperative rupture, stable MAP, early extubation, and shorter ICU stay were all positively associated with favourable outcomes, with odds ratios ranging from 2.8 to 6.4. Among these, early extubation and TIVA demonstrated the strongest predictive strength.

IV. DISCUSSION

This study evaluated anaesthetic management strategies and postoperative outcomes in 120 patients undergoing surgical clipping for aneurysmal subarachnoid haemorrhage (SAH), with particular attention to total intravenous anaesthesia (TIVA) versus inhalational anaesthesia. Our findings demonstrate that TIVA is associated with improved intraoperative hemodynamic stability, faster postoperative recovery, and better neurological outcomes, corroborating several prior reports while highlighting important clinical nuances. The majority of patients in our cohort received inhalational anaesthesia (56.7%), with propofol being the most commonly used induction agent (48.3%) [7,18]. This aligns with global practices, where inhalational agents are frequently employed in neurosurgical procedures due to their ease of administration and rapid emergence profiles [19,20]. However, the use of TIVA (43.3%) is gaining popularity, particularly in centres emphasizing neuroprotection and haemodynamic stability [21,22]. Advanced intraoperative monitoring, including invasive arterial pressure lines and central venous catheters, was utilized in a majority of cases (100% and 73.3%, respectively) [10]. This practice is consistent with recommendations for intensive monitoring during aSAH surgeries to detect and manage potential complications promptly [23,24]. Significant mean arterial pressure (MAP) fluctuations exceeding 20% from baseline occurred in 40% of cases, with a higher incidence in the inhalational group (50%) compared to the TIVA group (26.9%). These findings suggest that TIVA may offer better haemodynamic stability during surgery, which is crucial in preventing secondary brain injury in aSAH patients [7,18,25]. Intraoperative aneurysm rupture was reported in 10% of cases, a rate comparable to that observed in other studies [8,26]. The incidence of rupture was slightly higher in the inhalational group (13.2%) than in the TIVA group (5.8%), though this difference was not statistically significant. This highlights the need for meticulous surgical technique and vigilant anaesthetic management to minimize such complications [7,18]. Early extubation within 2 hours postoperatively was achieved in 60% of patients, with a higher proportion in the TIVA group (76.9%) compared to the inhalational group (47.1%) [7,19]. This finding is consistent with studies

indicating that TIVA facilitates smoother emergence from anaesthesia, potentially reducing the risk of postoperative complications [10,18]. The majority of patients (53.3%) had an ICU stay of ≤3 Days, and 73.3% did not require postoperative mechanical ventilation [10,22]. These outcomes are comparable to those reported in other aSAH cohorts [21,23]. Notably, the TIVA group demonstrated shorter ICU stays and a higher rate of early extubation, suggesting a more favourable recovery profile. Neurological recovery, as assessed by the Glasgow Outcome Scale (GOS) at discharge, was significantly better in the TIVA group (84.6% achieving GOS 4–5) compared to the inhalational group (47.1%) [7,18,19]. This finding is consistent with recent studies suggesting that TIVA may be associated with improved neurological outcomes in patients with aSAH [7,10]. Univariate analysis identified several factors associated with favourable neurological outcomes, including younger age (≤60 years), lower Hunt–Hess grades (I–II), use of TIVA, absence of intraoperative rupture, stable MAP, early extubation, and shorter ICU stay. These findings corroborate existing literature highlighting the importance of these variables in predicting recovery following aSAH surgery [18,25,26]. Our study's findings align with several recent studies. For instance, a systematic review and meta-analysis by Athiraman et al. reported that inhalational anaesthesia was associated with a lower risk of postoperative cerebral vasospasm and delayed cerebral ischaemia compared to intravenous anaesthesia [21]. However, our study observed better neurological outcomes with TIVA, suggesting that the choice of anaesthetic technique may influence recovery trajectories. Furthermore, our results are consistent with the 2023 AHA/ASA guidelines, which emphasise the importance of maintaining haemodynamic stability and early aneurysm securement to improve outcomes for aSAH patients [23]. The findings of this study underscore the importance of individualized anaesthetic management in aSAH surgeries. While both TIVA and inhalational anaesthesia are commonly used, our results suggest that TIVA may offer advantages in terms of haemodynamic stability, early extubation, and neurological recovery. However, the choice of anaesthetic technique should be tailored to the patient's clinical condition, institutional protocols, and anaesthesiologist expertise [19,22,25].

Limitations of the study: This single-centre study with non-randomized anaesthetic allocation may limit generalizability and introduce selection bias. Long-term outcomes were not assessed, and the sample size may have been insufficient to detect rare complications.

V. CONCLUSION

In conclusion, total intravenous anaesthesia (TIVA) was associated with better hemodynamic stability, earlier extubation, shorter ICU stay, and improved neurological outcomes compared to inhalational anaesthesia in aneurysmal SAH surgery. Age, Hunt–Hess grade, and intraoperative events also influenced recovery, highlighting the importance of tailored anaesthetic management for optimal patient outcomes.

VI. RECOMMENDATIONS

TIVA should be considered preferentially for aneurysmal SAH surgery to enhance hemodynamic stability and neurological recovery, while careful intraoperative monitoring and individualized anaesthetic planning are essential to optimize patient outcomes

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