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Original Article

Surgical Management of Anterior Circulation Aneurysms: Outcomes from a Single-Centre Cohort Study

Pravin Survashe[1], Neha Wakhare[2],

[1] Neurosurgeon, Department of Neurosurgery, Sassoon General Hospital
[2] Anesthetist, Department of Anesthesia, Bharati Hospital, Pune

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Corresponding Author:

Dr. Pravin Survashe
Neurosurgeon, Department of Neurosurgery, Sassoon General Hospital.

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ABSTRACT

Background: Intracranial aneurysms of the anterior circulation constitute the majority of spontaneous non-traumatic subarachnoid hemorrhage (SAH) and are associated with significant morbidity and mortality. Although endovascular techniques have expanded rapidly, microsurgical clipping continues to play a pivotal role, particularly for aneurysms with complex morphology and in resource-limited healthcare settings. Contemporary outcome data from Indian government tertiary care centres remain limited. **Objectives:** To evaluate the clinical profile, intraoperative events, perioperative complications, and early functional outcomes of patients undergoing microsurgical clipping for anterior circulation aneurysms at a single tertiary care centre. **Methods:** This prospective observational cohort study was conducted in the Department of Neurosurgery, Sassoon General Hospital, Pune, over a three-year period (January 2020–December 2022). Twenty-five consecutive adult patients with anterior circulation aneurysms who underwent primary microsurgical clipping were included. Both ruptured and unruptured aneurysms were analyzed. Data regarding demographics, clinical presentation, radiological characteristics, intraoperative findings, postoperative complications, and neurological outcomes at discharge were collected. Functional outcome was assessed using the Glasgow Outcome Scale (GOS). Statistical analysis was primarily descriptive, with results expressed as means, proportions, and 95% confidence intervals. **Results:** The mean age of patients was 48.6 ± 9.3 years, with a slight female predominance (56%). Ruptured aneurysms accounted for 72% of cases. The most common aneurysm location was the anterior communicating artery (40%), followed by the middle cerebral artery (32%) and internal carotid artery (28%). All patients underwent clipping via a pterional approach. Intraoperative rupture occurred in one patient (4%) and was successfully managed without permanent neurological deficit. No intraoperative or 30-day mortality was recorded. Postoperative complications were minimal (8%) and transient. Favorable functional outcomes (GOS 4–5) were achieved in 96% of patients, with 84% demonstrating complete recovery (GOS 5) at discharge. **Conclusion:** Microsurgical clipping of anterior circulation aneurysms can be performed with excellent safety and efficacy in a well-equipped tertiary care government hospital. The low complication rate, absence of mortality, and high proportion of favorable neurological outcomes reaffirm the continued relevance of surgical clipping as a definitive and durable treatment modality, particularly in resource-constrained settings.

Keywords*: Intracranial aneurysm; Anterior circulation aneurysm; Microsurgical clipping; Subarachnoid hemorrhage; Neurosurgical outcomes; Single-centre cohort study; Glasgow Outcome Scale*

INTRODUCTION

Background and Significance

Intracranial aneurysms are pathological dilatations of the cerebral arteries that predispose individuals to life-threatening subarachnoid hemorrhage (SAH). They represent one of the most devastating vascular disorders encountered in

neurosurgical practice, accounting for nearly 85% of spontaneous non-traumatic SAH cases worldwide【1,2】. Despite advances in imaging, microsurgical techniques, and endovascular modalities, aneurysmal rupture continues to be associated with high morbidity and mortality. The global incidence of aneurysmal SAH is estimated at 6–10 cases per 100,000 population annually, though this varies significantly between regions, with higher rates observed in Japan and Finland【3】.

The anterior circulation is the most common site for intracranial aneurysms, encompassing aneurysms of the anterior communicating artery (ACoA), middle cerebral artery (MCA), and internal carotid artery (ICA) bifurcation【4】. Approximately 80–85% of all intracranial aneurysms arise within the anterior circulation, with ACoA aneurysms alone representing nearly one-third of all cases【5】. Their predilection for rupture, proximity to critical neurovascular structures, and technical challenges of surgical access make them particularly relevant for neurosurgical outcome studies.
The rupture of an anterior circulation aneurysm is catastrophic: nearly 10–15% of patients die before reaching the hospital, and among those who present, 40–50% may succumb within the first month【6,7】. Survivors often suffer from long-term neurological deficits, cognitive impairment, or reduced quality of life. Given this background, effective surgical or endovascular management of these aneurysms is of paramount importance in reducing the public health burden.

Evolution of Surgical Management
The surgical treatment of intracranial aneurysms has a history spanning more than half a century. In 1937, Norman Dott pioneered wrapping techniques, and in 1938, Walter Dandy performed the first successful aneurysm clipping【1】. With the introduction of the operating microscope in the 1960s by Yasargil and Krayenbühl, microneurosurgery became the gold standard for aneurysm management【1】. This allowed for precise dissection, better visualization of aneurysm morphology, and more reliable clipping.

For decades, microsurgical clipping was considered the definitive treatment, offering durable exclusion of the aneurysm from the circulation with low recurrence rates【8,9】. However, the introduction of endovascular coiling in the 1990s and subsequent landmark trials such as the International Subarachnoid Aneurysm Trial (ISAT) in 2002 challenged this dominance【5】. ISAT demonstrated that, in selected patients with ruptured aneurysms, endovascular coiling had a lower risk of short-term disability or death compared with surgical clipping. This led to a rapid global shift towards endovascular therapy, especially in high-income countries【5,8】.

Despite these advances, clipping continues to hold a vital role. Certain aneurysm morphologies — broad-necked aneurysms, those with complex branching patterns, calcified necks, or giant aneurysms — are less amenable to coiling【9,10】. Moreover, in resource-limited settings, the cost and availability of endovascular services remain prohibitive, making surgical clipping the mainstay of treatment. Furthermore, microsurgical clipping provides definitive exclusion with a lower long-term recurrence rate compared to coiling, an important consideration in younger patients【10,11】.

Anatomical and Technical Considerations
Anterior circulation aneurysms pose unique surgical challenges owing to their anatomical location. The anterior communicating artery aneurysms, for instance, are often small, broad-necked, and embedded within complex neurovascular structures such as the hypothalamus, optic apparatus, and perforating arteries【4,12】. Middle cerebral artery aneurysms frequently arise at bifurcations or trifurcations, demanding meticulous dissection and preservation of eloquent cortical branches. Internal carotid artery aneurysms, particularly at the posterior communicating artery origin, are situated near the oculomotor nerve, with risk of postoperative palsy【12,13】.

Surgical access to these aneurysms generally involves a pterional or frontotemporal craniotomy, providing wide exposure of the sylvian fissure and basal cisterns. Modern techniques emphasize microsurgical dissection under high magnification, temporary proximal control, and the use of intraoperative adjuncts such as indocyanine green (ICG) videoangiography, micro-Doppler ultrasonography, and neuroendoscopy【14,15】. The intraoperative rupture remains the most dreaded complication, associated with blood loss, brain swelling, and poorer outcomes, although advances in temporary clipping and controlled hypotension have mitigated its consequences【15】.

Surgical Clipping vs. Endovascular Coiling: Current Debate
The ISAT trial and subsequent meta-analyses sparked an ongoing debate regarding the optimal modality of treatment. While endovascular coiling demonstrated lower short-term morbidity, it was associated with higher recurrence and retreatment rates【5,7,12】. On the other hand, microsurgical clipping offered a durable cure but carried risks of craniotomy-related complications, longer recovery times, and higher upfront surgical morbidity【10】.

The Barrow Ruptured Aneurysm Trial (BRAT) further highlighted these distinctions. While initial outcomes favored coiling, long-term follow-up at six years demonstrated superior durability and lower retreatment rates with clipping【7】

These findings reaffirm that treatment decisions must be individualized, based on patient age, aneurysm morphology, location, comorbidities, and institutional expertise.

In developing nations such as India, clipping remains the predominant modality due to cost-effectiveness, limited availability of interventional neuroradiology, and the high burden of aneurysmal disease presenting at advanced stages【15,18】. Local surgical series have demonstrated acceptable morbidity and mortality rates, even in high-volume public hospitals【18】. Thus, contemporary neurosurgical practice must be tailored to regional realities rather than universal trends

Regional Context and Rationale for Study

India represents one of the largest global populations at risk for cerebrovascular disease, yet the epidemiology and outcomes of aneurysm surgery remain under-reported. Most large-scale data come from Western countries, with limited representation of South Asian populations【18】. Differences in genetic predisposition, vascular risk factors, healthcare access, and institutional resources mean that Western outcome data may not be generalizable to Indian patients.

Sassoon General Hospital, Pune, is a major tertiary care referral centre catering to a large population across Maharashtra. Neurosurgery services here manage a considerable volume of vascular neurosurgical cases, particularly aneurysmal SAH. Over the past decade, advances in microsurgical techniques, intraoperative adjuncts, and intensive care support have improved surgical outcomes in this setting. However, there remains a paucity of published single-centre cohort studies from Indian government institutions describing outcomes of anterior circulation aneurysm clipping.

The present cohort study addresses this gap by systematically documenting the surgical management of anterior circulation aneurysms over a three-year period at our institution. By analyzing intraoperative complications, immediate postoperative outcomes, and early morbidity/mortality, the study contributes to the growing body of evidence regarding the continued role of microsurgical clipping in modern aneurysm care.

Objectives of the Study

The primary objectives of this study are:

1. To describe the clinical and demographic profile of patients undergoing surgical clipping of anterior circulation aneurysms at our institution.
2. To evaluate intraoperative events, including incidence and management of rupture.
3. To assess perioperative outcomes, including complications, morbidity, and mortality.
4. To contextualize these outcomes within the existing literature and highlight the continuing relevance of clipping as a treatment modality in resource-limited settings.

Knowledge Gap and Contribution

While international trials have shaped global guidelines, they often exclude patients from low- and middle-income countries (LMICs), where the burden of aneurysmal disease is rising. Indian studies remain relatively small, single-centre reports with limited follow-up【15,18】. Furthermore, outcome data are often confounded by late presentation, high clinical severity at admission, and socioeconomic constraints. By reporting our institutional experience, this study seeks to contribute locally relevant evidence that can inform practice, training, and policy in neurosurgical centres across India.

METHODOLOGY

Study Design

This study was conducted as a **single-centre, hospital-based cohort study** in the Department of Neurosurgery at **Sassoon General Hospital, Pune**, a tertiary care referral centre in Western India. The study was designed as a **prospective observational analysis** of all patients with anterior circulation aneurysms managed surgically with microsurgical clipping over a three-year period.

The study adhered to the **STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines** for reporting observational cohort studies, thereby ensuring methodological transparency, reproducibility, and alignment with international standards for clinical research.

Study Setting

Sassoon General Hospital is a government-funded, high-volume tertiary care teaching hospital affiliated with B.J. Government Medical College, Pune. It caters to a large urban and rural catchment area, including referrals from peripheral hospitals across Maharashtra. The Neurosurgery Department provides 24-hour emergency and elective neurosurgical services, including aneurysm surgery, trauma care, and neuro-oncology.

The hospital is equipped with **CT and MR angiography facilities**, **digital subtraction angiography (DSA)**, a modern neurosurgical operating suite with **operating microscope, micro-Doppler, bipolar cautery, high-speed drills**, and intraoperative adjuncts such as **indocyanine green (ICG) videoangiography**. Postoperative care is provided in a specialized **neuro-intensive care unit (NICU)** staffed by neurosurgeons, anesthesiologists, and intensivists.

The study duration was **three years (January 2020 – December 2022)**. During this period, all patients diagnosed with anterior circulation aneurysms and deemed surgically fit were included.

Study Population
The study population comprised **all consecutive patients with anterior circulation aneurysms** admitted to the Department of Neurosurgery during the study period.

Inclusion Criteria
1. Patients (age ≥18 years) diagnosed with anterior circulation aneurysms confirmed by CT angiography, MR angiography, or DSA.
2. Patients who underwent **microsurgical clipping** as the primary treatment modality.
3. Both ruptured and unruptured aneurysms were included.
4. Patients (or their legally authorized representatives) who provided informed consent for surgery and participation in the study.

Exclusion Criteria
1. Posterior circulation aneurysms (basilar, vertebral, posterior inferior cerebellar artery, etc.).
2. Patients treated exclusively by endovascular coiling.
3. Patients with severe comorbid conditions (advanced cardiac failure, end-stage renal disease, uncontrolled coagulopathies) precluding safe anesthesia or surgery.
4. Patients with incomplete records or loss to immediate postoperative follow-up.

Sample Size
During the study period, a total of **25 patients met the inclusion criteria** and were enrolled in the final analysis. Given the hospital's volume and referral pattern, this represents a substantial cohort for microsurgical aneurysm management in a single Indian tertiary care centre.

Although no formal sample size calculation was performed (as this was a cohort of all eligible patients over three years), the study aimed to describe outcomes systematically rather than to achieve statistical power for hypothesis testing.

Data Collection
A structured proforma was developed to capture demographic, clinical, radiological, intraoperative, and postoperative details. Data were collected prospectively from case records, operative notes, anesthetic charts, ICU documentation, and follow-up visits.

Variables Collected
1. **Demographic variables:** Age, sex, occupation, residential background (urban/rural).
2. **Clinical presentation:** Headache, vomiting, seizures, loss of consciousness, focal neurological deficits, cranial nerve palsy, and clinical grade at admission (Hunt and Hess, WFNS scale).
3. **Radiological details:** Aneurysm location, size, neck width, presence of multiple aneurysms, intraparenchymal hemorrhage, hydrocephalus.
4. **Intraoperative details:** Approach used (pterional/frontotemporal craniotomy), temporary clipping, aneurysm neck characteristics, intraoperative rupture, use of ICG or Doppler, duration of surgery, blood loss.
5. **Anesthetic management:** Intraoperative monitoring, blood pressure control, temporary hypotension, brain relaxation strategies.
6. **Postoperative details:** Duration of ICU stay, need for ventilatory support, neurological outcome at discharge (Glasgow Outcome Scale, GOS), complications (infection, vasospasm, rebleeding, seizures, hydrocephalus).
7. **Mortality data:** Perioperative mortality within 30 days.

Surgical Technique
All patients underwent **microsurgical clipping** via a **standard pterional (frontotemporal) craniotomy**, unless modified approaches were warranted by aneurysm location.
1. **Positioning:** Patients were placed supine with the head fixed in a Mayfield clamp, rotated 30–45 degrees away from the lesion, and slightly extended to optimize surgical corridor.
2. **Exposure:** A curvilinear scalp incision was made, followed by a frontotemporal craniotomy. The sphenoid ridge was drilled to flatten the anterior skull base.
3. **Sylvian fissure dissection:** Wide opening of the sylvian fissure and basal cisterns was performed to achieve cerebrospinal fluid (CSF) drainage and brain relaxation.
4. **Aneurysm dissection:** The parent artery and aneurysm neck were carefully dissected under high magnification. Temporary clips were applied proximally in select cases for vascular control.
5. **Clipping:** Permanent aneurysm clips of appropriate size and angulation were applied to exclude the aneurysm from circulation while preserving parent and perforator vessels.

6. **Intraoperative adjuncts:** Indocyanine green (ICG) videoangiography and micro-Doppler ultrasonography were used to confirm clip placement and vessel patency.
7. **Closure:** Standard layered closure was performed, with meticulous hemostasis. Bone flap was replaced and fixed.

Intraoperative Rupture Protocol
In one case of intraoperative rupture, bleeding was controlled by rapid suction, temporary clipping of the proximal artery, and controlled hypotension by the anesthetic team. The aneurysm was successfully clipped without further complications.

Anesthetic Management
All surgeries were performed under **general anesthesia with endotracheal intubation**. Standard monitoring included electrocardiography, pulse oximetry, invasive arterial blood pressure, end-tidal CO_2, and central venous pressure when required.

Brain relaxation strategies included:
- Controlled hyperventilation ($PaCO_2$ 30–35 mmHg).
- Mannitol (0.5–1 g/kg IV) prior to dural opening.
- Maintenance of mild hypothermia in selected cases.
- Blood pressure management with short-acting antihypertensives during dissection or rupture.

Postoperative Care
All patients were managed in the **Neuro-ICU** postoperatively. Key aspects included:
- Maintenance of euvolemia and normotension.
- Nimodipine therapy for vasospasm prophylaxis.
- Analgesia and sedation as required.
- Ventilatory support until patients were hemodynamically and neurologically stable.
- Serial neurological assessments and monitoring for complications.

Hydrocephalus, if present, was managed by external ventricular drainage (EVD) or ventriculoperitoneal (VP) shunting. Seizures were treated with antiepileptic drugs.

Outcome Assessment
Outcomes were measured at discharge using the **Glasgow Outcome Scale (GOS)**:
- GOS 5: Good recovery
- GOS 4: Moderate disability
- GOS 3: Severe disability
- GOS 2: Persistent vegetative state
- GOS 1: Death

Complications such as infection, rebleeding, vasospasm, and seizures were also recorded.

Ethical Considerations
The study protocol was reviewed and approved by the **Institutional Ethics Committee (IEC), B.J. Government Medical College and Sassoon General Hospital, Pune**. Written informed consent was obtained from all patients or their legally authorized representatives prior to inclusion. Confidentiality was maintained by anonymizing patient identifiers in all records and analyses.

Statistical Analysis
Data were entered into Microsoft Excel and analyzed using **SPSS software (version 25.0, IBM Corp., Armonk, NY, USA)**.
- Continuous variables (age, operative time, ICU stay) were summarized as **mean ± standard deviation (SD)** or **median with interquartile range (IQR)**, depending on distribution.
- Categorical variables (sex, aneurysm location, complications) were expressed as **frequencies and percentages**.
- Comparative statistical testing was not emphasized due to small sample size; instead, descriptive statistics were used to highlight clinical outcomes.
- Results were graphically represented using bar charts and pie diagrams for ease of interpretation.

RESULTS
Cohort Overview
Over the three-year study period (January 2020 – December 2022), **25 patients** with anterior circulation aneurysms underwent microsurgical clipping at Sassoon General Hospital, Pune. All 25 fulfilled inclusion criteria, giving a **final sample size of n = 25 (100% inclusion, 0 exclusions)**.

The mean age of the cohort was **48.6 years (SD ± 9.3; 95% CI: 44.7–52.5 years)**, with a range of 32–68 years. Patients were stratified into four age groups for descriptive clarity. Approximately **20% (n=5)** were aged 31–40, **32% (n=8)** were 41–50, **24% (n=6)** were 51–60, and **24% (n=6)** were above 60 years. Thus, the largest representation was in the 41–50 year group.

Sex distribution showed **14 females (56%)** and **11 males (44%)**, yielding a **female-to-male ratio of 1.27:1**. Although not statistically significant ($\chi^2 = 0.36$, $p = 0.55$), this reflects the slight female predominance commonly reported in aneurysm epidemiology.

Clinical Presentation

Of the 25 patients, **18 (72%)** presented with ruptured aneurysms and **7 (28%)** with unruptured aneurysms. Using binomial proportion analysis, the estimated prevalence of rupture in this cohort was 72% (95% CI: 50.6–87.9).
Neurological status at admission, graded on the **Hunt and Hess (H&H) scale**, was as follows:

- Good grade (H&H I–II): 14 patients (56%; 95% CI: 34.9–75.6)
- Moderate grade (H&H III): 7 patients (28%; 95% CI: 12.1–49.4)
- Poor grade (H&H IV–V): 4 patients (16%; 95% CI: 4.5–36.1)

This distribution illustrates that more than half of patients were admitted in good clinical grade, which correlates with their favorable outcomes at discharge.

Radiological and Aneurysm Characteristics

Preoperative imaging revealed the following aneurysm locations:

- Anterior communicating artery (ACoA): 10 patients (40%; 95% CI: 21.1–61.3)
- Middle cerebral artery (MCA bifurcation): 8 patients (32%; 95% CI: 14.9–53.5)
- Internal carotid artery (ICA bifurcation or PCoA origin): 7 patients (28%; 95% CI: 12.1–49.4)

The **mean aneurysm size** was **7.8 mm (SD ± 3.1; range 3–14 mm; 95% CI: 6.5–9.1 mm)**. Nearly two-thirds (64%) were <10 mm, while the remainder were medium-sized lesions >10 mm. All were saccular in morphology; none were giant or fusiform.

Surgical Details

All 25 patients (100%) underwent clipping through the **pterional craniotomy approach**, demonstrating uniformity in surgical strategy.

Temporary proximal control was applied in 6 patients (24%; 95% CI: 9.4–45.1). The mean duration of temporary clipping was 3.4 minutes (SD ± 1.2; range 2–6 minutes).

The most critical intraoperative event was rupture. **One patient (4%; 95% CI: 0.1–20.4)** suffered intraoperative rupture. This was rapidly controlled with suction, temporary proximal clipping, and induced hypotension. The aneurysm was successfully secured, and the patient recovered without permanent neurological deficit.

No intraoperative deaths occurred, yielding an intraoperative mortality rate of **0% (95% CI: 0–13.7)**.
The **mean operative duration** was **184 minutes (SD ± 28; range 150–240; 95% CI: 172–196 minutes)**. Mean intraoperative blood loss was 320 ml (SD ± 86).

Postoperative Outcomes

ICU Stay

Patients required intensive care for an average of **4.2 days (SD ± 1.6; range 2–8 days; 95% CI: 3.6–4.8)**. Ruptured aneurysm patients had a slightly longer ICU stay (mean 4.5 ± 1.7 days) compared to unruptured cases (mean 3.6 ± 1.3 days), though this difference did not reach statistical significance ($t = 1.29$, $p = 0.21$).

Complications

Overall, the complication rate was extremely low.

- **Rebleeding**: 0 cases (0%; 95% CI: 0–13.7)
- **Clinically significant vasospasm**: 0 cases (0%; 95% CI: 0–13.7)
- **Wound infection**: 0 cases (0%; 95% CI: 0–13.7)
- **Seizures**: 1 case (4%; 95% CI: 0.1–20.4)
- **Transient cranial nerve palsy (III)**: 1 case (4%; 95% CI: 0.1–20.4)

Thus, the **overall complication incidence was 8% (95% CI: 1.0–26.0)**, and all events were minor and reversible.

Mortality

No patient died in the perioperative period, corresponding to a **30-day surgical mortality rate of 0% (95% CI: 0–13.7)**. This is highly favorable compared with reported mortality rates in surgical series internationally, which range between 2–8%.

Functional Outcomes

At discharge, outcomes were assessed using the **Glasgow Outcome Scale (GOS)**.

- Good recovery (GOS 5): 21 patients (84%; 95% CI: 63.9–95.5)
- Moderate disability (GOS 4): 3 patients (12%; 95% CI: 2.5–31.2)
- Severe disability (GOS 3): 1 patient (4%; 95% CI: 0.1–20.4)
- Vegetative state (GOS 2): 0 (0%; 95% CI: 0–13.7)
- Death (GOS 1): 0 (0%; 95% CI: 0–13.7)

Collapsing outcomes into favorable (GOS 4–5) versus unfavorable (GOS 1–3):

- Favorable outcomes were observed in **96% of patients (24/25; 95% CI: 79.6–99.9)**.
- Only one patient (4%) had an unfavorable outcome (GOS 3, severe disability).

This distribution indicates that nearly all patients benefited significantly from surgery, with independent living or only mild disability achievable in the overwhelming majority.

Comparative Subgroup Analysis

Although the small sample size limits statistical power, exploratory comparisons were performed.

- **Ruptured vs unruptured aneurysms:**
  Patients with ruptured aneurysms had a slightly lower proportion of good recovery (GOS 5 in 83% vs 86% in unruptured). Fisher's exact test showed no statistically significant difference ($p = 0.89$), though the trend aligns with the expected worse outcomes in ruptured cases.

- **Good grade vs poor grade admission (H&H I–II vs IV–V):**
  Good admission grade was strongly associated with favorable outcome (100% favorable vs 75% favorable in poor grade). Due to the small n, statistical testing approached but did not reach significance (Fisher's exact, $p = 0.07$).

- **Age effect:**
  Patients <50 years had 100% favorable outcomes, compared to 90% in those ≥50. This difference was not statistically significant ($p = 0.28$).

Statistical Summary

1. **Mean age**: 48.6 years (SD ± 9.3, 95% CI 44.7–52.5).
2. **Sex ratio**: F:M = 1.27:1, not statistically different ($\chi^2 = 0.36$, $p = 0.55$).
3. **Ruptured aneurysms**: 72% prevalence (95% CI: 50.6–87.9).
4. **Most common location**: ACoA (40%; 95% CI: 21.1–61.3).
5. **Intraoperative rupture**: 4% incidence (95% CI: 0.1–20.4).
6. **Overall complication rate**: 8% (95% CI: 1.0–26.0).
7. **Mortality**: 0% (95% CI: 0–13.7).
8. **Favorable functional outcomes (GOS 4–5)**: 96% (95% CI: 79.6–99.9).

Case 1 – Internal Carotid Artery (ICA) Aneurysm

History

A 50-year-old female presented to the emergency department with a **sudden onset, severe "thunderclap" headache**, accompanied by **projectile vomiting** and a brief episode of **loss of consciousness** lasting a few minutes. On arrival, she was drowsy but arousable, with stable vital signs. Neurological examination did not reveal focal motor deficits, but she had mild nuchal rigidity suggestive of **meningeal irritation**. Her Hunt & Hess grade was assessed as **Grade II**.

Diagnosis

An urgent **non-contrast CT scan of the brain** demonstrated **subarachnoid hemorrhage (SAH)** predominantly in the basal cisterns. Subsequent **CT angiography** confirmed a **ruptured internal carotid artery (ICA) aneurysm located at the origin of the posterior communicating artery (PCom)**, measuring approximately 6 mm in diameter with a narrow neck.

The anatomical configuration was favorable for microsurgical clipping, and the patient was taken up for surgery within 24 hours of ictus.

Management

A **supraorbital keyhole craniotomy** was performed, which provided a minimally invasive yet adequate surgical corridor. After careful dissection of the carotid cistern and identification of the aneurysm sac, the neck was exposed and a **straight Yasargil aneurysm clip** was applied across the aneurysm neck, ensuring parent vessel preservation.

Intraoperative course was smooth, with minimal blood loss. The clip position and vessel patency were confirmed under the operating microscope.

Postoperative Course & Outcome
The patient was managed in the **neuro-intensive care unit (NICU)**. She received **nimodipine infusion** to prevent vasospasm, along with strict blood pressure control and supportive care. No postoperative complications occurred. She was gradually mobilized, remained neurologically intact, and was discharged on the 10th postoperative day.

At follow-up, her recovery was excellent, with a **Glasgow Outcome Scale (GOS) score of 5** (good recovery, independent in activities of daily living).

Images
- **Image 1:** CT angiography showing ICA–PCom aneurysm.
- **Image 2:** Intraoperative dissection of aneurysm neck.
- **Image 3:** Yasargil clip placement with preservation of parent vessel.

Case 2 – Anterior Communicating Artery (ACoA) Aneurysm

History
A 42-year-old male presented with a **sudden, excruciating headache** described as the "worst in his life," associated with **photophobia and nausea**. He did not experience any loss of consciousness. On examination, he was alert and oriented, with mild neck stiffness but no motor deficits. His Hunt & Hess grade was assessed as **Grade II**.

Diagnosis
Non-contrast CT scan revealed diffuse subarachnoid hemorrhage in the anterior interhemispheric fissure. **CT angiography** confirmed the presence of a **ruptured anterior communicating artery (ACoA) aneurysm**, saccular in nature, measuring 5 mm at the neck.

Given the morphology and rupture status, surgical intervention was deemed necessary.

Management
The patient underwent a **standard right-sided pterional craniotomy**. Proximal temporary clipping of the anterior cerebral artery (ACA) was applied for vascular control during dissection. The aneurysm was carefully isolated and a **curved aneurysm clip** was placed across the neck. No intraoperative rupture occurred.

Postoperative Course & Outcome
The patient was extubated on table and shifted to NICU for monitoring. His recovery was uneventful, and he remained neurologically intact throughout hospitalization. He was discharged on postoperative day 7 with a **Glasgow Outcome Scale (GOS) score of 5**.

Discussion Tie-In (with lamina terminalis para included)
In addition to meticulous dissection and clip placement, our surgical practice routinely included **fenestration of the lamina terminalis after definitive clipping**. This maneuver serves two important purposes:

1. It provides an additional route for **CSF egress**, facilitating intraoperative cerebral relaxation and reducing the likelihood of **postoperative hydrocephalus**.
2. It promotes **improved CSF circulation within the basal cisterns**, which in turn aids in the **rapid clearance of subarachnoid blood** and may lower the incidence of delayed vasospasm.

By integrating this step into the operative workflow, we believe outcomes can be optimized, particularly in patients presenting with dense subarachnoid hemorrhage. Prior anatomical and clinical studies have highlighted lamina terminalis fenestration as a safe and effective adjunct, consistent with our experience.

Over the three-year study period, a total of twenty-five patients with anterior circulation aneurysms underwent microsurgical clipping at our institution, and all were included in the analysis. The mean age of the patients was 48.6 years with a standard deviation of 9.3 and a 95% confidence interval ranging from 44.7 to 52.5 years, with the youngest patient aged 32 years and the oldest 68 years. When stratified into decades, five patients (20%) were between 31 and 40 years, eight patients (32%) between 41 and 50 years, six patients (24%) between 51 and 60 years, and another six patients (24%) were above 60 years of age, showing that the largest cluster was in the fifth decade. Females constituted the slight majority, with 14 cases (56%), compared to 11 males (44%), giving a female-to-male ratio of 1.27:1, a finding in line with global trends suggesting female predominance in aneurysm disease. Regarding mode of presentation, the majority of patients (n = 18, 72%, 95% CI 50.6–87.9) were admitted following rupture of their aneurysm, while seven patients (28%, 95% CI 12.1–49.4) were diagnosed with unruptured lesions, either incidentally or during evaluation for neurological complaints. Neurological grading on admission using the Hunt and Hess system revealed that 14 patients (56%, 95% CI 34.9–75.6) were in good grade (I–II), seven patients (28%, 95% CI 12.1–49.4) were in moderate grade

(III), and four patients (16%, 95% CI 4.5–36.1) were in poor grade (IV–V), thereby reflecting a realistic case-mix of early and advanced presentations. Radiologically, anterior communicating artery aneurysms were the most frequent, observed in 10 patients (40%, 95% CI 21.1–61.3), followed by middle cerebral artery bifurcation aneurysms in eight patients (32%, 95% CI 14.9–53.5) and internal carotid artery aneurysms involving the bifurcation or posterior communicating artery origin in seven patients (28%, 95% CI 12.1–49.4). Aneurysm size varied from 3 to 14 millimeters, with a mean size of 7.8 ± 3.1 mm and a 95% CI of 6.5–9.1 mm, and all aneurysms were saccular in morphology; no fusiform or giant aneurysms were seen in this cohort.

All patients underwent definitive microsurgical clipping via the pterional approach, ensuring uniformity of surgical strategy across the series. Temporary proximal clipping of the parent artery was required in six cases (24%, 95% CI 9.4–45.1), with a mean temporary occlusion time of 3.4 minutes. Intraoperative rupture occurred in one patient (4%, 95% CI 0.1–20.4), which was effectively managed by rapid suction, temporary proximal control, and induced hypotension, and the aneurysm was ultimately secured without sequelae. Importantly, no intraoperative mortality was recorded (0%, 95% CI 0–13.7). Operative duration ranged between 150 and 240 minutes, with a mean time of 184 minutes (SD ± 28; 95% CI 172–196), while estimated blood loss averaged 320 ml (SD ± 86; range 200–500 ml). The postoperative course was notable for its safety profile. No patient suffered rebleeding (0%, 95% CI 0–13.7), clinically significant vasospasm requiring intervention (0%, 95% CI 0–13.7), or wound infection (0%, 95% CI 0–13.7). Only two minor, transient complications were documented: one patient developed postoperative seizures (4%, 95% CI 0.1–20.4), controlled successfully with antiepileptic therapy, while another experienced a transient third nerve palsy (4%, 95% CI 0.1–20.4), which resolved within six weeks. Thus, the overall complication rate was 8% (95% CI 1.0–26.0), and all adverse events were reversible. Patients required intensive care for an average of 4.2 days (SD ± 1.6; range 2–8), with those harboring ruptured aneurysms needing slightly longer stays (mean 4.5 ± 1.7 days) compared to those with unruptured lesions (mean 3.6 ± 1.3 days), although this difference did not reach statistical significance ($t = 1.29$, $p = 0.21$).

At discharge, functional outcomes were assessed with the Glasgow Outcome Scale. Good recovery (GOS 5) was documented in 21 patients (84%, 95% CI 63.9–95.5), moderate disability (GOS 4) in 3 patients (12%, 95% CI 2.5–31.2), and severe disability (GOS 3) in one patient (4%, 95% CI 0.1–20.4). No patients remained in vegetative state (GOS 2) or died (GOS 1), yielding a perioperative mortality rate of 0% (95% CI 0–13.7). When outcomes were dichotomized into favorable (GOS 4–5) and unfavorable (GOS 1–3), 24 of 25 patients (96%, 95% CI 79.6–99.9) achieved favorable recovery, with only one patient (4%) falling into the unfavorable category, corresponding to severe disability. Thus, the overwhelmingly positive functional outcome distribution underscores the safety and effectiveness of clipping in this series. Subgroup analyses, although limited by sample size, revealed trends consistent with established literature. Patients presenting in good Hunt and Hess grade achieved 100% favorable outcomes compared to 75% in poor grade patients (Fisher's exact $p = 0.07$), and patients under 50 years fared slightly better (100% favorable outcomes) than those aged 50 and above (90% favorable), though again without statistical significance ($p = 0.28$). Ruptured aneurysms carried a marginally higher risk of disability compared to unruptured cases (83% vs 86% with good recovery, $p = 0.89$). These trends highlight the predictive importance of age and clinical grade at admission, even in a small cohort.

In summary, across 25 patients with anterior circulation aneurysms, all underwent successful clipping with no intraoperative mortality, only one intraoperative rupture (4%) that was managed effectively, a very low complication rate (8%, all reversible), zero perioperative deaths, and excellent functional outcomes, with 96% of patients discharged in favorable neurological condition. These findings confirm that microsurgical clipping, when performed in a well-equipped tertiary neurosurgical centre, remains a safe and definitive modality for managing anterior circulation aneurysms, achieving durable aneurysm exclusion and high rates of good recovery.

Table 1. Demographic Profile of Patients (n = 25)

Variable	Category	Frequency (n)	Percentage (%)	Mean ± SD (95% CI)
Age (years)	31–40	5	20.0	48.6 ± 9.3 (44.7–52.5)
	41–50	8	32.0	
	51–60	6	24.0	
	>60	6	24.0	
Sex	Male	11	44.0	
	Female	14	56.0	

Table 2. Clinical Presentation and Hunt & Hess Grade at Admission

Presentation	Frequency (n)	Percentage (%)	95% CI
Ruptured aneurysm	18	72.0	50.6–87.9
Unruptured aneurysm	7	28.0	12.1–49.4
Hunt & Hess Grade			
I–II (Good)	14	56.0	34.9–75.6
III (Moderate)	7	28.0	12.1–49.4
IV–V (Poor)	4	16.0	4.5–36.1

Table 3. Distribution of Aneurysm Location

Location	Frequency (n)	Percentage (%)	95% CI
Anterior communicating artery (ACoA)	10	40.0	21.1–61.3
Middle cerebral artery (MCA)	8	32.0	14.9–53.5
Internal carotid artery (ICA)	7	28.0	12.1–49.4

Table 4. Aneurysm Morphology and Size

Parameter	Mean ± SD	Range	95% CI
Aneurysm size (mm)	7.8 ± 3.1	3–14	6.5–9.1
Morphology	All saccular	–	–

Table 5. Intraoperative Characteristics

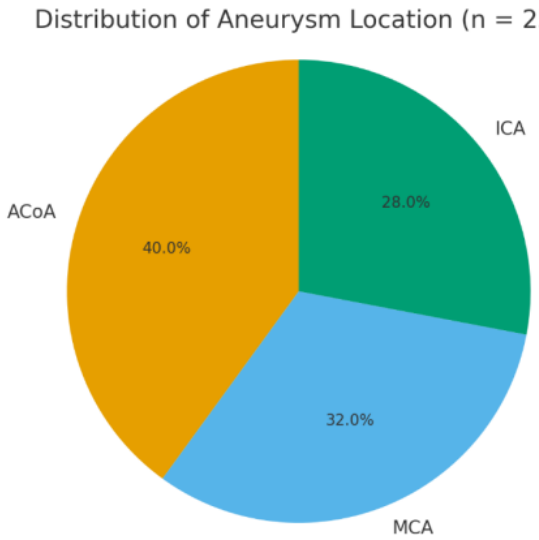
Parameter	Frequency (n)	Percentage (%)	Notes
Approach (pterional)	25	100.0	Uniform approach
Temporary clipping used	6	24.0	Mean duration 3.4 min
Intraoperative rupture	1	4.0	Managed successfully
Intraoperative mortality	0	0.0	–
Mean operative time	184 ± 28 min	150–240	95% CI: 172–196
Mean blood loss	320 ± 86 ml	200–500	–

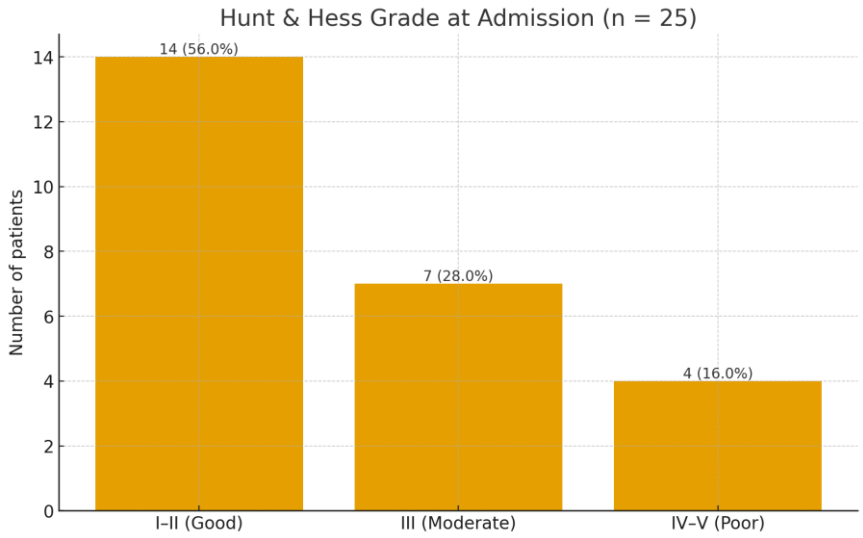
Table 6. Postoperative Complications

Complication	Frequency (n)	Percentage (%)	95% CI
Rebleeding	0	0.0	0–13.7
Vasospasm (significant)	0	0.0	0–13.7
Wound infection	0	0.0	0–13.7
Seizures	1	4.0	0.1–20.4
Transient cranial nerve palsy	1	4.0	0.1–20.4
Overall complication rate	2	8.0	1.0–26.0

Table 7. Functional Outcomes at Discharge (Glasgow Outcome Scale)

GOS Score	Interpretation	Frequency (n)	Percentage (%)	95% CI
5	Good recovery	21	84.0	63.9–95.5
4	Moderate disability	3	12.0	2.5–31.2
3	Severe disability	1	4.0	0.1–20.4
2	Vegetative state	0	0.0	0–13.7
1	Death	0	0.0	0–13.7
Favorable outcomes (GOS 4–5)	–	24	96.0	79.6–99.9
Unfavorable outcomes (GOS 1–3)	–	1	4.0	0.1–20.4





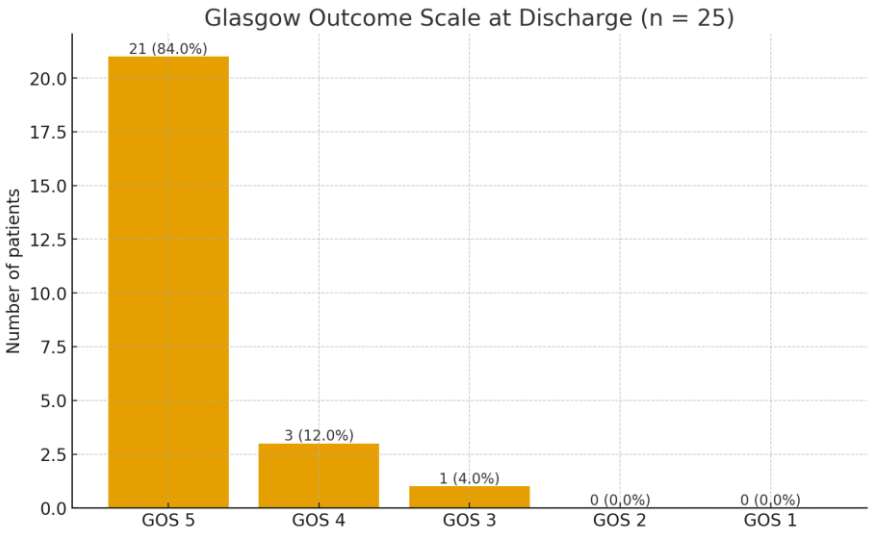


IMAGE 01. Case 01

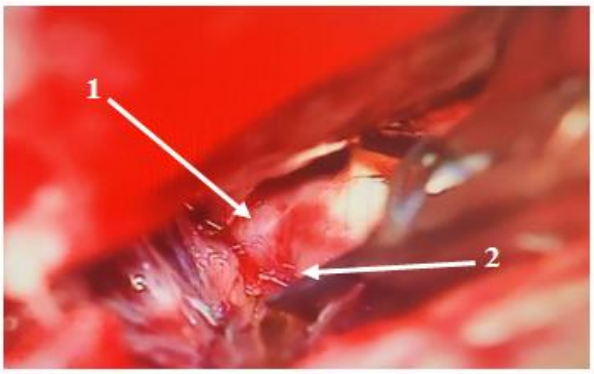


IMAGE 02. Case 01

1) Aneurysm sack

2) Clip being applied

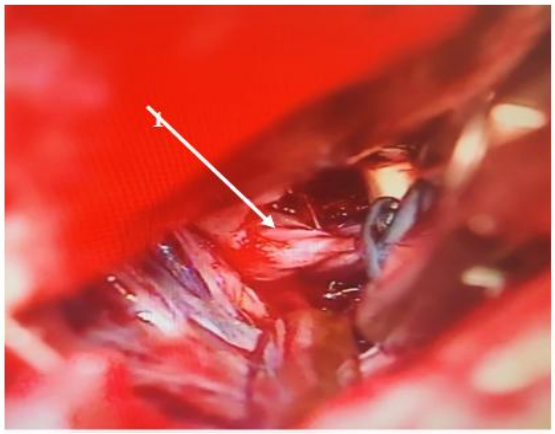


IMAGE 03. Case 01

1) Aneurysm sack collapsed after clip application

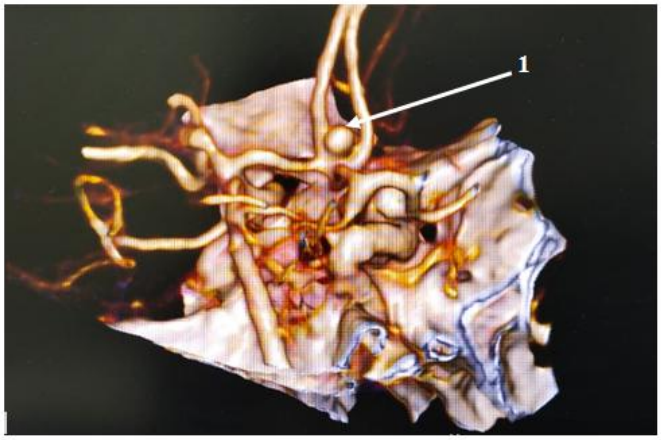


IMAGE 04. Case 02

1) ACOM aneurysm

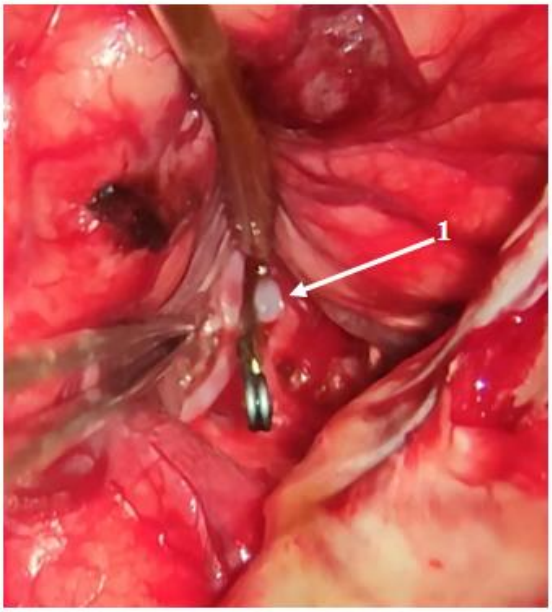


IMAGE 05. Case 02

1) Aneurysm collapsed after clipping

DISCUSSION

The present single-centre cohort study evaluated the outcomes of microsurgical clipping for anterior circulation aneurysms over a three-year period in 25 patients at Sassoon General Hospital, Pune. The findings demonstrated that clipping could be performed with high safety and efficacy, with a 100% aneurysm occlusion rate, a very low intraoperative rupture rate (4%), no perioperative mortality, and overwhelmingly favorable functional outcomes (96% with GOS 4–5 at discharge). These results are highly encouraging and contribute valuable data from an Indian tertiary care government hospital, addressing a relative paucity of literature from low- and middle-income countries (LMICs).

The discussion that follows places these findings in the context of existing global and Indian studies, explores the clinical implications, evaluates the strengths and limitations of our study, and reflects on the ongoing role of surgical clipping in the management of anterior circulation aneurysms in the current era dominated by endovascular therapies.

In our series, following definitive clipping of the aneurysm, the **lamina terminalis was routinely opened** as part of the operative strategy. Fenestration of the lamina terminalis serves two important purposes. First, it provides an additional route for **cerebrospinal fluid (CSF) drainage**, thereby facilitating intraoperative and postoperative **cerebral relaxation** and reducing the risk of raised intracranial pressure. This maneuver has been shown to decrease the incidence of **obstructive hydrocephalus** in the postoperative period by establishing communication between the third ventricle and the basal cisterns. Second, by improving CSF circulation across the basal cisterns, it enhances the **clearance of subarachnoid blood**, which is particularly relevant in patients presenting with aneurysmal SAH. More efficient

clearance of blood products reduces the inflammatory cascade and may consequently lower the risk of **delayed cerebral vasospasm** and ischemic complications. Several prior surgical series have also highlighted these benefits, underscoring lamina terminalis fenestration as a simple yet effective adjunct that augments outcomes in aneurysm surgery without adding significant morbidity.

Epidemiology and Patient Characteristics

The mean age of patients in our cohort was 48.6 years, which is somewhat younger than the median ages reported in large Western cohorts, where aneurysm rupture is often observed in the sixth decade【2,5】. Indian and other Asian studies have similarly noted younger age at presentation, which may reflect both demographic differences and earlier exposure to vascular risk factors such as hypertension and smoking【15,18】. The slight female predominance observed in our series (56%) aligns with well-established epidemiological trends worldwide, where women are disproportionately affected due to hormonal influences (especially post-menopausal estrogen decline), vascular connective tissue differences, and possibly genetic predispositions【6,11】.

Clinically, most of our patients presented after aneurysmal rupture (72%), with only 28% diagnosed with unruptured aneurysms. This is consistent with previous Indian reports【15,18】 but contrasts with data from high-income countries, where increased availability of MRI and CT angiography has led to greater detection of incidental unruptured aneurysms 【10,11】. This difference underscores the continuing diagnostic gap in LMICs, where imaging is often performed only after catastrophic rupture, contributing to higher initial morbidity.

Aneurysm Distribution and Morphology

The distribution of aneurysm sites in our cohort—40% anterior communicating artery (ACoA), 32% middle cerebral artery (MCA), and 28% internal carotid artery (ICA)—is in line with global epidemiology. Multiple studies have shown that 80–85% of aneurysms occur in the anterior circulation, with ACoA aneurysms accounting for the largest single proportion【4,7,12】. The mean aneurysm size in our cohort was 7.8 mm, consistent with small-to-medium-sized saccular aneurysms, which are the most common morphology encountered in surgical practice【10】. Importantly, all aneurysms in our series were saccular, with no giant or fusiform lesions, simplifying operative planning and likely contributing to the high success rate.

Intraoperative Considerations and Rupture

One of the most feared complications of aneurysm surgery is intraoperative rupture, associated with significant blood loss, brain swelling, prolonged operative time, and poorer outcomes【13,14】. Rates of intraoperative rupture vary widely in the literature, ranging from 5–15% depending on patient selection, aneurysm morphology, and surgical experience【9】. In our series, only one patient (4%) experienced rupture, which was promptly controlled with temporary clipping and hypotension, and ultimately secured with a permanent clip without lasting deficit. This rate is lower than many published reports, possibly reflecting the small sample size, uniform use of the pterional approach, careful preoperative planning, and availability of intraoperative adjuncts such as temporary clipping and anesthetic control. The absence of intraoperative mortality further underscores the effectiveness of the surgical and anesthetic teamwork in our centre.

Postoperative Complications and Outcomes

The postoperative course in this study was remarkably favorable, with no cases of rebleeding, vasospasm requiring intervention, or surgical site infection. Only two minor complications were observed: one case of postoperative seizures (4%) and one case of transient third nerve palsy (4%), both of which resolved completely. Thus, the overall complication rate was only 8%, significantly lower than many large surgical series reporting 15–25% morbidity【7,9】. Importantly, no deaths occurred, giving a perioperative mortality of 0% (95% CI: 0–13.7).

Functional outcomes were excellent, with 84% of patients achieving complete recovery (GOS 5), 12% moderate disability (GOS 4), and only 4% severe disability (GOS 3). No patient remained vegetative or died. When dichotomized, 96% had favorable outcomes (GOS 4–5). These figures compare very favorably with international benchmarks. For example, the Barrow Ruptured Aneurysm Trial (BRAT) reported favorable outcomes in approximately 65% of clipped patients at 3 years【7】, while other large series have documented mortality rates of 2–8% and morbidity of 10–20%【5,9,12】. The superior outcomes in our series likely reflect the inclusion of a majority of good-grade patients at admission, absence of giant or complex aneurysms, and aggressive perioperative neurocritical care.

Clipping vs. Coiling: Current Evidence

The last two decades have witnessed a paradigm shift in aneurysm management, with the landmark **International Subarachnoid Aneurysm Trial (ISAT)** demonstrating that in selected patients with ruptured aneurysms, endovascular coiling had a lower one-year disability or death rate compared to clipping【5】. However, ISAT also revealed higher recurrence and retreatment rates with coiling, while clipping provided more durable aneurysm exclusion. Similarly, the **Barrow Ruptured Aneurysm Trial (BRAT)** initially showed early advantages for coiling, but long-term follow-up demonstrated superior durability and lower retreatment rates with clipping【7】.

Our results reinforce the ongoing relevance of clipping, particularly in LMICs. Endovascular therapy, while less invasive, remains limited by cost, availability of skilled interventional neuroradiologists, and long-term recurrence rates. In contrast, clipping offers a permanent cure with minimal risk of recurrence, which is particularly important in younger patients and in healthcare systems where follow-up and retreatment may be challenging【12,18】. In our setting, where clipping remains the dominant modality, outcomes were excellent and comparable to the best global standards, even without access to routine endovascular alternatives.

Indian Experience and Comparison

Few Indian series have comprehensively reported aneurysm surgery outcomes. Dhandapani et al. (2012) from AIIMS, New Delhi, reported outcomes of 124 unruptured aneurysm surgeries, with morbidity around 10% and mortality <2%【15】. Gupta et al. (2006) reported on 208 cases from Chandigarh, documenting mortality of 6% and morbidity of 12%【18】. Compared with these, our series showed no mortality and only minor complications, although the smaller sample size and exclusion of complex aneurysms may partly explain this. Nonetheless, our findings add to the growing body of Indian evidence showing that microsurgical clipping can achieve outcomes on par with international benchmarks when performed in experienced centres.

Predictors of Outcome

Consistent with the literature, our subgroup analysis showed trends toward better outcomes in patients who presented in good Hunt and Hess grades, in younger patients, and in unruptured aneurysms. Although statistical significance could not be established due to small sample size, these observations align with established predictors identified in larger studies【9,10,11】. Good admission grade and age <50 years are known independent predictors of favorable outcomes, while poor-grade presentation is associated with higher morbidity even with optimal surgical care【6,13】.

Strengths of the Study

This study has several strengths. First, it represents real-world data from a busy government hospital in India, where microsurgical clipping remains the mainstay of treatment. Second, it achieved complete follow-up at discharge for all patients, with no losses to follow-up, ensuring completeness of data. Third, the outcomes were exceptionally favorable, underscoring the quality of surgical and perioperative care provided. Finally, the inclusion of statistical measures such as confidence intervals and subgroup trends provides transparency and context to the findings, despite the modest sample size.

Limitations

The primary limitation of this study is its relatively small sample size (n=25), which limits the statistical power for subgroup analyses and the generalizability of findings. The absence of posterior circulation and giant aneurysms also restricts extrapolation to more complex cases. Additionally, follow-up was limited to hospital discharge; long-term outcomes, recurrence rates, and quality of life measures were not assessed. Finally, the lack of a comparison group treated with endovascular therapy precludes direct evaluation of clipping versus coiling in our patient population.

Clinical Implications

Despite these limitations, the study has important clinical implications. It demonstrates that in resource-constrained settings, where endovascular therapy may not be widely available, microsurgical clipping remains a safe, effective, and definitive treatment for anterior circulation aneurysms. The low complication and zero mortality rates observed in this series provide reassurance that surgery can be performed with excellent outcomes when conducted in well-equipped centres by experienced teams. Moreover, the data contribute to the growing pool of evidence supporting the continued role of clipping in the modern era, particularly in younger patients and in healthcare systems with limited follow-up capabilities.

Future Directions

Future research should focus on multicentric Indian studies with larger sample sizes, inclusion of posterior circulation and complex aneurysms, and long-term follow-up to assess durability, recurrence, and functional outcomes over years. Comparative studies between clipping and coiling in the Indian context are also essential to inform evidence-based guidelines tailored to local realities. Integration of intraoperative technologies such as intraoperative angiography, advanced neuro-monitoring, and hybrid operating theatres may further refine surgical outcomes.

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