Clinical Outcomes and Systemic Barriers to Endovascular Treatment for Aneurysmal Subarachnoid Hemorrhage in Nepal: A Single Center Prospective Observational Study

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ABSTRACT

Background

Aneurysmal subarachnoid hemorrhage (aSAH) is a devastating neurovascular emergency with significant mortality and morbidity. While endovascular treatment has demonstrated superior outcomes in various landmark international trials, its implementation in low- and middle-income countries like Nepal remains a struggle due to socioeconomic and infrastructural barriers.

Objective

To evaluate the feasibility, safety, clinical outcomes, and descriptive cost assessment of endovascular treatment for aSAH in a resource-limited setting.

Method

Nineteen patients with angiographically confirmed aSAH who underwent endovascular treatment from January 2024 to December 2024 were included. Clinical outcomes were assessed using the modified Rankin Scale at discharge and three months, while angiographic outcomes were evaluated using the Raymond-Roy Occlusion Classification (RROC) and O'Kelly - Marotta Scale at the end of the procedure and at six months. Cost analysis was performed to determine the economic burden on patients and families.

Result

The mean age of patients was 57.63 ± 10.98 years, with a female predominance (73.70%). The anterior communicating artery was the most common aneurysm location (47.40%), and 15.78% of patients had multifocal aneurysms. Technical success was achieved in all cases (100%). Immediate post-procedural angiography demonstrated complete occlusion (RROC I) in 14/19 cases (73.68%), while RROC II was observed in 3/19 cases (15.78%). Two cases treated with flow diversion demonstrated O'Kelly - Marotta grade B3 occlusion. Favorable functional outcome (modified Rankin Scale ≤ 2) at discharge was achieved in 15/19 patients (78.94%). In-hospital mortality was 5.26%, with no procedure-related deaths. The majority of patients (84.20%) belonged to the upper-middle socioeconomic class according to the modified Kuppuswamy index (2023). The mean total treatment cost was Nepalese Rupees (NRs.) 7,48,294.37 ± 211,242.07, with device and consumable expenses accounting for 58.61% ± 14.12 of total costs. National health insurance provided partial reimbursement with a median coverage of NRs. 70,000 (IQR: 78,023.47; range: NRs.0 – 1,00,000).

Conclusion

Endovascular treatment for ruptured cerebral aneurysms appears feasible and safe in a semi-urban Nepalese setting when supported by structured training and strategic resource management.

KEY WORDS

Aneurysm, Cost and cost analysis, Endovascular procedures, Subarachnoid hemorrhage, Treatment outcome

INTRODUCTION

Aneurysmal subarachnoid hemorrhage (aSAH), a neurovascular emergency associated with high fatality and morbidity, with worldwide crude incidence ranging from 5.70 – 7.90 per 100,000 person - year.[1-3] Although existing studies suggest the true burden of aSAH in low- and middle-income countries may be comparable to that in high income countries, it is important to note that many cases likely remain undocumented because of limited access to health care services.[4-7] In Nepal, nearly 2,000 individuals are believed to suffer from intracranial aneurysm rupture annually.[8] But only few reach to the tertiary center capable of catering the comprehensive treatment.[8,9]

Microsurgical clipping has remained the cornerstone of aneurysm treatment in Nepal, despite the catastrophic risk of intraoperative rupture.[10,11] Hence, surgical expertise remains pivotal to patient's outcome.[12] However not only that, multiple other factors like associated comorbidities, patient's clinical grade on admission (Hunt and Hess Scale), radiological severity (Modified Fisher Scale), aneurysm characteristics dictate prognosis.[11] While landmark trials like International Subarachnoid Aneurysm Trial (ISAT – 2002, 2005) have already demonstrated superior outcomes with endovascular coiling, the reality in Nepal remains constrained by its socioeconomic and infrastructural barriers.[13,14] Even though constrained, various papers from India have reiterated that providing the state of art service in resource constrained setup is not impossible, but have their own challenges.[15,16]

Understanding these challenges and outcomes of these efforts is essential to shape evidence-based neurosurgical policies in Nepal as well. Hence, this study aims to present the early experiences of endovascular treatment of ruptured intracranial aneurysms in a semi urban setup at Dhulikhel Hospital.

METHODS

This prospective observational study was conducted at Dhulikhel Hospital, Kathmandu University Hospital, Nepal, between January 2024 to December 2024. Ethical approval was obtained from the Institutional Review Committee of Kathmandu University School of Medical Sciences. Informed consent was obtained from the patients' legal guardians prior to inclusion in the study. The study was designed to evaluate the feasibility, safety, clinical outcomes, and economic implications of endovascular treatment in patients with aneurysmal subarachnoid hemorrhage (aSAH).

All adult patients (≥ 18 years) with angiographically confirmed aSAH who underwent endovascular treatment during the study period were included using a consecutive convenience sampling approach. Selection of treatment modality was individualized through multidisciplinary assessment of aneurysm anatomy and location, patient-specific factors, procedural feasibility and institutional expertise. The final treatment modality was chosen by the patient or their family after informed counseling regarding available treatment options. Patients with incomplete clinical data or lack of consent were excluded. As this study represents an exploratory evaluation of a newly established neuro-endovascular service, no formal sample size calculation was performed. Instead, all eligible patients treated during the study period were enrolled to assess procedural feasibility, safety, early clinical outcomes, and treatment costs. The final sample size (n = 19) reflects the total number of patients who underwent endovascular treatment during the study period. Patients diagnosed with intracranial aneurysms who did not undergo or declined endovascular treatment were not included in the analysis. The limited sample size further reflects restricted acceptance of endovascular treatment in the local setting, influenced by procedural costs, belief in quality service availability, and patient or family's treatment preferences.

Feasibility was operationally assessed using predefined indicators including successful completion of the intended neuro-endovascular procedure without referral to another center, technical success and acceptable peri-procedural complication rates. The primary study endpoints included technical success based on angiographic occlusion of aneurysm, periprocedural complications, functional outcome at discharge and treatment-related costs. Post-treatment angiographic outcomes for coiling of aneurysm were graded using the Raymond–Roy Occlusion Classification (RROC) and those who underwent flow diversion were graded using O' Kelly - Marotta Scale.[17,18] Secondary endpoints included functional outcomes at 3 months, and angiographic outcome at 6 months. Functional outcomes were assessed at the time of discharge and at 3 months in out-patient department using the modified Rankin Scale (mRS).[19] These assessments were conducted by a trained research assistant who was not involved in the treatment of the patients. Follow-up angiography was performed at 6 months to evaluate aneurysm occlusion status.

Demographic characteristics, clinical presentation, aneurysm morphology, procedural details, and in-hospital outcomes were prospectively recorded from hospital records during index hospitalization. One patient died during index hospitalization and one additional patient was lost to follow-up. Therefore, follow-up angiographic outcome data were available for 17 patients.

Statistical analysis was performed using IBM SPSS statistics version 27. Given the exploratory nature of study and limited sample size, analyses were primarily descriptive. Data were tested for normality using Shapiro-wilk test. Continuous variables with normal distribution are presented as mean ± standard deviation, whereas non-normally distributed continuous variables are presented as median and interquartile range (IQR). Categorical variables are reported as frequencies and percentages. All data were anonymized, securely stored, and analyzed in accordance with institutional research ethics standards.

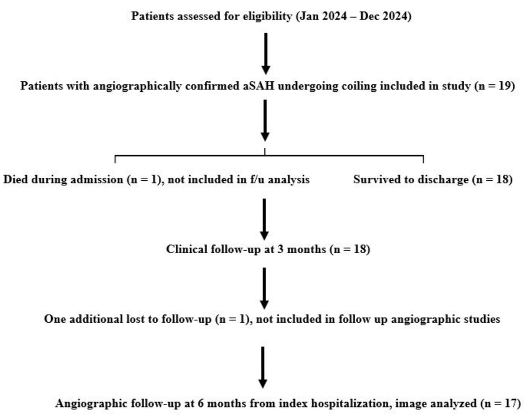

Figure 1. Flow diagram illustrating patient selection and follow-up in the study.

RESULTS

A total of 19 patients with angiographically confirmed aSAH underwent endovascular treatment during the study period. The mean age was 57.63 ± 10.98 years (range: 42 - 75), with majority being female (73.70%), 47.40% patients presented with modified Glasgow Coma Scale of less than 14. Assessment using the World Federation of Neurosurgical Societies (WFNS) scale showed that score I and III had equal patient distribution 31.60% each and score II was noted in 26.30% of patients. A total of 47.40% of patients presented with Hunt and Hess grade II, making it the most common clinical grade of severity at admission, followed by grade III in 36.80%.

On admission non-contrast computed tomography (NCCT) of head, modified Fisher grade II pattern was most commonly observed (31.60%), followed by grades IV (26.30%), III and I (21.10%) each. Regarding associated risk factors for aSAH, smoking was the most prevalent among patients (73.70%), followed by hypertension (68.40%). Post-menopausal status and regular alcohol consumption were also frequently noted, each occurring in 57.90% and 52.60% of total cohort respectively.[16] out of 19 (84.20%) patients included in this study belonged to upper middle socio-economic strata according to modified kuppuswamy scale 2023. Two (10.52%) were from lower middle class and only one patient (5.26%) was from upper lower class, who opted for endovascular treatment for ruptured aneurysm in our study. In terms of geographical proximity to Dhulikhel Hospital, 68.42% patients originated from nearby municipalities within 30 km or travel time less than one hour in an ambulance, followed by 15.78% from moderately distant districts (31 to 100 km) or travel time less than two hours in an ambulance, and 15.78% were referred from distant regions more than 100 km or travel time more than three hours in an ambulance. The median symptom onset to door time in our cohort was 48 hours (IQR: 84).

All neuro-endovascular treatment were performed under general anesthesia using Philips Allura Xper FD 20 monoplane fluoroscopy guidance. Considering aneurysm characteristics and procedure details, Anterior communicating artery (ACom) was the most frequent aneurysm site (47.40%), followed by posterior communicating artery (PCom) (21.10%) and middle cerebral artery (MCA) (10.50%). The median door to treatment time was noted to be 48 hours (IQR: 72, range: 24 – 240 hours).

Aneurysm morphology was documented using pictures obtained on 3D rotational angiography. The median maximum dome diameter of the aneurysms in our cohort was 4.81 mm (IQR: 3.77) and median neck width was 2.83 mm (IQR: 2.09). Immediate post treatment angiography demonstrated complete occlusion (RROC I) was achieved in 73.68% of aneurysms, while residual neck filling (RROC II) was seen in 15.70%. O'Kelly - Marotta scale B3 was observed in 10.52% of treated cases, who have undergone flow diversion owing to complex aneurysm morphology. The mean procedure duration was 2.71 ± 0.84 hours (range 1.45 – 4 hours). The mean intensive care unit (ICU) stay was 7 ± 4.73 days (range 1–17 days), while the median total hospital stay was 12 days (IQR 10).

Periprocedural complications were infrequent, with no intraoperative aneurysm rupture or procedure-related mortality. All cases of intra-procedural thrombus formation were successfully managed with intra-arterial tirofiban, with subsequent angiographic runs confirming no progression or residual thrombus. Among neurological complications during hospitalization, symptomatic cerebral vasospasm was successfully managed with medical optimization, including nimodipine, hemodynamic augmentation, and milrinone infusion. Delayed cerebral ischemia was associated with unfavorable clinical outcomes. Periprocedural and in-hospital complications are summarized in table 1.

Table 1. Periprocedural and In-hospital Complications following Endovascular treatment of ruptured aneurysmal subarachnoid hemorrhage (n = 19)

Category	Complication	n (%)
Periprocedural complications	Intra-procedural thrombus formation	2 (10.52)
	Access-site complications	2 (10.52)
	Intraoperative aneurysm rupture	0 (0.0)
	Procedure-related mortality	0 (0.0)
Neurological complications during hospitalization	Symptomatic cerebral vasospasm	2 (10.52)
	Delayed cerebral ischemia	2 (10.52)
	Symptomatic hydrocephalus	1 (5.26)
Medical complications during hospitalization	Hospital-acquired pneumonia	4 (21.05)
	Delirium	1 (5.26)
	External ventricular drain–related infection	1 (5.26)

At hospital discharge, 15 patients out of 19 emergency procedures (78.94%) achieved a favorable outcome modified Rankin Scale (mRS) ≤ 2, while 3 patients (15.78%) had moderate-to-severe disability (mRS 3, 4 and 5 respectively). There were no procedure-related mortalities. Overall, in-hospital mortality was 5.26%, due to delayed cerebral ischemia leading to refractory brain swelling complicated with hospital acquired pneumonia.

At 3-months follow-up, functional outcome was available for 18 patients, while one patient died (mRS = 6) during index hospitalization. Among remaining 18 patients, 94.40% (n =17) patients achieved favorable outcomes (mRS ≤ 2), while one patient remained moderate - severely disabled (mRS = 4). With additional one patient lost to follow up at 6 months, follow-up angiography demonstrated interval stability in 17 patients, with no significant recanalization requiring re-treatment.

Cost analysis demonstrated that the mean total treatment expenditure was NRs. 7,48,294 ± 2,11,242.07 (range: NRs. 3,72,837.32 – 12,19,441.72). A detailed cost breakdown revealed that material-related expenses constituted the largest proportion of the total cost (58.61 ± 14.12%), followed by hospital-related costs (41.39 ± 14.12%). Hospital-related expenses included charges for hospital stay, procedure charges, routine medical supplies, medications, physiotherapy services, as well as laboratory and radiological investigations. Among the 19 patients included in the study, 15 were enrolled under the national health insurance scheme. The median financial support received through insurance was NRs. 70,000 (IQR: NRs.78,023.47).

With respect to procedural material costs across different device combinations, including cases with multiple or complex aneurysms, the median material cost was NRs. 4,00,000 (IQR: NRs.2,50,000). Stratified analysis based on the type of endovascular treatment demonstrated that the mean total treatment cost for coil-only embolization was NRs. 3,90,882.35 ± 1,18,720.19, whereas higher costs were observed in cases requiring adjunctive devices like coil embolization with flow diverter placement (n=2) averaging NRs. 9,25,000.00 ± 1,06,066.01.

DISCUSSIONS

Neurological illnesses such as ruptured aSAH often requires long periods of recovery, may leave patients with substantial disability and in severe situations may lead to premature death.[20-22] In Nepal, particularly those living outside major cities, access to a center capable of providing life-saving intervention itself is a formidable challenge.[23] Difficult geography, long travel distances, and limited access to specialized care often mean that patients and their families must undertake exhausting journeys during some of the most critical moments of their lives.[24] Additionally, decisions regarding the most appropriate management are frequently shaped not only by clinical considerations but also by the financial realities faced by the patient's family.[25,26] Every decision taken further carries the huge burden of uncertainty.[27] Balancing the risk of rebleeding and mortality against the possibility of survival without or with disability, while also confronting the difficult question of whether long-term postoperative care will remain financially sustainable.[28]

Against this backdrop, this study presents our preliminary experience of neuro-endovascular treatment of ruptured aSAH in a resource-limited setting at Dhulikhel Hospital, Nepal. We observed that endovascular treatment could be performed with high technical success, acceptable complication rates, and favorable early functional outcomes despite considerable infrastructural and financial constraints. However, we also noted access to this treatment modality for aSAH is largely limited to patients from the upper-middle socioeconomic class owing to financial affordability. As a result, our cohort underrepresent patients from lower socioeconomic strata among those receiving endovascular treatment creating an inherent selection bias, despite having comparable disease burden.[4,5] Even among those who proceeded with treatment, families required a median of 48 hours (IQR: 72) to reach a decision regarding endovascular treatment. Echoing our experience, various studies examining neurosurgical care in LMICs consistently identify financial constraints as one of the most significant barriers limiting access to timely and appropriate treatment.[29-31]

The risk factor profile of our cohort reflects established associations with intracranial aneurysm formation and rupture. Smoking demonstrated the highest prevalence (73.70%), consistent with its dose-dependent relationship with aneurysm formation and rupture risk.[32] Hypertension (68.40%), represents another key modifiable target for primary prevention in our catchment area.[33] Female predominance (73.70%) with associated postmenopausal status (57.90%) aligns with known hormonal influences on aneurysm pathobiology, where estrogen decline accelerates vascular remodeling.[34] Although limited by sample size, clustering of these factors could be the base for targeted screening and risk factor modification strategies for aneurysm prevention in at risk populations.

The primary measure of success in treating aSAH is completing procedure without complications and then achieving a favorable functional outcome.[35,36] In our cohort, we achieved complete aneurysm occlusion (RROC I) in 73.68% of cases. Further 15.78% showed only a small residual neck (RROC II). While 10.52% of cases treated with flow diversion demonstrated stagnation of contrast with delayed washout consistent with O'Kelly - Marotta grade B3. Periprocedural complications were relatively infrequent, occurring in 18.18% of cases, and were primarily limited to access site issues and two events of intra procedural thrombus formation at the target site. These findings are consistent with major international trials such as ATENA and CLARITY, which demonstrated high technical success with acceptable morbidity and mortality profiles favoring endovascular treatment of ruptured intracranial aneurysms.[37,38] Additionally, we noted favorable functional outcome rate of 78.94% at discharge (mRS ≤ 2) for our patients, which improved to 94.44% at 3-month follow-up. Although result interpretation is limited by small sample size and short term follow up, these early outcomes appear to follow trends reported as international standards by Hosogai et al.[39]

Beyond clinical outcomes, our experience also highlights practical barriers associated with establishing neuro-endovascular services in resource-constrained settings. We faced many operational challenges including delays in treatment decision by families owing to economic constraints, limitations in intensive care unit beds, Cath lab and technical staffs' availability, expensive equipment scarcity compounded by limited availability of neurointerventional specialist. These findings reflect broader socioeconomic and health care system issues common to all LMICs in providing advanced neurosurgical facilities.[40] These institutional challenges are further compounded by Nepal's limited neurosurgical workforce. Recent nationwide surveys indicate there are around 114 actively practicing neurosurgeons for a population of over 30 million, yielding a ratio of nearly 1 neurosurgeon per 2,63,158 people far below the ideal benchmark of 1 per 100,000.[41] Furthermore, more than half of these specialists are concentrated in major cities, leaving rural and semi-urban populations with limited access to basic neurosurgical care.[42] This geographic distribution creates significant barriers for patients requiring time-sensitive interventions as in aSAH or stroke, where delays in treatment substantially increases chance of morbidity and mortality.[43]

Our experience at Dhulikhel Hospital, located approximately 30 kilometers East and 1 hours by travel time from Kathmandu demonstrates that initiation of endovascular services at resource limited setup can mitigate these access gaps. By establishing endovascular neurosurgical capability, we substantially reduced the need for referrals and travel burdens for 89.47% of patients in our cohort residing within 100 kms of Dhulikhel but away from Kathmandu, thereby addressing a critical determinant of outcomes – 'time' in aSAH management.[44]

Perhaps the greatest challenge identified by our study was the financial burden associated with endovascular treatment. Previous study from Ghimire et al. found out that approximately 9–13% of households in rural Nepal have a bitter experience with catastrophic health spending for major illnesses in family.[45] Against this background, the economic burden (mean procedural expenditures for simple coiling NRs. 3,90,882.35 ± 1,18,720.19 to NRs. 9,25,000.00 ± 1,06,066.01 for complex interventions) that comes along with neuro-endovascular treatment becomes major barrier for patients' family when deciding to opt treatment for aSAH. Even when it covered only a fraction of total costs, median insurance reimbursement of NRs. 70,000 (IQR 78023.47) was pivotal on beginning the treatment. In a country where projected per capita GDP 2026 is approximately USD 1,548 and averaging out-of-pocket expenses account for over 92.08 % of health expenditure, these costs constitute catastrophic health expenditure for most households.

Device related costs particularly coils and access catheters account for the 58.61% ± 14.12 of the total cost, underscoring the urgent need for innovative financing mechanisms. These substantial out-of-pocket expenditures likely explain the predominance of upper-middle socioeconomic patients in our cohort and reinforce the socioeconomic selection bias under-representing rural and lower income Nepalese patients in our study. With our experiences we recommend potential solutions including hospital-level subsidization for stroke care, expansion of national health insurance schemes inclusive of neurological emergencies not limiting to trauma, and strategic international donor partnerships for sustainable neuro endovascular program development. By combining these approaches with careful institutional cost-management, it appears possible to preserve both affordability for patients and sustainability for the hospital, while ensuring that life-saving endovascular neurosurgery becomes a realistic option all over Nepal.

The study is limited by its single-center design, small sample size of patients limiting statistical power. Our follow-up duration was limited to 3 months for clinical outcome and 6 months for angiographic outcome. Given the known risk of delayed aneurysm recurrence or recanalization after endovascular treatment, these findings should be interpreted as early procedural and functional outcomes rather than definitive evidence of long-term durability. Furthermore, significant selection bias is likely present limiting generalizability of results to Nepalese population from rural and lower income strata. We request for future researches to focus on larger multicenter studies, long-term follow-up, and comparative analyses with surgical clipping to further define the economic burden of aSAH better and explore the role of endovascular neurosurgical care for its treatment in Nepal.

CONCLUSION

Nepal, in its struggle to provide equitable and advanced neurosurgical care to its people is faced with numerous hurdles. Our findings suggest that endovascular treatment for ruptured aSAH is feasible and safe treatment option in a resource-limited setting, with favorable early clinical and angiographic outcome when supported by dedicated expertise, careful patient selection, and efficient resource utilization.

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