Coiling Embolization of Small Ruptured Intracranial Aneurysms (SRA): Clinical Outcomes and Complications

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Abstract

Objective: To evaluated the clinical outcomes, complications, and factors associated with unfavorable outcomes in patients undergoing coil embolization for small ruptured intracranial aneurysms (SRA).

Materials and Methods: This study conducted a retrospective review of patients with ruptured true saccular intracranial aneurysms who underwent coiling embolization. The authors collected clinical outcomes, complications, and factors associated with unfavorable outcomes.

Results: Fifty patients, 35 (70%) of whom were women, with a mean age of 55.7 years, were included in this study. Clinical presentation according to the Hunt and Hess scale showed grade I-II in 26 patients (52%) and grade III-V in 24 (48%). Treatment modalities included simple coiling and stent-assisted coiling in 47 patients (94%) and 3 (6%), respectively. Clinical outcomes demonstrated favorable outcomes (mRS 0-2) in 37 patients (74%) and unfavorable outcomes (mRS 3-6) in 13 patients (26%). The mean aneurysm dome size and mean neck size were 3.1±0.9 and 2.2±0.7 mm, respectively, with a mean dome-to-neck ratio of 1.4±0.3 and mean aspect ratio of 1.5±0.4. Complications occurred in five patients (10%): one suffered an intraprocedural aneurysm rupture, and there were four thromboembolic events. No cases of rebleeding were observed. In the multivariate analysis, age >60 years (p=0.04) and Hunt and Hess grade III-V (p=0.02) were independent factors associated with unfavorable outcomes.

Conclusion: Coiling embolization of SRA appears to be safe and effective, even during the early phase of an endovascular neurosurgeon's experience. This favorable safety profile is probably attributable to ongoing advancements in endovascular devices and procedural techniques. Advanced age (>60 years) and higher clinical severity, defined as Hunt and Hess grades III-V, were significantly associated with unfavorable outcomes.

Keywords: Coiling; Intracranial aneurysm; Rupture; Complication; Clinical outcome

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Since the publication of the International Subarachnoid Aneurysm Trial (ISAT)[1] report in 2002, endovascular coiling has been acknowledged as a superior treatment modality for ruptured intracranial aneurysms. Following the ISAT, numerous studies have demonstrated a paradigm shift toward endovascular treatment. However, evidence from the BRAT study[2] indicates that, for very small aneurysms, endovascular coiling achieves comparable long-term outcomes to those of surgical clipping; however, it was associated with a higher rate of crossover to microsurgical clipping. Coiling small ruptured aneurysms remains technically challenging[3,4] due to factors such as relatively broad aneurysm necks, shallow domes, complex morphology, difficulty in maintaining microcatheter stability, and an increased risk of intraprocedural rupture or early rebleeding. Recent advances in endovascular techniques and device technology[5,6], such as the evolution of various kinds

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What is already known about this topic?

Following the previous paper, numerous studies have demonstrated a paradigm shift toward endovascular treatment. For small aneurysms, coiling ruptured aneurysms remains technically challenging due to factors such as relatively broad aneurysm necks, shallow domes, complex morphology, difficulty in maintaining microcatheter stability, and an increased risk of intraprocedural rupture or early rebleeding. Recent advances in endovascular techniques and device technology have contributed to the achievement of improved clinical outcomes.

What does this study add?

Coiling embolization of small ruptured intracranial aneurysms appears to be a safe and effective procedure, demonstrating a low rate of procedural complications even during the early phase of an endovascular neurosurgeon's experience. This favorable safety profile is probably attributable to ongoing advancements in endovascular devices and procedural techniques. Advanced age (>60 years) and higher clinical severity as defined by Hunt and Hess grades III-V were significantly associated with unfavorable clinical outcomes.

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of coils or stents, new microcatheters, or microwires, have contributed to the achievement of improved clinical outcomes. The objective of this study was to evaluate the clinical outcomes, complications, and factors associated with unfavorable outcomes in patients undergoing endovascular coiling for small ruptured intracranial aneurysms (SRA).

Materials and Methods

We conducted a retrospective review of patients with ruptured true saccular intracranial aneurysms who had undergone endovascular coil embolization between January 2023 and August 2025. Three-dimensional (3D) rotational angiography was performed in all cases with a maximum aneurysm diameter of 5 mm or less in any direction on 3D angiography. In patients with multiple aneurysms, the most probable source of hemorrhage was determined based on computed tomography (CT) findings. Patients with fusiform, dissecting, or blister aneurysms were excluded. Aneurysm morphology was classified as regular when the surface was smooth across all projections and as irregular when the surface had irregularities, including small blebs or bilobular or multilobular shape[7]. All procedures were performed by two neurosurgeons subspecializing in neurovascular disease, one with fewer than two years of independent experience and the other with fewer than six years. Clinical follow-up was conducted for a minimum of six months post-procedure. Detailed clinical and radiological data were collected, including age, sex, aneurysm location and morphology, Hunt and Hess Scale, Modified Fisher Scale, treatment technique, procedural complications, immediate angiographic results, and clinical outcomes. Procedural complications assessed included hemorrhagic or ischemic events, vessel dissection, and intraoperative rupture. Clinical outcomes were evaluated using the modified Rankin Scale (mRS), with scores of 0-2 categorized as favorable outcomes and scores of 3-6 categorized as unfavorable.

Endovascular Procedure

All procedures were performed under general anesthesia using a femoral artery approach. An intravenous bolus of heparin was not administered, but a continuous intravenous infusion of heparin (5,000 units of heparin per 1,000 mL of saline) was maintained throughout the procedure. The goal of coil embolization was to achieve maximal packing of the aneurysm. For patients undergoing stent-assisted coiling, a loading dose of 600 mg of aspirin and 300 mg of clopidogrel was administered at least 15 to 30 minutes before stent deployment.

Statistical Analysis

All data in this study were analyzed utilizing IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA). Quantitative variables are presented as means ± standard deviation (SD), while categorical variables are expressed as frequencies and percentages. For intergroup comparisons, Pearson's chi-square test (or Fisher's exact test) was employed for categorical variables, and an independent t-test was applied to continuous variables. A binary logistic regression model was used to evaluate factors associated with unfavorable outcomes, and a p-value less than 0.05 was considered statistically significant.

Ethical Approval

This study was approved by the Rajavithi Ethics Committee (No.68077, 090/2568; approved May 1, 2025) and conducted in accordance with the Declaration of Helsinki.

Results

Baseline Characteristics of Patients

A total of 50 patients were included in this study, and these 35 women and 15 men had an overall mean age of 55.7 years (range 31-83). Thirty-two patients (64%) had a history of hypertension, 5 (10%) had diabetes mellitus, and 9 (18%) were identified as current smokers. Clinical presentation, according to the Hunt and Hess Scale, was grade I-II in 26 patients (52%) and grade III-V in the other 24 (48%). CT demonstrated Modified Fisher grade I-II in 20 patients (40%) and grade III-IV in 30 (60%). Treatment was initiated within 72 hours of clinical onset in 33 of the patients (66%). Treatment modalities included simple coiling in 47 patients (94%) and stent-assisted coiling in the other 3 (6%). Immediate post-procedural angiography demonstrated complete occlusion in 32% of patients, a neck remnant in 52%, and a residual sac in 16%. Clinical outcomes, evaluated using the mRS, showed favorable outcomes (mRS 0-2) in 37 patients (74%) and unfavorable outcomes (mRS 3-6) in 13 (26%). Aneurysm locations included the anterior communicating artery in 16 patients (32%), the posterior communicating artery in 9 (18%), the basilar tip and basilar trunk in 8 (16%), the superior cerebellar artery in 6 (12%), and the posterior inferior cerebellar artery (PICA) in 5 (10%). Additionally, aneurysms were located in the anterior choroidal artery in 2 patients (4%). There was one case each involving the anterior inferior cerebellar artery, pericallosal artery,

posterior cerebral artery, and the paraclinoid segment of the internal carotid artery. The mean aneurysm dome size was 3.1±0.9 mm (range 1.5-4.9), and the mean neck size was 2.2±0.7 mm (range 1.0-4.6). The mean dome-to-neck ratio was 1.4±0.3 (range 0.9-2.2), and the mean aspect ratio was 1.5±0.4 (range 0.8-2.4). Aneurysm morphology was characterized as regular in 10 patients (20%) and irregular (characterized by irregular margins, daughter sacs, or lobulation) in 40 (80%). Detailed baseline and aneurysm characteristics, treatment methods, and outcomes are summarized in Table 1 and 2.

Clinical Outcomes and Complications

Among these 50 patients, 37 who exhibited an mRS score of 0-2 were classified as having a favorable outcome, whereas 13 with an mRS score of 3-6 were designated as having an unfavorable outcome. A comparative analysis between the two groups was conducted to identify factors associated with unfavorable outcomes. Age (p=0.002), high Fisher grade (p=0.035), and high Hunt and Hess grade (p=0.001) were statistically significant predictors (Table 3). In univariate analysis, age >60 years, Modified Fisher grade III-IV, and Hunt and Hess grade III-V remained significantly associated with outcomes; however, in the multivariate analysis, only age >60 years (p=0.04) and Hunt and Hess grade III-V (p=0.02) remained independently associated with unfavorable outcomes (Table 4).

Procedural Complications occurred in five patients. One (2%) suffered an intraprocedural aneurysm rupture; coils were rapidly deployed into the aneurysm sac, and an external ventriculostomy was performed due to intraventricular hemorrhage. Four patients (8%) experienced thromboembolic events. Among these, one patient had challenging vascular access via the transfemoral route and subsequently developed an embolus in the middle cerebral artery; after unsuccessful transradial access, the patient ultimately underwent direct carotid puncture, followed by successful mechanical thrombectomy and coil embolization (Figure 1). The remaining three patients were successfully managed with thrombectomy or intra-arterial rtPA. No cases of rebleeding were observed. Details of complications and outcomes are shown in Table 5.

Discussion

Approximately 50% of ruptured intracranial aneurysms are categorized as small, measuring less than 5 mm in diameter[8]. Coiling embolization for

Table 1. Characteristics of patients at baseline

Baseline characteristics	Total (n=50)
Age (years); mean±SD	55.7±14.3
Female sex; n (%)	35 (70)
Hunt and Hess grade; n (%)	
I-II	26 (52)
III-V	24 (48)
Modified Fisher grade; n (%)	
I-II	20 (40)
III-IV	30 (60)
Hypertension; n (%)	32 (64)
Diabetes; n (%)	5 (10)
Smoking history; n (%)	9 (18)
Treatment <72 hours after onset; n (%)	28 (66)
Treatment method; n (%)	
Simple coiling	47 (94)
Stent-assisted coiling	3 (6)
Complication; n (%)	
Thromboembolism	4 (8)
Intraprocedural rupture	1 (2)
Immediate angiographic results; n (%)	
Complete occlusion	16 (32)
Neck remnant	26 (52)
Residual sac	8 (16)
Clinical outcome (mRS); n (%)	
Good outcome (mRS 0-2)	37 (74)
Poor outcome (mRS 3-6)	13 (26)

SD=standard deviation; mRS=modified Rankin Scale

Table 2. Aneurysm characteristics

Aneurysm characteristics	Total (n=50)
Location of aneurysm; n (%)	
Anterior communicating artery	16 (32)
Posterior communicating artery	9 (18)
Basilar tip & basilar trunk	8 (16)
Superior cerebellar artery	6 (12)
Posterior inferior cerebellar artery	5 (10)
Anterior choroidal artery	2 (4)
Other	4 (8)
Dome size (mm); mean±SD	3.1±0.9
Neck size (mm); mean±SD	2.2±0.7
Dome/neck ratio; mean±SD	1.4±0.3
Aspect ratio; mean±SD	1.5±0.4
Aneurysm size; n (%)	
Small (3-5 mm)	34 (68)
Tiny (<3 mm)	16 (32)
Aneurysm feature; n (%)	
Regular	10 (20)
Irregular (irregular, daughter sac)	40 (80)

SD=standard deviation

Table 3. Factors associated with unfavorable outcome

Factor	Favorable outcome (n=37)	Unfavorable outcome (n=13)	p-value
Age (year); mean±SD	52.1±12.6	65.9±14.3	0.002*
Female sex; n (%)	28 (75.7)	7 (53.8)	0.170
Hunt and Hess grade III-V; n (%)	12 (32.4)	11 (84.6.)	0.001*
Modified Fisher grade III-IV; n (%)	19 (51.3)	11 (84.6)	0.035*
Treatment >72 hours after onset; n (%)	11 (29.7)	6 (46.1)	0.322
Posterior circulation location; n (%)	16 (43.2)	5 (38.5)	0.764
Size of aneurysm (mm); mean±SD	3.05±0.92	3.38±0.87	0.272
Neck of aneurysm (mm); mean±SD	2.13±0.69	2.56±0.78	0.064
Dome/neck ratio; mean±SD	1.48±0.35	1.35±0.23	0.227
Aspect ratio; mean±SD	1.53±0.38	1.40±0.40	0.300
Tiny aneurysm (size <3 mm); n (%)	12 (32.4)	4 (30.8)	1.000
Intraoperative complication; n (%)	3 (8.1)	2 (15.4)	0.595

SD=standard deviation

* Indicates a significant difference for factors associated with unfavorable outcome

Table 4. Univariate and multivariate analysis of the factors associated with unfavorable outcome

Factor associated with unfavorable outcome	Univariable			Multivariable		
	Crude OR	95% CI	p-value	Adjust OR	95% CI	p-value
Age >60 years	7.00	1.732 to 28.297	0.006*	5.3	1.082 to 25.948	0.04*
Hunt and Hess grade III-V	11.46	2.186 to 60.048	0.004*	8.26	1.391 to 49.072	0.02*
Modified Fisher grade III-IV	5.21	1.012 to 26.828	0.048*	2.62	0.411 to 16.726	0.308

OR=odds ratio; CI=confidence interval

* Indicates a significant difference for factor associated with unfavorable outcome

Table 5. Summary of procedural complications by coiling embolization in 5 patients

Case No.	Age (years), sex	Location of aneurysm	Size of aneurysm (mm)	Type of complication	mRS
1	66, F	Basilar tip	1.5*2.0	Thromboembolism	1
2	53, M	ACoA	4.7*4.9	Intraprocedural rupture	3
6	81, F	ACoA	2.2*2.8	Thromboembolism	4
11	37, F	Paraclinoid ICA	3.5*3.9	Thromboembolism	0
39	76, F	AChA	2.0*3.3	Thromboembolism	2

F=female; M=male; ACoA=anterior communicating aneurysm; ICA=internal carotid artery; AChA=anterior choroidal artery

SRA presents several challenges, including a broad-based neck, shallow dome, difficulty in maintaining microcatheter stability, and problems in achieving complete coil packing. Two illustrative cases featuring a ruptured right anterior communicating aneurysm (ACoA) and a left PICA aneurysm are presented in Figure 2 and 3.

Clinical Outcomes

Our comparative analysis of favorable versus unfavorable outcomes demonstrated that 74% of patients achieved favorable outcomes (mRS 0-2). This result is consistent with those of previously published studies, which have reported achievement of favorable outcomes ranging from approximately 65% to 89.7%[6,9-13]. Literature reviews have shown that comparisons between surgical clipping and endovascular coiling have shown no statistically significant differences in outcomes[2,14], including in cases involving very small aneurysms[15]. Several independent predictors of unfavorable outcomes have been identified in prior studies, including advanced age[16], higher Hunt and Hess grades[9,13,16], higher Fisher grades[9,16], aneurysm size greater than 10 mm[16], intraoperative thrombosis[9], and periprocedural complications[12,13]. Our multivariate analysis indicated that older age groups (age >60 years) and preoperative Hunt and Hess grades III-V were significant factors

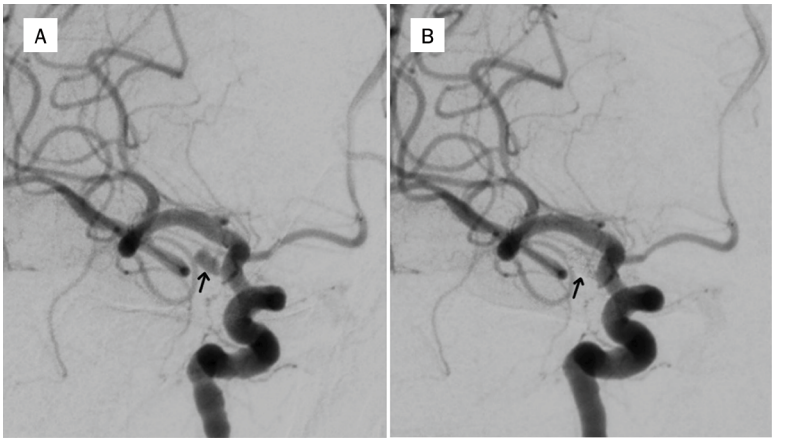


Figure 1. Images of a 76-year-old woman (case no. 39, Table 5) with a ruptured aneurysm of the anterior choroidal artery (AChA). During the procedure, significant vascular access difficulties were encountered, and the patient subsequently developed an embolus in the middle cerebral artery. Direct carotid artery puncture was performed, followed by successful mechanical thrombectomy and coil embolization. (A) Diagnostic angiography demonstrates a 2.0*3.3 mm saccular aneurysm (arrow) arising at the right AchA. (B) Imaging obtained immediately after simple coil deployment demonstrates complete occlusion of the aneurysm (arrow).

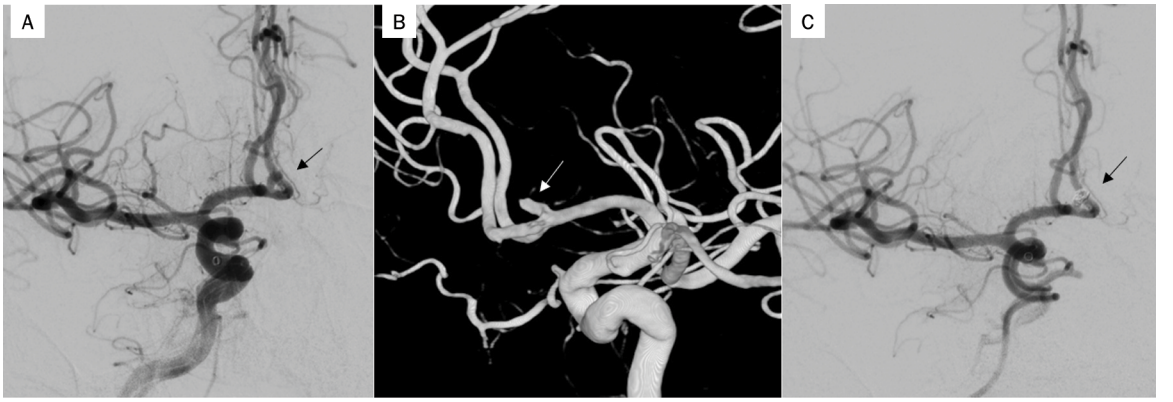


Figure 2. Images of a 55-year-old man with a ruptured aneurysm of the anterior communicating artery (ACoA). (A) Diagnostic angiography demonstrates a 2.1*2.9 mm saccular aneurysm (arrow) arising at the right ACoA. (B) Three-dimensional angiography (3D) demonstrates a superior projection (arrow). (C) Imaging obtained immediately after simple coil deployment demonstrates a neck remnant of the aneurysm (arrow).

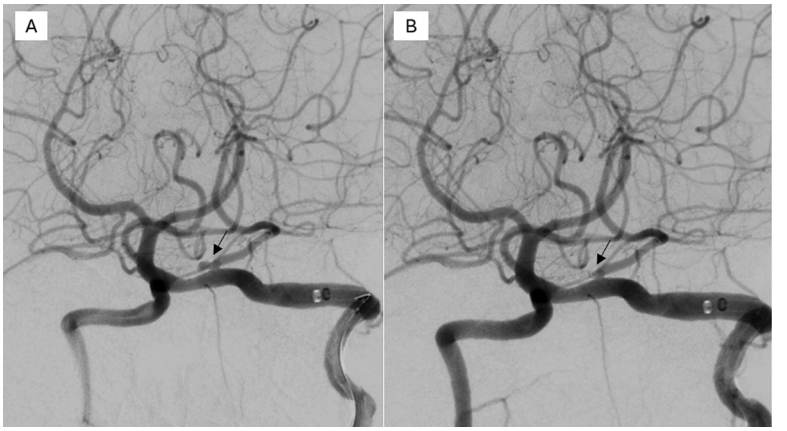


Figure 3. Images of a 50-year-old woman with a ruptured aneurysm of the posterior inferior cerebellar artery (PICA). (A) Diagnostic angiography demonstrates a 1.9 mm saccular aneurysm (arrow) arising at the left PICA. (B) Image acquired immediately after simple coiling demonstrates a minimal neck remnant of the aneurysm (arrow).

associated with unfavorable outcomes; however, when analyzing aneurysm characteristics such as aneurysm size, neck size, morphology, dome neck ratio, and aspect ratio, we did not find any statistically significant association with outcome, and this is in line with the findings of a previous study[9]. In this research, there was a trend toward larger neck sizes in patients with unfavorable outcomes (mean neck size 2.56 mm) compared to those with favorable outcomes (mean neck size 2.13 mm), though this difference did not reach statistical significance (p=0.064).

Complications

The most concerning complication associated with coil embolization of ruptured intracranial aneurysms is intraprocedural rupture, which occurs significantly more often in posterior circulation locations[17], and there is a pronounced tendency for intraprocedural rupture in aneurysms with a diameter ≤5 mm[17], particularly those measuring less than 3 mm, where the limited aneurysm sac space can constrain microcatheter or coil positioning near the rupture point. Studies by Nguyen et al.[18], Yamaki et al.[10], Kim et al.[11], and Qin et al.[12] have reported intraprocedural rupture rates of 11.7%, 9%, 5.7%, and 1.3%, respectively. The next most critical complication is thromboembolism, with reported risks ranging from 4.7% to 19.7%[17,19-23] in prior studies, and attributed to various factors such as guiding catheters, intimal injury, the surface of the coil mass or coil protrusion, and anatomical variables. In the current study, there was only one intraprocedural rupture (2%), while thromboembolic events were observed in four cases (8%), rates that are slightly lower than those reported in several previous studies. The relatively low incidence of complications may be attributable to the development of new materials[24,25], as well as recent advances in endovascular techniques. In particular, advances in coil design such as improved frame stability and increased softness have substantially enhanced the safety and technical success of coiling procedures. Some studies advocate the administration of pre-procedural antiplatelet medication[19,21,22] or intra-procedural tirofiban[20] in addition to intravenous heparin in order to reduce thromboembolic events and enhance clinical outcomes.

This study demonstrated that coil embolization yielded clinical outcomes and complication rates comparable with established standards, even during the early phase of an endovascular neurosurgeon's experience. Regarding angiographic outcomes, coil embolization for small aneurysms yielded generally favorable results. The present study achieved an adequate occlusion rate of 84% (comprising 32% complete occlusions and 52% neck remnants). Although a residual aneurysm persisted in 16% of cases, no patients experienced rebleeding during follow-up. This overall success rate is highly consistent with prior literature reporting adequate occlusion rates between 78.4% and 95.3%[9,10,11,25]. These findings may contribute to the ongoing paradigm shift in the management of cerebral aneurysms from microsurgical clipping to endovascular coiling. This transition has been supported by evidence of reduced hospitalization duration and an increasing preference for minimally invasive treatment strategies. Several limitations should be acknowledged. First, this was a single-center study using a retrospective design. Second, the follow-up period was relatively short. In addition, angiographic follow-up data were not available, which limited our ability to assess long-term radiological outcomes, such as aneurysm recurrence.

Conclusion

Coiling embolization of SRA appears to be a safe and effective procedure, demonstrating a low rate of procedural complications even during the early phase of an endovascular neurosurgeon's experience. This favorable safety profile is probably attributable to ongoing advancements in endovascular devices and procedural techniques. Advanced age (>60 years) and higher clinical severity as defined by Hunt and Hess grades III-V were significantly associated with unfavorable clinical outcomes.

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Authors Contributions

All authors meet ICMJE authorship criteria. SR: Conceptualization; study design; qualitative research design and analysis; quantitative data collection and analysis; original manuscript editing and critical revision. WR: Conceptualization; study design; qualitative research design and analysis. Both authors approved the final version and are jointly accountable for all aspects of the work.

Clinical Trial Registration

This study was not registered as a clinical trial because it is a retrospective study, and there was no experiment or procedure performed on the patient.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The de-identified dataset from this study is available from the corresponding author upon reasonable request with appropriate ethics approval. Public data sharing is restricted per Rajavithi Ethics Committee requirements. Qualitative transcripts contain potentially identifiable information and cannot be shared publicly, though coded themes may be available upon request.

Ethics Approval and Consent to Participate

This study was approved by the Rajavithi Ethics Committee (No.68077, 090/2568; approved May 1, 2025) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

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Use of Artificial Intelligence

All scientific content—including study design, data collection, analysis, interpretation, and conclusions—was conducted exclusively by the authors. The authors take full responsibility for the integrity and originality of all content. AI tools are not listed as authors per ICMJE criteria.

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