Outcome of Microsurgery for Arteriovenous Malformations in a Resource-Restricted Environment: Single-Surgeon Series from Vietnam

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■ BACKGROUND: **The health care expenditure in Vietnam is equivalent to 1% of that in the United States. For most patients with brain arteriovenous malformations (AVM), surgery is the only available treatment modality. This study reports on the outcomes on AVM microsurgery in this resource-restricted environment.**

■ METHODS: **This is a prospectively collected, retrospectively analyzed case series of consecutive patients who underwent surgical resection of AVM by a single surgeon in Vietnam. All surgeries were performed in a 3-year period in Hanoi. The primary endpoints were obliteration of the AVM and surgical morbidity (modified Rankin Scale [mRS] > 1).**

■ RESULTS: **There were 86 patients and 62% presented with hemorrhage. Only 2 patients had preoperative embolization, and 47 patients (54%) had preoperative digital subtraction angiography. All patients underwent microsurgical resection of their AVM. Excluding the 4 patients who died, the AVM obliteration rate was 98%. The mean follow-up was 20.1 months. Before surgery, 36% of patients had at least some disability (mRS > 1). Postoperatively, this was reduced to 10% (McNemar $P = 0.007$). For the overall cohort, neurologic status was improved from initial encounter to final assessment ($P = 0.001$). Because of resource restrictions, some patients with hemorrhage experienced delays in treatment. There was no difference in outcome between patients who were admitted before or after 24 hours post ictus ($P = 0.6$). The days spent waiting for surgery did not correlate with final mRS in univariate regression ($R^2 = 0.01$).**

■ CONCLUSIONS: **Notwithstanding the limitation in health care resources in Vietnam, surgery for AVMs was successful in eliminating the malformation, with obliteration rates and morbidity comparable with international standards.**

INTRODUCTION

Surgical treatment for cerebral arteriovenous malformation (AVM) is expensive throughout the world. This topic was studied in 127 German patients whose average hospital stay was 15.4 days.[1] The average cost of microsurgical treatment was €10,814. In the United Kingdom, the inpatient cost over 3 years for each surgically treated AVM patient was £11,000,[2] while in the United States, the average cost per AVM surgery was $49,000, escalating to $78,000 if supplemented with preoperative embolization.[3]

Endovascular treatment is not affordable in low-to-middle income countries such as the Socialist Republic of Vietnam. The gross domestic product of the country was 224 billion in 2017, and the health care expenditure per capita is 1/30 that of the United Kingdom, 1/36 of Germany, and 1/100 of the United States.[4] Under this financial backdrop, patients with both unruptured and ruptured AVMs are treated with microsurgery in centralized specialty hospitals in major urban centers of Vietnam. The current study investigates the outcomes of a single surgeon's patient cohort from Viet Duc Hospital in Hanoi, Vietnam. We seek to document the surgical outcomes in these resource-intense neurosurgical patients who were treated in an environment with severe resource constraints.

Key words
- Arteriovenous malformation
- Intracerebral hemorrhage
- Modified Rankin Scale
- Vietnam

Abbreviations and Acronyms
AVM: Arteriovenous malformation
CTA: Computed tomography angiogram
DSA: Digital subtraction angiography
GCS: Glasgow Coma Scale
ICU: Intensive care unit
mRS: Modified Rankin Scale
SM: Spetzler-Martin

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METHODS

Patients

This is a case series of consecutive patients who underwent surgical resection of AVM by a single surgeon (H.M.N.). All surgeries were performed in the 3-year period from the beginning of 2015 to the end of 2017 at the Viet Duc Hospital in Hanoi, Vietnam. All demographic information and clinical data at presentation and during follow-up were collected by the operating surgeon in a prospective manner and retrospectively analyzed. The research registry number is researchregistry5035. Because the study was a retrospect chart review, no patient consent was needed.

During the first half of the study, until the middle of 2016, all patients with AVMs were treated with surgery unless the operating surgeon deemed it too risky, such as for patients with high Spetzler-Martin (SM) grade AVM. Full-length journal articles are scarcely available in Vietnam, and the influence for A Randomized Trial of Unruptured Brain Arteriovenous Malformation (ARUBA)[5] did not reach Hanoi until 2016. From that time until the end, patients with unruptured AVM had surgery only if their AVM had a nidal aneurysm, they had seizures refractory to medication, or they preferred surgery over nonoperative management. Hemorrhagic patients continued to be treated with microsurgical resection.

Restricted Resources

Viet Duc is a central-level hospital with specialty care, and patients with ruptured AVM often pass through several layers of a provincial hospital before admission to Viet Duc Hospital. It is the surgeon's practice to operate on hemorrhagic patients at the earliest possibility, but because of limitations in both staffing and hospital capacity, hemorrhagic patients with good neurologic status may have a variable wait time before their surgery. The management of hemorrhagic patients is summarized in Figure 1. Time intervals between ictus and admission, as well as between admission and surgery, were carefully recorded for analysis.

All patients had either computed tomography angiography (CTA) or magnetic resonance angiography before surgery. With limitations in catheter-based angiography resources and long wait times, surgery for some critically ill patients took place without angiography. After surgery, however, all except 2 patients received digital subtraction angiography (DSA) to evaluate the extent of resection, for the majority before their hospital discharge and for

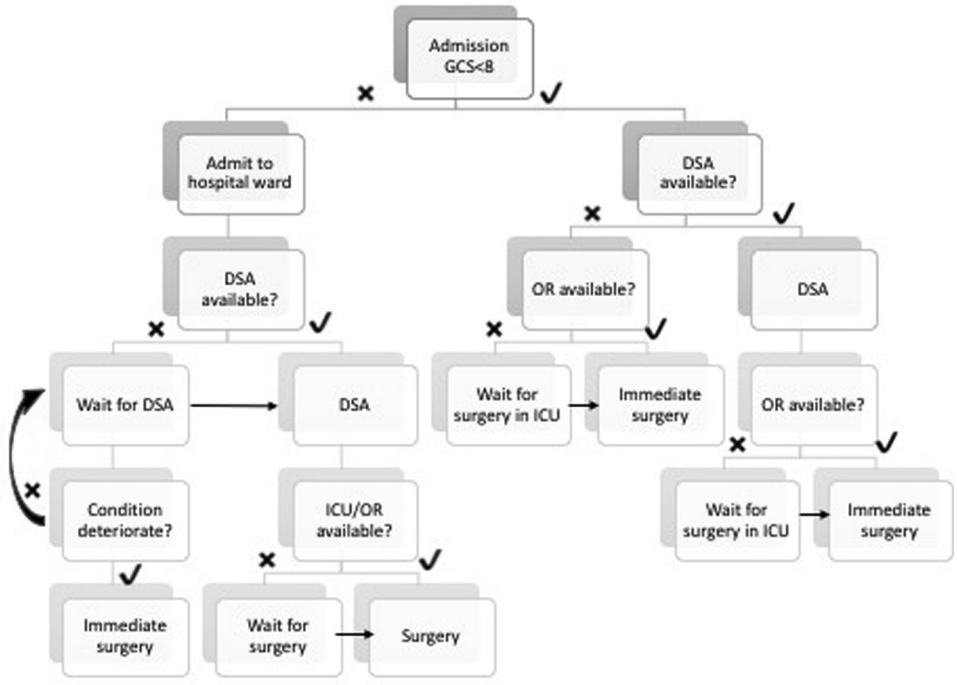

Figure 1. Flow chart describing the management paradigm for patients presenting with ruptured arteriovenous malformation. Patients with Glasgow Coma Scale (GCS) score <8 (i.e., "critically ill") had surgery emergently unless the operating room (OR) was unavailable. If so, these patients were admitted to the intensive care unit (ICU) for blood pressure control (systolic blood pressure [SBP] <130 mm Hg). Intracranial pressure monitors were used on occasion when the equipment was available. As soon as there was OR availability, their surgery proceeded. For patients with presenting with higher GCS, they were admitted to the hospital ward and the subset with GCS between 9 and 13 would have frequent neurologic examination and blood pressure control (SBP <130 mm Hg). These patients will wait for the availability of angiography and ICU/OR space.

the rest, at the 1-month follow-up. Unable to afford the expense, the 2 remaining patients had noninvasive angiography for their postoperative evaluation.

Clinical Assessment and Data Analysis

Neurologic examinations were performed by a single physician (H.M.N.) during the postoperative period, as well as during follow-up at 1, 3, 6, and 12 month after surgery. The primary outcomes analyzed were the complete obliteration of the AVM and the development of new permanent neurologic deficit with a modified Rankin Scale score of >1. This study and its protocol received approval from the Institutional Review Board of the University of Virginia (IRB-HSR 21507).

Data analysis was performed with *Excel* (Microsoft Office 2013). The 2-tailed *t*-test was used for numeric data, and the χ^2 and McNemar tests were used for categoric data as appropriate. Univariate and multivariate logistic regression were used to test the correlation between data sets. $P < 0.05$ was interpreted to mean that a significant difference exists between sets.

RESULTS

Patient Demographics and Arteriovenous Malformation Characteristics

The patient cohort consisted of 50 men and 36 women with the mean age of 35.2 (range: 8–65). Fifty-three (62%) presented with hemorrhage, with 4 of these having had prior hemorrhages (Table 1). The majority of AVMs were lobar in location (90%), had superficial drainage (76%), and did not have nidal aneurysms (77%). AVMs with noneloquent localization pertained to nearly half of the study cohort (47%). Taken together, this meant that the majority of AVMs were SM grades I and II (65%).

DSA was performed in all but 2 patients to evaluate the results of surgery, with the vast majority of testing done before discharge and, for the rest, at the 1-month follow-up. Lacking insurance, the remaining 2 patients could only afford noninvasive angiography for evaluation after surgery. The AVM was eliminated by surgery in 80 patients, and excluding the 4 patients who died after surgery, the obliteration rate was 98%. The endpoint of the study was *pre hoc* determined to be 12 months, and 78 patients reached this point with only 2 patients lost to follow-up after the first month. The mean follow-up for all patients was 20.1 months.

Surgical Outcome and Influence of Patient and Arteriovenous Malformation Characteristics

Before surgery, 31 patients (36%) had at least some disability with modified Rankin Scale (mRS) >1. This increased to 34 (40%) immediately after surgery, but a good final outcome of mRS 0–1 was achieved in 74 (90%) patients (Figure 2). Four patients died (5%) in the postoperative period, and 2 more died by the end of the 6-month follow-up, leading to a total mortality rate of 7% of the entire cohort. There was no significant change in neurologic status in the patients before and immediately after surgery (mean mRS 1.65 vs. 1.76, 2-tailed *t*-test $P = 0.6$). However, when comparing preoperative and final mRS, the change was statistically significant (mean mRS 1.65 vs. 0.90, $P = 0.001$). The number of patients with deficits (mRS >1) were also significantly reduced from initial encounter to final assessment (McNemar $P < 0.01$, see Figure 2). The average postoperative mRS and final mRS were not significantly influenced by components of the SM scale (i.e., location in eloquent cortex, venous drainage pattern, nidus size, and presence of nidal aneurysm) (see Table 1).

Relationships between SM grade and outcome are shown in Figure 3. In none of the total unruptured or ruptured cohorts was there a significant relationship between SM grade and the change in the patients' neurologic status (i.e., improved vs. deteriorated; χ^2 $P = 0.69$, 0.49, and 0.14, respectively). In univariate and multivariate logistic regression, neither the postoperative nor final mRS correlated with preoperative mRS and SM grade. Similarly, the patients' age did not correlate with either the final mRS ($R^2 = 0.05$) or the change between preoperative and final mRS ($R^2 = 0.01$).

Effect of Resource Restrictions

Because of cost and availability, only 2 of the study patients (2%), 1 with a ruptured SM4 and the other with an unruptured SM3 AVM, had embolization before their surgery. Furthermore, with only 1 angiography suite for a hospital of nearly 1000 beds, waiting for DSA was often not possible for critically ill patients. For the entire cohort of patients, only 47 patients (54%) had DSA before AVM resection. Surgery for the rest of the cohort was based on CTA or magnetic resonance angiography instead. Patients presenting with hemorrhage were less likely to have DSA compared with patients with unruptured AVMs (χ^2, $P < 0.01$). However, comparing the patients with or without DSA, final mRS scores were no different (mean 0.85 vs. 0.97, 2-tailed *t*-test $P = 0.73$, Table 2).

Despite the emergent nature of their illness, patient presenting with hemorrhage often had to filter through the provincial hospitals before reaching Viet Duc Hospital for definitive treatment of their AVM. Of the 53 patients whose AVM ruptured, 30 arrived more than 24 hours after their ictus. However, comparing the hemorrhagic patients who arrived before or after 24 hours, the postoperative mRS (mean 1.78 vs. 1.63, 2-tailed *t*-test $P = 0.7$) and final mRS (mean 0.69 vs. 0.93, 2-tailed *t*-test $P = 0.6$) were not significantly different (see Table 2).

Although it is the operating surgeon's practice to perform surgery on ruptured AVMs at the earliest possibility, because of limited staffing and capacity both in the operating rooms and intensive care units, patients with presenting Glasgow Coma Scale (GCS) 13–15 often had to wait for their surgery to avoid suboptimal conditions (i.e., inexperienced operating room staff, surgery late into night). For the entire subset of hemorrhagic patients, the wait time ranged from 0–40 days, with a mean of 6.58 days. With univariate logistic regression, there was no correlation between days in waiting with either the postoperative ($R^2 = 0.06$) or final mRS ($R^2 = 0.01$).

Ruptured versus Unruptured Arteriovenous Malformations

The distribution of AVMs across the SM groups was not significantly different between patients who hemorrhaged compared with those who did not (χ^2, $P = 0.6$). Patients presenting with ruptured AVMs had significantly higher preoperative mRS compared with patients with unruptured AVMs (mean 2.20 vs.

Table 1. Characteristics of Arteriovenous Malformation Cohort

	Ruptured AVMs	Unruptured AVMs	Total	Impact on Average of: Postoperative mRS	Impact on Average of: Final mRS
Number	53	33	86		
Sex					
Male	29	21	50		
Female	24	12	36		
Age					
0–19	13	1	14		
20–39	21	18	39		
40–59	15	12	27		
>60	4	2	6		
AVM size (cm)				$P = 0.7$	$P = 0.6$
0–3	39	11	50		
3–6	11	21	32		
>6	3	1	4		
Eloquence				$P = 0.3$	$P = 0.3$
Noneloquent	21	19	40		
Eloquent	32	14	46		
Location					
Lobar	46	31	77		
Cerebellar	5	1	6		
Ventricular	2	1	3		
Venous drainage				$P = 0.1$	$P = 0.5$
Superficial	38	27	65		
Deep	15	6	21		
Nidal aneurysm				$P = 0.9$	$P = 0.9$
Present	12	8	20		
Absent	41	25	66		
DSA					$P = 0.7$
Performed	23	24	47		
Not performed	30	9	39		
Spetzler-Martin					
I	11	7	18		
II	26	12	38		
III	11	11	22		
IV	4	3	7		
V	1	0	1		
mRS at presentation					
0	3	9	12		
1	20	23	43		
2	11	1	12		
3	7	0	7		
4	6	0	6		
5	6	0	6		
Final mRS					
0	30	18	31		
1	17	9	26		
2	2	2	4		
3	1	1	2		
4	0	0	0		
5	0	0	0		
6	3	3	6		
Obliteration rate	96%	100%	98%		
Permanent deficits (mRS >1)	11%	18%	10%		
Mortality	6%	9%	7%		

P values pertain to 2-tailed *t*-test comparing the patients' mRS.
AVM, arteriovenous malformation; mRS, modified Rankin Scale; DSA, digital subtraction angiography.

0.76, 2-tailed t-test $P < 0.001$) (Table 3). However, there was no significant difference in the final mRS in the ruptured compared with the unruptured group (mean 0.8 vs. 1.0, 2-tailed t-test $P = 0.5$). The percentage of patients in the 2 groups with permanent deficits (mRS >1) were also similar (11% vs., 18%, χ^2 $P = 0.4$).

In the cohort of patient who suffered a hemorrhage, 42 out of 53 (80%) remained stable or improved after surgery, while in the unruptured group, this proportion was 24 out of 33 (72%). The difference was not statistically significant (χ^2 $P = 0.49$). However, when examining the numerical change in the preoperative and final mRS, a trend toward significant differences was seen between the ruptured and unruptured groups (mean Δ mRS +0.5 vs. −0.3, 2-tailed t-test $P = 0.07$, see Table 3).

ARUBA-Eligible and Ponce Class A (unruptured) Arteriovenous Malformation Patients

A total of 26 patients within the total cohort met inclusion criteria for the ARUBA study (i.e., adult patients (≥18)) with no prior history of hemorrhage. The majority of these AVMs had lobar

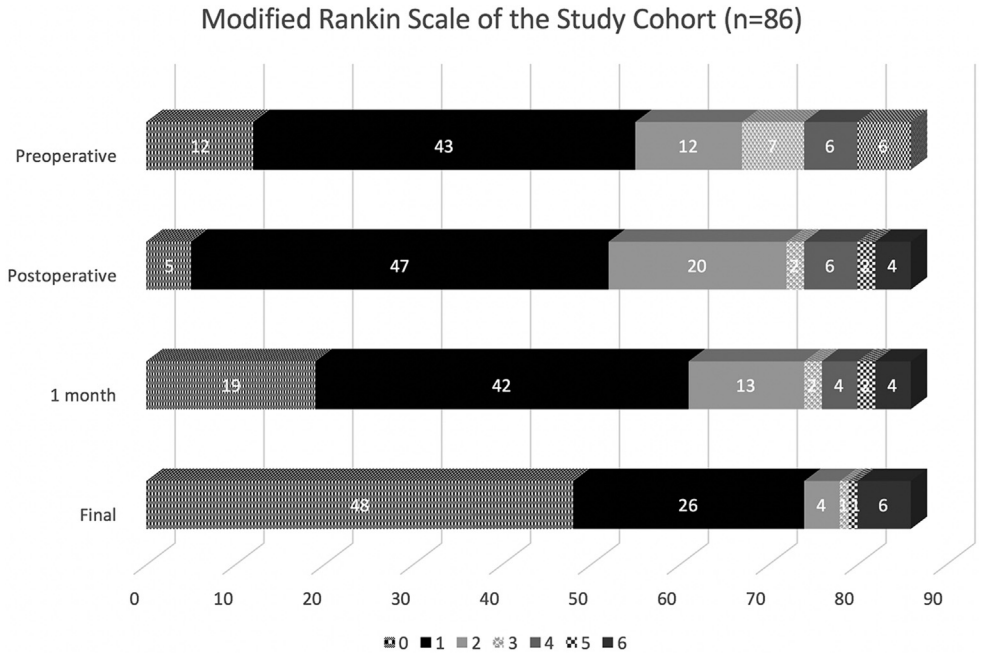

Figure 2. Modified Rankin Score (mRS) of patients. The preoperative and postoperative neurologic statuses of the patients are displayed here by their mRS. The numbers within the bars denote the number of patients with that mRS. The total cohort was 86 patients. The number of patients with significant deficits (mRS >1) were not significantly different between preoperative and postoperative, as well as between preoperative and 1 month, statistics. However, on comparing preoperative and final assessments, the number of patients with deficits (mRS >1) was significantly reduced (McNemar $P < 0.01$).

location (96%), superficial venous drainage (81%), and size between 3 cm and 6 cm (73%) (Table 4). The preoperative mRS was <2 in all except 1 patient (4%). One patient with an SM 3 AVM was embolized before surgery, and all 26 AVMs were successfully treated with microsurgical excision. Permanent deficit on final evaluation, with mRS>1, was found in 5 patients (19%). Three patients died in the perioperative period (12%). Of these, 2 patients (1 SM 2 and 1 SM 3) died from postoperative hematoma. Another patient with an SM 3 AVM died from pneumonia after discharge from surgery.

There were 19 patients with unruptured Ponce class A (SM 1 and 2) AVMs. None of them had preoperative endovascular treatment, and all of them were also successfully obliterated with surgery. A total of 3 patients had a final mRS >1 (15%). This included the aforementioned patient with an SM2 AVM who died after surgery from a postoperative hematoma.

DISCUSSION

Aspect of Vietnamese Health Care System Pertinent to Cerebrovascular Disease

Vietnam has a population of 96 million people and a GDP in 2017 of 224 million (USD).[4] Their health care expenditure was 5.6% of GDP in 2015. By comparison, this is equivalent to 1/100 of the U.S. expenditure on health care per capita. Government-sponsored insurance was introduced in 1993, and currently 77% of the Vietnamese population is covered.

For specialty care pertinent to cerebrovascular disease, hospitals are structured in a pyramid system with 4 tiers: communal level (covering 5–10,000 people), district level (100–200 thousand), provincial level (1–2 million), and central level. Viet Duc Hospital belongs in the final tier (i.e., central level) and represents 1 of a dozen hospitals in the country equipped to handle complex cerebrovascular disease such as AVMs. To encourage proper usage of this pyramid system and to keep less-complex patients in the lower-tier centers, the government-sponsored insurance covers 80% of all costs for patients who ascended the hospital tiers in the proper sequence. This coverage drops to 40% for patients who bypass the lower tiers and elect to present directly to the central-tier hospitals.

The government budgeted a total of $225,000 USD for the neurosurgery department at Viet Duc hospital for the year 2018, which covered approximately 5000 admissions and 3500 neurosurgical operations, from diagnostic procedures to intensive care unit expenditures. To put the figure into perspective, this annual budget is less than the monthly *waste* from the neurosurgical operating rooms in a large university hospital in the United States.[6] Because CTA costs $100, this would mean that if half the admitted patients received CTA, the expenditure for this alone would use up the total budget for the year. This budget was intentionally restricted, once again, to force the central-tier

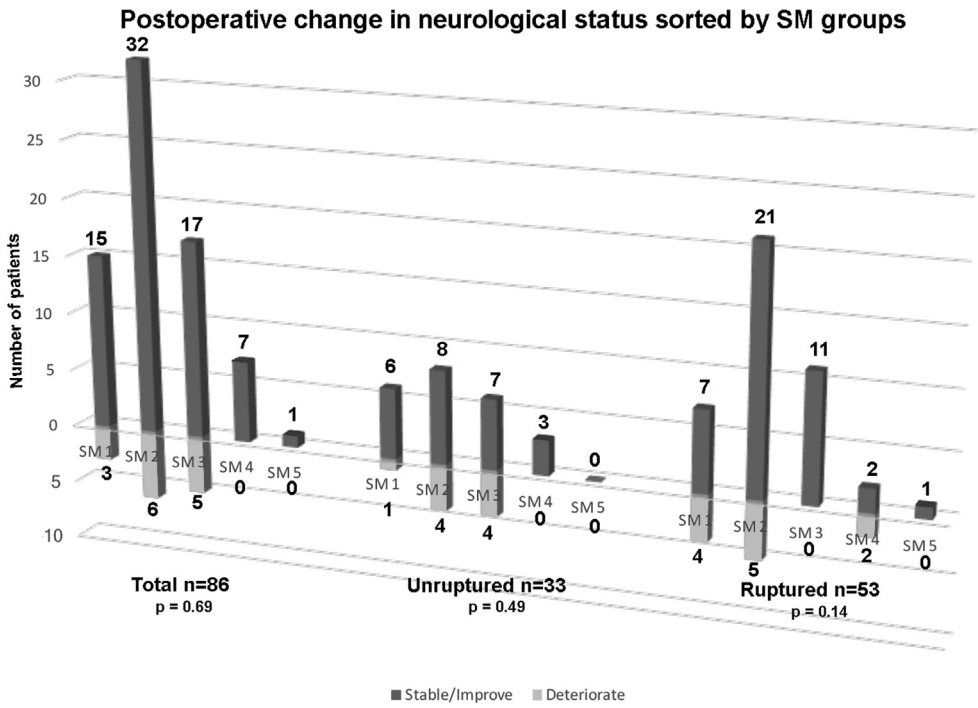

Figure 3. The change in patients' neurologic status during the study is sorted by their Spetzler-Martin grade. The grade of the arteriovenous malformation did not significantly influence whether the patient improved or remained stable versus deteriorated after surgery. This is reflected in the individual *P* values of the χ^2 test.

hospital to focus only on the most complex patients. The reality, however, is that despite the financial disincentive, the population continues to gravitate to the high-level hospitals. But contrary to their expectation, the patients often find that the quality of care at central specialty hospitals is compromised by budget restriction and overcrowding. The bed-occupancy rate at Viet Duc Hospital is frequently at 120%–160%, which means that it is not uncommon for 2 patients to have to share a bed.

Influence of Restriction Resource on Decision Making for Arteriovenous Malformation Treatment: Illustrative Case

In January 2019, neurosurgeons at Viet Duc Hospital started a collaboration with Global Brainsurgery Initiative (GBI), a U.S.-based organization focused on international neurosurgical education, for joint clinical and academic activities in Hanoi. While the U.S. surgeons were on site, a 47-year-old man presented with intraparenchymal and intraventricular hemorrhage from a left parietal AVM, which was shown on CTA (Figure 4). When solicited for opinion, the visiting neurosurgeons recommended placement of a ventriculostomy, onyx-embolization of the main feeder(s), and waiting for a brief period of neurologic recovery, the length of

Table 2. Resource Restriction

	Yes	No	*P* Value
DSA	0.85	0.97	0.73
>24 before admission	0.93	0.69	0.6

The average final mRS of the patients are sorted by whether a preoperative digital subtraction angiography (DSA) was performed and whether it took more than 24 hours after hemorrhage before admission. The comparisons showed no statistical significance in 2-tailed *t*-test analysis.

Table 3. Difference Between Ruptured and Unruptured Arteriovenous Malformations (AVMs)

	Pre mRS	Final mRS	Change mRS
Ruptured	2.2	0.83	0.5
Unruptured	0.76	1.0	−0.3
P value	<0.0001*	0.5	0.07†

mRS, modified Rankin Scale.
*The average preoperative mRS was significantly higher in the group of patients who had ruptured AVMs (2-tailed *t*-test $P < 0.0001$).
†When the change between preoperative and final mRS is calculated for each patient, the average change between hemorrhagic and nonhemorrhagic patients was different, but this did not reach statistical significance.

Table 4. Characteristics and Surgical Outcome for Patients with Unruptured Arteriovenous Malformations (AVMs)

	ARUBA Eligible	Ponce Class A/Unruptured
Number	26	19
AVM size (cm)		
0–3	6	10
3–6	19	9
>6	1	0
Eloquence		
Noneloquent	16	17
Eloquent	10	2
Location		
Lobar	25	18
Cerebellar	1	1
Venous drainage		
Superficial	21	18
Deep	5	1
Nidal aneurysm		
Present	8	3
Absent	16	16
Spetzler-Martin grade		
I	4	7
II	11	12
III	8	0
IV	3	0
V	0	0
Preoperative mRS		
0	8	5
1	17	14
2	1	0
3	0	0
4	0	0
5	0	0
Final mRS		
0	15	12
1	6	4
2	1	1
3	1	1
4	0	0
5	0	0
6	3	1
Obliteration rate	100%	100%
Permanent deficit (mRS >1)	19%	15%
Mortality	12%	5%

ARUBA, A Randomized Trial of Unruptured Brain Arteriovenous Malformation; mRS, modified Rankin Scale.

which would be determined by the clinical course in the intensive care unit and surgical resection of the AVM after that.

The recommendation was not feasible at the Viet Duc Hospital because of the expenses of embolization, the limited intensive care unit (ICU) capacity for prolonged stay, and a wait for DSA that could take days, which was dangerous for this patient with a poor neurologic examination, so the admitting neurosurgeon (H.M.N.) planned surgery for that evening. The AVM was successfully removed through a joint Vietnamese-U.S. effort. Of note, this operation took place after the study period and the patient was not part of the study cohort.

Treatment of Arteriovenous Malformation at Viet Duc Hospital

Viet Duc Hospital has 1 angiography suite shared by multiple services. The data in this study showed that less than half of the patients with ruptured AVMs received a preoperative DSA. Because intensive care is a resource even more scarce, early surgical intervention allowed for definitive treatment of the AVM with better intracranial pressure control while hastening ventilator weaning and, ultimately, reducing ICU stay. A significant proportion of patients bypassed the lower-tier hospital and presented to Viet Duc Hospital directly, and the 40% of governmental coverage makes the $300–$500/night ICU cost extremely expensive for the patient and, if the patient defaults, for the hospital. The common practice in the developed world of embolizing main feeding vessels and allowing time for some neurologic recovery in the ICU before definitive surgical treatment is unaffordable in Vietnam because both endovascular and ICU interventions are expensive.

Conversely, AVM patients who were admitted in good neurologic status may have a variable wait time for their surgery because of staffing shortage and limited capacity in the operating rooms and ICU. In the current study, the hemorrhagic cohort had a wait time of 0–40 days, with the average of nearly a week. Fortunately, the data showed that delays did not adversely affect the outcome.

Outcomes in Vietnam Compared with Other Countries

Endovascular treatment is commonly employed to treat AVMs around the world, and the utilization of it before definitive surgery ranges from 14%–53%.[7-15] Only 2 of the patients in this cohort of 86 (2%) had preoperative embolization and, in fact, only 47 patients had DSA before treatment. Radiosurgery is also expensive, and only 2 patients received this form of treatment, both before their surgery. One of the 2, with an SM 3 unruptured AVM, had both stereotactic radiosurgery and embolization.

In 80 patients (98%), the AVM was successfully obliterated with surgical treatment. This, along with the 10% of permanent deficit,

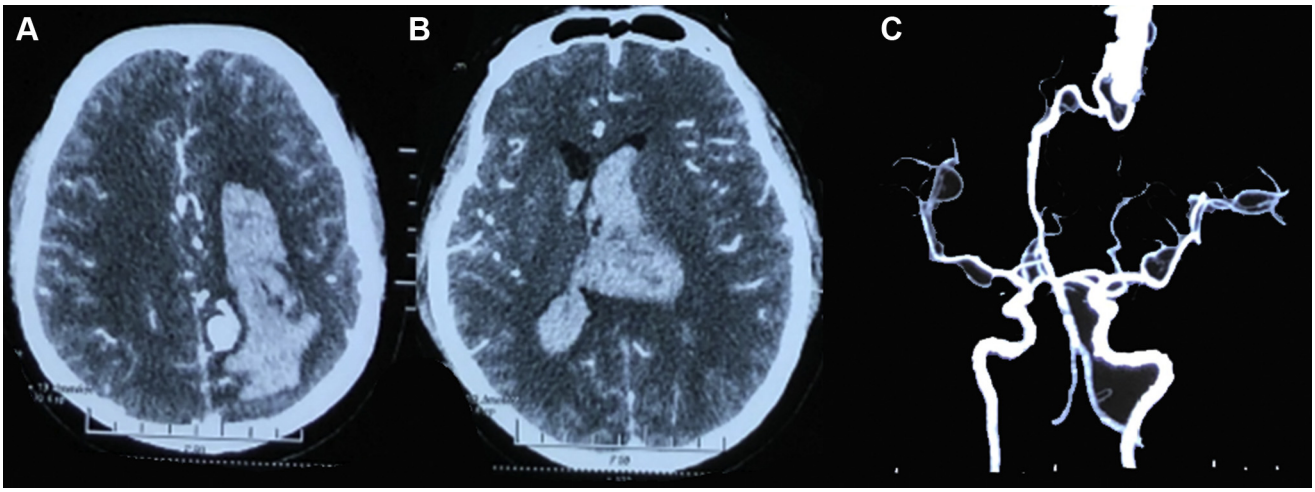

Figure 4. Case illustration of arteriovenous malformation (AVM) at Viet Duc Hospital. (**A**) Computed tomography axial (CTA) image of AVM of a patient who presented after acute hemorrhage from rupture of his AVM. (**B**) Lateral ventricles were filled with blood. (**C**) CTA demonstrated the AVM and its feeders.

is comparable with data from other studies from around the world (Table 5). Several large series have identified factors that influence the outcome of surgery, such as age at presentation, SM grade, presence in eloquent areas, and deep venous drainage.[9,15,16] None of these factors related in a statistically significant way to the final mRS in the current study, perhaps because of the size of the cohort and the relative paucity of older patients and high SM grade lesions in it. Regarding the effect of hemorrhage, the study from UCSF showed that although there was no difference in the final outcome between the ruptured and unruptured groups, patients with unruptured AVMs tended to worsen after surgery while patients with ruptured AVMs tended to improve.[7] The findings in this study confirmed that hemorrhage did not influence the final outcome, but difference between unruptured patients deteriorating and hemorrhagic patients improving stopped short of being statistically significant ($P = 0.07$).

The surgical results of unruptured AVM in ARUBA-eligible patients have been reported from across the globe, and the rate of postoperative permanent neurologic deficit ranged from 5.9%–16.1%[8,11,12,15] (see Table 4). Many recent studies pointed to a

Table 5. Comparative Rates of Obliteration and Morbidity of Arteriovenous Malformation (AVM) Microsurgery Worldwide

	All AVMs		ARUBA-Eligible		Ponce Class A/Unruptured	
Reference	Obliteration Rate	Permanent Neurologic Deficits	Obliteration Rate	Permanent Neurologic Deficits	Obliteration Rate	Permanent Neurologic Deficits[11]
14	98.2% ($n = 282$)	13.1%	N/A	N/A	100% ($n = 186$)	7.5%
15	N/A	12% ($n = 233$)	93% ($n = 155$)	16.1%	99.2% ($n = 118$)	3.4%
9–11	98% ($n = 224$)	25.9% (mRS >2)	93% ($n = 43$)	14.6%	95% ($n = 112$)	3%
8	N/A	N/A	100% ($n = 34$)	5.9%	100% ($n = 24$)	4.2%
19	93% ($n = 545$)	7%	N/A	N/A	N/A	3% ($n = 116$)
7	96.1% ($n = 76$)	N/A	N/A	N/A	N/A	N/A
12	99% ($n = 288$)	12.2%	98.7% ($n = 104$)	7.7%	98.7% ($n = 167$)	7.2%
16–18	97% ($n = 513$)	9%	98% ($n = 341$)	10%	N/A	1.6% ($n = 190$)
Current study	98% ($n = 86$)	10%	100% ($n = 26$)	19%	100% ($n = 19$)	15%

ARUBA, A Randomized Trial of Unruptured Brain Arteriovenous Malformation; N/A, not available; mRS, modified Rankin Scale.

common finding that surgical morbidity for unruptured AVM is lower than reported in the original ARUBA study.[5] In the current investigation, 26 patients met inclusion criteria for ARUBA[5] patients whose final mRS was >1 (19%). Similarly, international studies on unruptured Ponce class A (SM 1 and 2) demonstrate a risk of postoperative neurologic deficit of 1.6%–7.5%.[10,16-18] Comparatively, in the 19 Vietnamese patients with Ponce class A AVM, the risk of neurologic deficit with final mRS >1 was 15%. There was also 1 death in this subgroup, a young patient with SM 2 occipital AVM, from postoperative hematoma.

If the overall success of surgery is similar around the world, then why are risks in these unruptured subgroups slightly higher in Vietnam? One possible explanation is that higher-risk patients in rich countries may have been treated with radiosurgery and thus excluded from analysis of surgical results. With the expense and paucity of radiosurgery centers in Vietnam, our study cohort may have a higher surgical risk profile compared with others. An additional explanation may be embolization. Whereas only 1 patient with unruptured AVM received embolization in Vietnam (1.2%), the percentage is between 25% and 53% internationally.[8,10,11,15,19] If preoperative embolization has a protective effect specific to unruptured AVMs, then that would explain the discrepancy we see.[20]

Limitations of Current Study

Neurologic assessments of the patients, both before and after surgery, were done by the operating surgeon in this study. Theoretically, an independent observer would have provided clinical data with less bias, but in a hospital in which patients have to share beds, one can perhaps understand why an independent observer was not available. The results of the ARUBA study[5] started to influence the operating surgeon in the middle of 2016. It would be interesting to compare the data, especially regarding unruptured AVM and patients eligible for ARUBA, before and after this point. However, the number of patients proved too small to make a meaningful analysis. The transit times of hemorrhagic patients from the lower-tier hospitals to Viet Duc Hospital was only recorded as either >24 hours or <24 hours. If more granular data were available, the detrimental aspect of delay of care might have been more evident.

CONCLUSIONS

Because of restricted resources, Vietnamese patients with ruptured AVMs suffer doubly: those in extremis may experience a delay in care as they filter up the hospital hierarchy from provincial to central specialty hospitals, whereas those who bypass the process and present directly to the central hospital may face financial hardship from large "out-of-pocket" expenses. Furthermore, patients with fair neurologic status may have to wait even more because of staffing and capacity issues at the central hospitals. Data from the current study showed that fortunately, the wait times were not associated with poorer outcome, despite the intangible suffering of patient and family anxiously awaiting definitive treatment.

Notwithstanding the limitation in facility, staffing, and the overall health care system in Vietnam, surgery for AVMs in the Viet Duc Hospital was successful in eliminating the malformation, with obliteration rates and morbidity comparable with Centers of Excellence from across the globe. The slight difference in unruptured subgroups will hopefully become less noticeable when radiosurgery and endovascular treatments become more widely available and affordable.

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