Journal of Institute of Medicine Nepal
Institute of Medicine, Kathmandu, Nepal

Original Article

JIOM Nepal. 2024 Aug;46(2):7-16.

Factors Influencing Intraoperative Rupture of Intracranial Aneurysms

Namrata Khadka, Binod Rajbhandari, Sameer Aryal, Sushil Mohan Bhattarai, Rajendra Shrestha, Rajiv Jha

Author(s) affiliation

Department of Neurosurgery, National Neurosurgical Referral Centre, Bir Hospital, National Academy of Medical Sciences, Mahaboudha, Kathmandu, Nepal

Corresponding author

Namrata Khadka, MBBS, MS
dr.namratakhadka@gmail.com

DOI
10.59779/jiomnepal.1331

Submitted
Jul 8, 2024

Accepted
Aug 5, 2024

ABSTRACT

Introduction

Intraoperative rupture (IOR) is the most anticipated yet dreaded complication during intracranial aneurysmal surgery, leading to severe adverse outcomes. This study aims to analyze various risk factors contributing to IOR.

Methods

It was an analytical study of 46 cases of intracranial aneurysms treated at Department of Neurosurgery, Bir Hospital including both ruptured (n=43) and unruptured (n=3) aneurysms. Incidence of IOR, demographic data, preoperative grading scales, aneurysm morphology, phases and severity of IOR along with postoperative complications and outcomes were assessed.

Results

IOR occurred in 28.26% (13/46) cases of intracranial aneurysms. Most common aneurysm was anterior communicating artery aneurysm (43.5%, 20/46) with majority of IOR (65.1%).Younger patients and males had higher rates of IOR, and early surgical intervention (within 72 hours) was associated with increased incidence (69.2%,9/13). Although preoperative factors showed no direct correlation with IOR, aneurysm size and morphology - dome height and width ratio (H/W) and irregular shapes of aneurysm emerged as critical risk factors ($p<0.05$). Temporary clipping during surgery appeared to reduce IOR, mostly mild (13.04%, 6/13) and occurred in second phase (17.39%; 8/13, during microdissection and neck preparation). However, IOR did not have adverse effects on postoperative complications and Glasgow Outcome Scale Extended (GOSE) at discharge.

Conclusion

Incidence of IOR was 28.65%. Younger age, males, higher Fisher score, early timing of surgery of aneurysms and larger size increased the risk, while use of temporary clip reduced the risk. Dome H/W ratio and irregular shapes of aneurysm were important factors predicting IOR in this study.

Keywords

Intracranial aneurysm; intraoperative rupture; neurosurgery; risk factors

INTRODUCTION

Intracranial cerebral aneurysms are the most challenging pathology even in era of modern neurosurgery. Many patients with ruptured cerebral aneurysm die before reaching hospital, while half live with severe disability. International Study of Unruptured Intracranial Aneurysms (ISUIA) trial states risk of rupture from <0.5% -2-5% per year. This demands need for timely management of both ruptured and unrptured aneurysms which involves microsurgical clipping or endovascular methods.

Intraoperative rupture (IOR) and the risk factors are scarce in literature. Incidence of IOR is estimated to be 5-50%.[1] Kassel reported incidence of IOR of 26%[2], whereas, Graf has IOR of 18%.[3] It is much lower during endovascular procedures(2.4% and 2.9%).[4] Schramm and Cedzich reported more frequent IOR in aneurysms of anterior communicating artery.[5] The size of aneurysm affects IOR with smaller diameter having lower rate.[6] Delayed surgery reduces risk of IOR.[7] Majority of IOR (58.23%) happened in early surgeries (first 72 hours after SAH).[1] Expertise of operating neurosurgeon has shown to find prompt solution for disastrous bleeding, reduces time of temporary clipping, surgical mortality and improves outcome.[8]

Microsurgical clipping is commonly performed procedure at National Neurosurgical Referral Centre, Bir Hospital. However, there is only one retrospective study from our centre in 2011 done in 127 patients over 5years, stating the incidence of IOR to be 13.2%.[9] Our study performed after more than a decade where case volume has markedly increased aims to identify incidence along with demographic and clinical profile, morphology of aneurysm and various perioperative factors influencing IOR. Hence, this study will contribute to new surgical protocol refining the existing one.

METHODS

This was an analytical study done in Department of Neurosurgery, Bir Hospital, Kathmandu, Nepal in 46 patients from November 2023 to June 2024; after approval from Institutional Review Board, National Academy of Medical Sciences (Reference Number – 574/2080/81). The study utilized nonprobability (convenience) sampling, excluding individuals under 18 years of age and those unable or unwilling to provide informed consent.

Evaluations were performed by residents or consultant neurosurgeons. After evidence of aneurysmal subarachnoid hemorrhage (aSAH) or clinical suspicion, CT angiography was conducted, with digital subtraction angiography (DSA) performed if CT angiography results were negative. Aneurysm morphology was assessed using 3D reconstructions from both CT angiography and DSA. Aneurysm clipping procedures were carried out by consultant neurosurgeons, with perioperative variables recorded on semi-structured proforma. At our hospital, there is a standard operating procedure that recommends maintenance of the blood pressure at a mean arterial pressure at 90-110 mm Hg during clipping surgery. On IOR, the patients were ventilated with pure oxygen, while maintaining the mean arterial pressure. Temporary parent artery occlusion and suctioning were allowed for managing IOR followed by definitive clip placement. Adequate aneurysm occlusion and parent artery patency were confirmed by indocyanine green video angiography in all cases. Postoperative CT scans were performed as required.

Postoperative length of hospital stay (LOS) was taken from day of surgery to discharge. IOR defined as any bleeding from aneurysm neck or dome requiring surgical measures to stop.[10] Size of aneurysm[1] categorised as: Small : <12mm, Big: 12mm-25mm and Giant : >25mm. Aneurysm morphology [11] were defined as size: maximum distance of dome from neck plane, aspect ratio (AR): calculated from maximum perpendicular height divided by average neck diameter, Size ratio (SR): maximum height divided by mean vessel diameter of all branches associated, Height: maximum perpendicular distance of dome from neck plane, width: maximum width parallel to neck, height–width (H/W) ratio: ratio of height to width, aneurysm width–parent artery diameter (W/L) ratio: between aneurysm diameter and associated vessel diameter, flow angle (FA): angle between maximum height and parent vessel. Aneurysms were divided into single-sac aneurysm with regular margin (SSR), single-sac aneurysm with unregular margin (SSUR) or lobulated aneurysm. SSRs were considered regular aneurysms (RAs), and other morphologic subtypes were classified as irregular aneurysms (IRAs).

Timing to clipping[1] was categorized as: early: <72 hours, intermediate: 4-10 days, late: >11 days and phases of aneurysm rupture[12] as first phase: initial exposure or predissection, second phase: actual dissection or microdissection and third phase: clipping of aneurysm. Severity of IOR was defined according to Thomas and Jennifer as minor , moderate, and major[12] (minor: small and easily controlled by 3-French microsuction, moderate:requiring temporary occlusion of proximal arterial segment or tamponade of the aneurysm and major: significant hemorrhage with hemodynamic changes. Delayed ischemic neurological deficit (DIND)[13] has been defined to differentiate from VS identified on imaging examinations, as focal (hemiparesis, aphasia, hemianopia, or neglect) or global (two points decrease on Glasgow Coma Scale) new onset neurological impairment lasting for at least 1 h and/or cerebral infarction, when all other potential causes of clinical deterioration were excluded (hydrocephalus, seizure, rebleeding, and hyponatremia).

All data were analyzed using SPSS (version 22.0). The results were expressed as the mean±SD/ median (range) for the quantitative data. The categorical data were compared using χ^2 test or Fisher's exact test. Univariate and multivariate analysis were done to correlate various variables. p-value < 0.05 was taken as statistically significant.

RESULTS

Total of 46 patients were studied prospectively out of which majority 93.47%(43/46) was of aSAH and only 6.5 % (3/46)was of unruptured aneurysm. Majority were females 73.9% (34/46) and most patients (78.3%;36/46) had KPS of 100.

***Table 1**. Demographics, clinical characteristics and postoperative outcomes of patients with IOR*

Characteristics		Values
Age (Mean±SD)		53.5±11.6
Sex	Male	12 (26.1)
	Female	34 (73.9)
KPS	100	36 (78.3)
	90	9 (19.6)
	80	1 (2.2)
Ictal day(Mean±SD)/Median(IQR)		5.3±5.9, 3(2,5)
Smoking and alcohol	None	21(45.7)
	Alcohol only	2(4.3)
	Smoking only	18(39.1)
	Both	5(10.9)
Past history of SAH		0
Family history		0
Preoperative hydrocephalus		4(8.6)
Preoperative hematoma		4(8.6)
Location of aneurysm	Acom	20(43.5)
	MCA	9(19.6)
	ICA	8(17.4)
	Pcom	6(13)
	DACA	3(6.5)
Postoperaptive Outcomes		
Postoperaptive complications	None	21(45.7)
	Vasospasm	18(39.1)
	DIND	5(10.9)
	Hemiparesis	4(8.7)
	Infarction	2(4.3)
	Seizure	1(2.2)
	HCP	1(2.2)
	Ventriculitis	1(2.2)
Mechanical ventilator days (Mean±SD)		1.4±1.7
GOSE at discharge	Dead (1/8)	5(10.9)
	Lower severe disability (3/8)	3(6.5)
	Upper severe disability (4/8)	1(2.2)
	Lower good recovery (7/8)	5(10.9)
	Upper good recovery (8/8)	30(65.2)
Length of ICU stay median(IQR)		4(3,5)
LOS Median(IQR)		14(11,147)
Mean duration of surgery (min) Mean±SD		202.5±75.2

Table 2. Preoperative grading of patients with ruptured aneurysm

Grading System	Number (%)
Modified Fisher Grade	
1	5 (11.6)
2	2 (4.7)
3	25 (58.1)
4	11 (25.6)
Hunt and Hess Grade	
1	3 (7.0)
2	33 (76.7)
3	5 (11.6)
4	2 (4.7)
WFNS Grade	
1	32 (74.4)
2	3 (7.0)
3	4 (9.3)
4	4(9.3)

Mean age of patients was 53.5 years (SD ± 11.6). Hypertension was present in 54.3% and 39.1% of the patients were smokers. Mean number of ictal days was 5.3 (SD ± 5.9), with range of 26 days . Acom aneurysm (43.5%) was most common. (Table1).

Majority of the ruptured aneurysm had Modified Fisher grade 3 (58.13%,25/43), Hunt and Hess grade 2 (76.76%,33/43) and WFNS grade 1 (74.41% ,32/43). (Table 2) VS and DIND occurred in 39.1%(18/46) and 10.9%(5/46) respectively. Most patients (65.2%) had GOSE 8/8. Median length of ICU and hospital stay was 4 and 14 days respectively. (Table 1).

Majority (47.8%,22/46) had early surgery, dome being mostly anterior and 87.0% (40/46) were small aneurysms with 93.47%(43/46) single aneurysm. Mean neck size was 4.4 mm (SD ± 1.8), aspect ratio 1.7 (SD ± 0.9), size ratio 1.6 (SD ± 0.9), H/W ratio 1.2 (SD ± 0.3) , W/L ratio1.4 (SD ± 0.9) and mean flow angle 69.7 degrees (SD ± 30.5).65.21%(30/46) SSUR, 21.73%(10/46) SS and 13.03%(6/46) were lobulated, hence 78.26% were IRA. IOR occurred in 28.26%(13/46). Nearly17.39%(8/13) IOR occurred during second phase and was mild in 13.04%(6/13). (Table 3).

On univariate and multivariate logistic regression analysis mean age for patients with rupture was lower at 52.3±11.1 years (p=0.54), higher in males (30.8% vs. 24.2%,p=0.54 and p=0.46),shorter ictal days (3.3 vs. 6.2 minutes, p=0.08) and increased smoking/alcohol use (23.1% vs. 6.1%, p=0.32) with MFS-3 (69.2% vs. 53.3%) and higher Hunt and Hess grades (p=0.62 and p=0.47).(Table 4).

Acom aneurysms and early surgeries had frequent ruptures (69.2% vs. 39.4%, p=0.18, 65.1% vs. 36.4%,p=0.23). Temporary clipping time was shorter in ruptures (3.3±3.0 minutes vs 6.2±6.6 minutes, p=0.08, p=0.63),but in 76.9% of IOR temporary clip was not used (Table 5).

Ruptured cases had slightly larger dome height, width (11.4±14.9 mm, p=0.340,12.3±16.2,p=0.96), neck (4.8±2.2 mm, p=0.40) but lower flow angles (59.6±27.4, p=0.19). H/W ratio was lower in ruptures (1.0±0.3vs. 1.3±0.3, p=0.002 ,aOR=0.044, 95% CI=0.002-1.155, p=0.06).Shape and margin were significant (p=0.001;p=0.04), with SSUR and IRA being more frequent in ruptures(aOR=1.075, 95% CI=0.000-NA, p=1.00;aOR=0.000, 95%CI=0.000-NA,p=1.00) (Table 6).

DISCUSSION

IOR is the most anticipated,yet dreaded complication of aneurysm clipping. Among 46 cases in our study, 43 cases were ruptured aneurysms with three unruptured aneurysm without aSAH. There was no IOR in all three unruptured aneurysms. Importantly, all IOR in our study occurred in aSAH during clipping,highlighting ruptured status as the significant risk factor. We had 28.26%(13/46) IOR, similar to Kassel et al. (26%)[2] IOR has preponderance to ruptured aneurysms than unruptured (6-40% vs 1-20%)making ruptured status itself risk factor[14] supporting our study as 93.47%(43/46) of cases included in our study were ruptured aneurysms with aSAH. IOR has substantially increased in our centre in contrast to retrospective study done in 127 patients in 2011 (13.2%),underscoring learning curve in aneurysm clipping.[9]

IOR was more common in younger patients and

***Table 3**. Morphology of aneurysm and procedure characteristics*

	Characteristics	Values
No of aneurysm	Single Multiple	43(93.47) 3(6.52)
Aneurysm morphology	Dome height(Mean±SD) Dome Width (Mean±SD) Size of neck(mm) (Mean±SD)	9.7±10.2 9.3±11.0 4.4±1.8
Size	Small <12mm Big (12-25mm) Giant >25mm	40(87) 5(10.9) 1(2.2)
Aspect ratio	Aspect ratio	1.7±0.9
Size ratio	Size Ratio	1.6±0.9
W/L ratio	W/L ratio	1.4±0.9
Flow angle	Flow Angle	69.7±30.5
H/W ratio	H/W ratio	1.2±0.3
Shape	SSR SSUR Lobulated	10(21.73) 30(65.21) 6(13.03)
Margin	RA IRA	10(21.73) 36(78.26)
Use of temporary clip	No	35(76.1)
Median blood loss (ml) Median (IQR):		300(200,425)
Timing of surgery	Early Intermediate Late	22(47.82) 14(30.43) 10(21.73)
Dome projection	Anteroinferiorly Anterolateral Anterosuperiorly Laterally Posterinferiorly Inferiorly Posterolaterally Superiorly Anteriorly Anteromedially Posteriorly Superolaterally Inferolaterally Posterolateral Posteromedially Posterosuperiorly Superiomedially Superoposterolateral	5(10.9) 5(10.9) 5(10.9) 5(10.9) 4(8.7) 3(6.5) 3(6.5) 3(6.5) 2(4.3) 2(4.3) 2(4.3) 2(4.3) 1(2.2) 1(2.2) 1(2.2) 1(2.2) 1(2.2) 1(2.2)
Intraoperative rupture (IOR)	Absent Present	33(71.73) 13(28.26)
Severity of IOR	Mild Moderate Major	6(13.04) 5(10.86) 2(4.3)
Phases of IOR	Second phase Third phase	8(17.39) 5(10.86)

Table 4. Comparison of demographics and clinical characteristics between patients with IOR and without IOR

Characteristics	IOR		p-value
	No	Yes	
Number			
Ruptured aneurysm	30	13	
Unruptured	3	0	
Age (Mean±SD)	54.0±11.9	52.3±11.1	0.54*
Sex			0.46**
Female	25(75.8%)	9(69.2%)	
Male	8(24.2%)	4(30.8%)	
KPS			0.41
100	1(3.0%)	0(0.0%)	
90	5(15.2%)	4(30.8%)	
80	27(81.8%)	9(69.2%)	
Comorbidity			0.93
None	11(33.3%)	5(38.5%)	
Hypertension	18(54.5%)	7(53.8%)	
Diabetes Mellitus	1(3.4%)	0(0.0%)	
Both	1(3.0%)	0(0.0%)	
Thyroid Disorder	2(6.1%)	1(7.7%)	
Ictal (Mean±SD)	6.2±6.6	3.3±3.0	0.08*
Smoking and Alcohol			0.32
None	16(48.5%)	5(38.3%)	
Alcohol only	1(3.0%)	1(7.7%)	
Smoking only	14(42.4%)	4(30.8%)	
Both	2(6.1%)	3(23.1%)	
Modified Fisher Grade			0.62
1	4(13.3%)	1(7.7%)	
2	1(3.3%)	1(7.7%)	
3	16(53.3%)	9(69.2%)	
4	9(30.0%)	2(15.4%)	
Hunt and Hess Grade			0.47
1	3(10.0%)	0(0.0%)	
2	22(73.3%)	11(84.6%)	
3	3(10.0%)	2(15.4%)	
4	2(6.7%)	0(0.0%)	
WFNS Grade			0.09
1	19(63.3%)	13(100.0%)	
2	3(10.0%)	0(0.0%)	
3	4(13.3%)	0(0.0%)	
4	4(13.3%)	0(0.0%)	
Location of Aneurysm			0.23
Acom	12(36.4%)	8(61.5%)	
MCA	9(27.3%)	0(0.0%)	
ICA	5(15.2%)	3(23.1%)	
Pcom	5(15.2%)	1(7.7%)	
DACA	2(6.1%)	1(7.7%)	

* Mann-Whitney U test, Chi-Square test,** Fisher Exact test

***Table 5**. Comparison of procedure characteristics and postoperative outcomes between patients with IOR and without IOR*

Characteristics	IOR		p-value
	No	Yes	
Duration of Surgery	212.2±77.5	179.2±66.3	0.20
Timing of surgery			0.18
Early	13(39.4%)	9(69.2%)	
Intermediate	12(36.4%)	2(15.4%)	
Late	8(24.2%)	2(15.4%)	
Use of Temporary Clip			0.63**
No	25(75.8%)	10(76.9%)	
Yes	8(24.2%)	3(23.1%)	
Postoperative Complications			
DIND	5(15.2%)	1(7.7%)	0.45
Vasopasm	13(39.4%)	5(38.5%)	0.95
Seizure	1(3.0%)	0(0.0%)	0.53
Infarct	3(9.1%)	0(0.0%)	0.36
HCP	2(6.1%)	0(0.0%)	0.51
Ventriculitis	1(3.0%)	0(0.0%)	072
Hemiparesis	3(9.1%)	0(0.0%)	0.36
Mechanical Ventilator Days (Mean±SD)	1.5±1.9	1.3±1.2	0.88*
GOSE			0.66
Dead	4(12.1%)	1(7.7%)	
Lower Severe Disability	3(9.1%)	0(0.0%)	
Upper Severe Disability	1(3.0%)	0(0.0%)	
Upper Moderate Disability	2(6.1%)	0(0.0%)	
Lower Good Recovery	3(9.1%)	2(15.4%)	
Upper Good Recovery	20(60.6%)	10(76.9%)	
Length of ICU Stay Median (IQR)	4(3.5)	5(3,5)	0.68*
LOS Median (IQR)	13.5(11.0,16.2)	14(11.0,17.5)	0.99*

* Mann-Whitney U test, Chi-Square test,** Fisher Exact test

males (4/12,33.33%),similar to study by Novak et.al.[1] We found lower IOR with higher KPS scores, a factor not yet explored in other studies. Comorbidities, smoking and alcohol did not show direct correlation, contrary to Sharma et. al.[15], although our study did observe higher IOR in alcohol users and smokers. Preoperative MFS, Hunt and Hess and WFNS grade had no correlation, although most IOR occurred in MF-3 and higher Hunt and Hess grades.

Early surgery accounted majority of IOR (9/13, 69.3%) aligning with most literatures (58.23% in early surgeries, 27.54% in intermediary period and 24.27% in delayed surgeries).[1] Delayed surgery reduces IOR.[8,16] Schramm and Cedzich[5] noticed more IOR in Acom aneurysms[1] , also MCA aneurysm in some series are associated with lower IOR, similar to our study with no IOR in MCA aneurysm. Ruptured Acom aneurysms were more (43.47%, 20/46) in our study, with higher IOR (61.5%,8/13).

Aneurysm size affects IOR, with larger diameters showing IOR . In our study, most aneurysms were small; and one giant aneurysm, that had IOR, supporting previous studies. While not statistically significant, IOR was observed more frequently with larger dome width and height. Dome projection was not significant, but our study reflected less IOR in posterior projection, consistent with Acom aneurysm studies.[17] Our findings suggest that larger neck and W/L ratio increase IOR, with significant lesser H/W ratio ($p<0.05$). Study by Jirjees et.al[18] mentioned that larger neck and size are risk factors contributing to IOR. Additionally, irregular single-sac aneurysms (SSUR/IRA) emerged as independent risk factors ($p<0.05$), similar to study by Lukas et al., 2018 (IOR greater in IRAs than RAs ,31.1% vs. 9.4% ,p =0.02). [10]

Temporary clipping reduced IOR incidence (76.9% vs. 23.1%) in our study, aligning with findings that

Table 6. Comparison of aneurysm morphology between patients with IOR and without IOR

Characteristics	IOR		p-value
	No	Yes	
No of aneurysm			0.33**
Single	27(90.0%)	13(100.0%)	
Multiple	3(10.1%)	0(0.0%)	
Size of dome			0.26
Small 12mm	29(87.9%)	11(84.6%)	
Big (12-25mm)	4(12.1%)	1(7.7%)	
Giant 25mm	0(0.0%)	1(7.7%)	
Dome height (Mean±SD)	9.0±7.6	11.4±14.9	0.34
Dome width (Mean±SD)	8.1±8.2	12.3±16.1	0.96
Dome projection			0.44
Anteriorly	2(6.1%)	0(0.0%)	
Anteroinferiorly	2(6.1%)	2(15.4%)	
Anterolateral	4(12.1%)	1(7.7%)	
Anteromedially	0(0.0%)	2(15.4%)	
Anterosuperiorly	3(9.1%)	2(15.4%)	
Inferiorly	2(6.1%)	1(7.7%)	
Inferolaterally	1(3.0%)	0(0.0%)	
Laterally	5(15.2%)	0(0.0%)	
Posterinferiorly	2(6.1%)	2(15.4%)	
Posteriorly	1(3.0%)	1(7.7%)	
Posterolateral	1(3.0%)	0(0.0%)	
Posterolaterally	3(9.1%)	0(0.0%)	
Posteromedially	1(3.0%)	0(0.0%)	
Posterosuperiorly	1(3.0%)	0(0.0%)	
Superiomedially	0(0.0%)	1(7.7%)	
Superiorly	2(6.1%)	1(7.7%)	
Superolaterally	2(6.1%)	0(0.0%)	
Superoposterolateral	1(3.0%)	0(0.0%)	
Size of neck(mm) mean ±SD	4.2±1.6	4.8±2.2	0.40*
Aspect ratio	1.9±0.9	1.5±0.8	0.06*
Size ratio	1.6±0.9	1.4±1.0	0.39*
W/L ratio	1.4±0.6	1.6±1.4	0.93*
Flow angle	74.0±31.3	59.6±27.4	0.19*
H/W ratio	1.3±0.3	1.0±0.3	0.002*
Shape			0.001
SSUR	17(51.5%)	13(100.0%)	
SSR	10(30.3%)	0(0.0%)	
Lobulated	6(18.2%)	0(0.0%)	
Margin			0.04**
IRA	23(69.7%)	13(100.0%)	
RA	10(30.3%)	0(0.0%)	

* Mann-Whitney U test, Chi-Square test,** Fisher Exact test

it lowers IOR risk. [1]While IOR didn't impact GOSE or postoperative complications, hospital and ICU stays were longer in cases with IOR . This is supported by Seth et.al stating that IOR doesn't influence vasosapam.[19]This may be explained by strategic management of IOR with experience of operating neurosurgeons .[14]This is in contrast to other studies which have stated that IOR is very likely to increase chance of permanent neurological deficit or death, and may be a risk for vasospasm and delayed ischemia.[2]

CONCLUSION

IOR was a significant complication in intracranial aneurysms during clipping, particularly in ruptured ones with aSAH. Factors influencing IOR were younger age and male sex, higher MFS and Hunt and Hess grades, larger size, larger neck, irregular morphology, higher W/L ratio, and early surgical timing. Similarly, importance of aneurysm morphology as larger size contributed to IOR with less H/W ratio and irregular shapes were independent predictors ($p<0.05$). Increased IOR incidence in our center emphasizes the importance of role of surgical expertise and experience, underscoring importance of learning curve.

IOR did not directly affect the postoperative complications, however, the length of ICU stay and hospital stay had increased. So, meticulous planning, particularly for high-risk cases such as ruptured Acom aneurysms with strategies such as temporary clipping and expertise development in aneurysm surgery may help mitigate the risk of IOR.

FINANCIAL SUPPORT

The author(s) did not receive any financial support for the research and/or publication of this article.

CONFLICT OF INTEREST

The author(s) declare that they do not have any conflicts of interest with respect to the research, authorship, and/or publication of this article.

AUTHOR CONTRIBUTIONS

NK: Research concept, research design, literature review, research experiment, data collection, data analysis, manuscript preparation; BR, SA, SMB: Literature review, research experiment, data analysis; RS: Literature review, research experiment, data analysis, manuscript preparation; RJ: Research concept, research design, research experiment, literature review, data analysis.

REFERENCES

1. Lakićević N, Vujotić L, Radulović D, et al. Factors Influencing Intraoperative Rupture of Intracranial Aneurysms. Turk Neurosurg.2015;25(6):858-85.doi:10.5137/1019-5149.JTN.12966-14.2.
2. Kassell NF, Boarini DJ, Adams HP Jr, et al. Overall management of ruptured aneurysm: comparison of early and late operation. Neurosurgery. 1981 Aug;9(2):120-8. doi: 10.1227/00006123-198108000-00002.
3. Graf CJ, Nibbelink DW. Cooperative study of intracranial aneurysms and subarachnoid hemorrhage. Report on a randomized treatment study. 3. Intracranial surgery. Stroke. 1974 Jul-Aug;5(4):557-601. doi: 10.1161/01.str.5.4.557.
4. Guglielmi G, Viñuela F, Duckwiler G, et al. Endovascular treatment of posterior circulation aneurysms by electrothrombosis using electrically detachable coils. J Neurosurg. 1992 Oct;77(4):515-24. doi: 10.3171/jns.1992.77.4.0515.
5. Schramm J, Cedzich C. Outcome and management of intraoperative aneurysm rupture. Surg Neurol. 1993 Jul;40(1):26-30. doi: 10.1016/0090-3019(93)90165-w.
6. Sluzewski M, Bosch JA, van Rooij WJ, et. al. Rupture of intracranial aneurysms during treatment with Guglielmi detachable coils: incidence, outcome, and risk factors. J Neurosurg. 2001 Feb;94(2):238-40. doi: 10.3171/jns.2001.94.2.0238.
7. Le Roux PD, Elliot JP, Newell DW, et al. The incidence of surgical complications is similar in good and poor grade patients undergoing repair of ruptured anterior circulation aneurysms: a retrospective review of 355 patients. Neurosurgery. 1996 May;38(5):887-93; discussion 893-5. DOI: 10.1097/00006123-199605000-00006.
8. Lawton MT, Du R. Effect of the Neurosurgeon's surgical experience on outcomes from intraoperative aneurysmal rupture. Neurosurgery.2005 July;57(1):p 9-15. DOI: 10.1227/01.NEU.0000163082.20941.EF
9. Sharma GR, Kausal P, Jha R,et.al. Outcome of Microsurgical Clipping of Intracranial Aneurysms in Bir Hospital. Nep J Neurosci [Internet]. 2011 Dec. 29. https://doi.org/10.3126/njn.v8i2.22766
10. Goertz L, Hamisch C, Telentschak S, et al. Impact of Aneurysm Shape on Intraoperative Rupture During Clipping of Ruptured Intracranial Aneurysms.World Neurosurg.2018;118:e806-e812. doi:10.1016/j.wneu.2018.07.058
11. Duan Z, Li Y, Guan S et al. Morphological parameters and anatomical locations associated with rupture status of small intracranial aneurysms. Scientific Reports. 2018;8(1):6440. https://doi.org/10.1038/s41598-018-24732-1
12. Chen SF, Kato Y, Kumar A, et al. Intraoperative rupture in the surgical treatment of patients with intracranial aneurysms. J Clin Neurosci. 2016;34:63-69. doi:10.1016/j.jocn.2016.01.045
13. Yamaki VN, Cavalcanti DD, Figueiredo EG. Delayed Ischemic Neurologic Deficit after Aneurysmal Subarachnoid Hemorrhage. Asian J Neurosurg. 2019 Jul-Sep;14(3):641-647. doi: 10.4103/ajns.AJNS_15_19.
14. Kheĭreddin AS, Filatov IuM, Belousova OB, et al. [Intraoperative rupture of cerebral aneurysm--incidence and risk factors]. Zh Vopr Neirokhir Im N N Burdenko. 2007 Oct-Dec;(4):33-8; discussion 38. Russian. PMID: 18274133.
15. Sharma GR, Joshi S, Paudel P, et al. Risk factors and outcome analysis of patients with intraoperative rupture (IOR) of ruptured cerebral aneurysm during microsurgical clipping. Br J Neurosurg. 2024 Oct;38(5):1086-1090. doi: 10.1080/02688697.2021.2022096.
16. Leipzig TJ, Morgan J, Horner TG, et.al. Analysis of intraoperative rupture in the surgical treatment of 1694 saccular aneurysms. Neurosurgery. 2005 March;56(3): 455-468. https://doi.org/10.1227/01.NEU.0000154697.75300.C2
17. Patnaik A, SJ, Sekar A, Bansal S, et.al. Correlation between

aneurysm dome direction and patient outcomes following surgery for ruptured anterior communicating artery aneurysms. Cureus. 2023 Oct 31;15(10):e48051. doi: 10.7759/cureus.48051.

18. Jirjees S, Htun ZM, Aldawudi I et.al: Role of morphological and hemodynamic factors in predicting intracranial aneurysm rupture: A Review. Cureus. 2020 Jul 14;12(7):e9178. doi: 10.7759/cureus.9178.

19. Sheth SA, Hausrath D, Numis AL,et al. Intraoperative rerupture during surgical treatment of aneurysmal subarachnoid hemorrhage is not associated with an increased risk of vasospasm. J Neurosurg. 2014 Feb;120(2):409-14. doi: 10.3171/2013.10.JNS13934.