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Technical aspects and outcomes of endovascular treatment for vertebrobasilar tandem occlusions as compared to isolated basilar artery occlusion

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Abstract

Background: The optimal treatment approach for posterior circulation tandem occlusion remains unclear. This study aimed to assess the efficacy and safety of treatment strategies for vertebrobasilar tandem occlusions as compared to isolated basilar artery occlusions. This study investigates the challenges of managing these complex cerebrovascular conditions and explores the feasibility of optimizing treatment approaches to improve patient outcomes and safety. *Methods:* Fifty-nine patients with acute posterior large-vessel occlusion stroke who underwent mechanical thrombectomy between November 2016 and December 2022 were retrospectively analyzed. Patients were categorized as isolated or tandem basilar artery occlusion. The baseline patient characteristics, risk factors, time metrics, recanalization rates, and angiographic characteristics were compared between groups. The study analyzed various interventional strategies, including thrombectomy technique, additional angioplasty, the approach to lesion patterns (ipsilateral to steno-occlusive VA lesion: dirty road or contralateral: clean road), and the sequence of actions during the procedures. The outcome measures were a 90-day modified Rankin scale (mRS) of 4-6, post-thrombectomy recanalization defined as mTICI -2b, 90-day mortality. *Results:* Out of the 59 patients, 39 (66%) had isolated basilar occlusion(i-BAO), while 20 (33%) presented with tandem occlusions (t-BAO). Patients with i-BAO and t-BAO had mean ages of 59.08±12.53 and 56.30±12.94 years, respectively. Both groups had a median NIHSS score of 22 upon admission. t-BAO group had longer times from symptom onset to hospital admission and recanalization times compared to i-BAO. (median 270 min versus 60min, p=0.015; 384 min versus 240 min, p=0.03). Successful recanalization (modified thrombolysis in cerebral infarction score ≥2b) was obtained in 13 (76.4%) versus 35 (89.7%) patients with t-BAO versus i-BAO, respectively. Thrombectomy performed aspiration with a distal access catheter (CA) was more common in the isolated basilar occlusion group (73.7% vs. 43.8%). In contrast, stent retrievers (SR) were more common in the tandem group (37.5% vs. 18.4). Access was achieved in 17 patients with tandem occlusion. The clean road approach was used in 58.8 % of cases, and the dirty road in 41.2%. t-BAO procedures involved a higher number of intraprocedural passes (median 2.5 vs. 1.5, p=0.047). Third-month mortality rate was significantly higher in the t-BAO group (66.7% vs. 38.5%, p=0.047). Multivariate logistic regression identified a number of passes ≥3 as an independent risk factor for poor clinical outcome at three months (OR=14; 95% CI, 2.596-77.208).
Conclusions: Endovascular intervention via mechanical thrombectomy has been demonstrated to be both safe and feasible as a treatment approach for patients presenting with tandem occlusions in the posterior circulation.

Keywords: Vertebrobasilar tandem occlusions, endovascular treatment, thrombectomy techniques

INTRODUCTION

Basilar artery occlusions account for 1% of all acute strokes and only 5-10% of large vessel occlusions. The infrequent incidence of basilar artery occlusion (BAO) has resulted in a shortage of observational data on the effectiveness and safety of endovascular treatment (EVT) in this patient population. The initial data coming from observational studies revealed that EVT may

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supply beneficial effects in cases of BAO.[1] Still, the results of the BEST and BASIC randomized controlled clinical trials conducted in 2020 and 2021 have caused some confusion. Unfortunately, both studies produced inconclusive results due to selection bias and a crossed-over sample population. Although the BASICS and BEST studies have been criticized in these aspects, these studies have suggested a potential benefit of endovascular thrombectomy in BAO and have been instrumental in shaping the design of subsequent positive studies.[2,3] Finally, the ATTENTION (2022) and BAOCHE (2022) studies demonstrated that EVT had better functional clinical outcomes at three months in patients with acute BAO compared to those treated only with best medical treatment.[4,5] A meta-analysis that included these four studies showed that EVT may be associated with improved clinical outcomes for selected acute BAO patients.[6]

Characteristics and outcomes of mechanical thrombectomy (MT) for acute BAO vary depending on the underlying pathological mechanism. An embolus of cardiac origin usually causes isolated basilar artery occlusion (i-BAO) without underlying atherosclerotic stenosis of the vertebral or basilar arteries. In contrast, unilateral or bilateral concomitant vertebral artery occlusion or severe VA stenosis may lead to tandem basilar artery occlusion (t-BAO).[7] Successful recanalization and favorable clinical outcomes have been achieved in patients with i-BAO using stent retrievers, aspiration catheters, balloons, and intracranial stent devices with appropriate techniques. In tandem vertebrobasilar occlusions, mechanical thrombectomy differs from i-BAO. Anatomical variations in the vertebral arteries, such as hypoplasia and the posterior inferior cerebellar artery ending, can pose technical challenges in accessing the basilar artery.[8] In tandem lesions, where there is stenosis or occlusion of the non-dominant vertebral artery (VA), intracranial access can be achieved through contralateral VA, which is referred to as a “clean road.” Conversely, an occluded VA (dirty road) may be the only option for thrombectomy. In these cases, balloon angioplasty and/or stenting may be required.[9] This retrospective study aimed to assess the technical aspects of mechanical thrombectomy (MT) in patients with tandem vertebrobasilar occlusion treated at our medical center. Additionally, the study aimed to explore the demographic, angiographic, and clinical outcome differences between t-BAO and the i-BAO group.

METHODS

The records of 68 patients with posterior-circulation ischemic stroke and acute major vessel occlusion who underwent endovascular treatment at our center between November 2016 and December 2022 were retrospectively reviewed (Figure 1). This study was approved by the ethics committee. The inclusion criteria were (1) having acute neurologic symptoms caused by BAO as defined by contrast-enhanced computer tomography angiography (CTA), (2) ≤24 hours from the onset of symptoms to femoral puncture, (3) having a National Institutes of Health Stroke Scale score (NIHSS) score ≥6, and (4) having a premorbid modified Rankin Scale (mRS) score ≤2. The exclusion criterion was having isolated posterior cerebral artery occlusion without BAO.

The samples were then divided into two groups. The first group consisted of patients with t-BAO is characterized by acute basilary occlusion with concomitant occlusion or severe stenosis (≥70%) of the vertebral artery V1-proximal V2 segment, unilaterally or bilaterally. The second group comprised patients with i-BAO, with or without underlying intracranial atherosclerosis.

Baseline demographic characteristics, risk factors, initial NIHSS scores, intravenous tissue plasminogen activator (tPA) administration, and stroke subtypes (TOAST classification) were recorded from the database. Outcome measure was poor outcome at three months (mRS 4 or 5, or death). Two endovascular neurologists who were blind to previous clinical information and treatment reviewed all images and three months outcomes. Early ischemia findings were evaluated by calculating the posterior circulation Alberta Stroke Program Early CT (pc-ASPECT) scores and collateral circulation by calculating the Basilar Artery on Computed Tomography (BATMAN) scores.[10,11] The occlusion localization, underlying intracranial atherosclerotic disease (defined as a fixed stenosis degree >70% or stenosis >50% with distal blood flow impairment or evidence of repeated re-occlusion after thrombectomy), and procedure-related complications (distal embolization, arterial perforation, and arterial dissection) were recorded on DSA images. BAO localization was defined as proximal segment: vertebral artery between the end of V4 segment and anterior inferior cerebellar artery (AICA); mid basilar segment: between AICA and superior cerebellar artery (SCA); distal segment: between SCA and top of the basilar; patient’s vertebrobasilar segment: between V4 segment and proximal basilar artery.

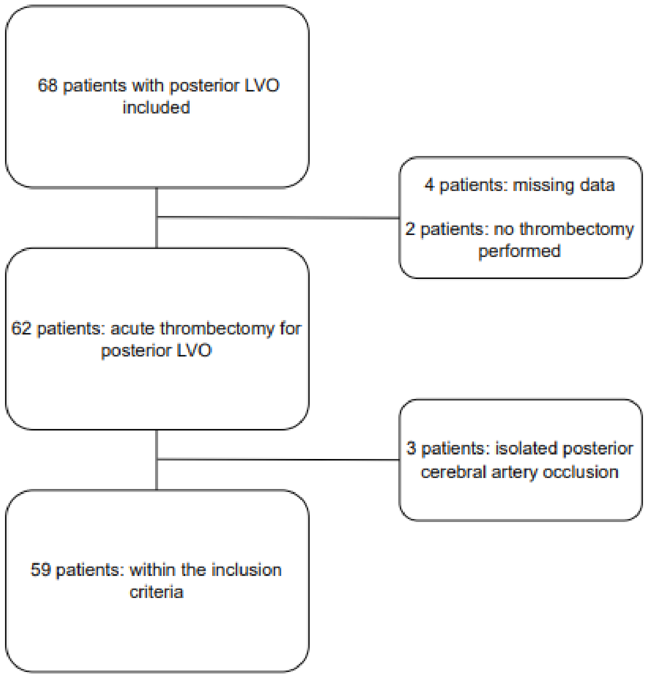

Figure 1. Flow chart showing the patient inclusion algorithm from our database.

Experienced neurointerventionalists performed the procedures under conscious sedation or general anesthesia. The choice of devices and techniques for recanalization therapy was left to the discretion of the operator. Vessel recanalization was achieved using stent retriever approaches and/or aspiration thrombectomy. Patients presenting with tandem vertebral artery (VA) lesions or underlying basilar artery (BA) in situ atherosclerosis underwent balloon angioplasty or a combination with permanent stent placement. The approach laterality to vertebral stenosis or occlusion was documented as either "ipsilateral" ("dirty road") or "contralateral"("clean road").[12,13] The term "procedure time" denotes the duration from groin puncture to the completion of the final angiographic evaluation.[7]

Successful recanalization following mechanical thrombectomy, as assessed using a modified Thrombolysis in Cerebral Infarction (mTICI) score, was defined as mTICI 2b/3.[14] All patients underwent a plain CT scan between 18 and 24 hours post-EVT to identify intracranial hemorrhage. Hemorrhagic complications were categorized according to the criteria outlined in the European Cooperative Acute Stroke Study III.[15] Symptomatic intracerebral hemorrhage was characterized by hemorrhage on a follow-up CT imaging scan associated with a 4-point increase in the NIHSS score. Clinical outcomes at the three-month mark were categorized as favorable (mRS score 0-3) or poor (mRS score 4-6).[2]

Data were analyzed using the Statistical Package for Social Sciences (version 24.0; SPSS, Chicago, IL, USA). Chi-squared test or Fisher's exact test was used for categorical variables, and the Mann–Whitney U test was used to compare baseline, procedural, and outcome parameters between the groups. A multivariate logistic regression model was developed to identify factors associated with poor clinical outcomes (mRS4-6) at 90 days. First, univariate models were performed with the mRS score at 90 days as the response variable and the characteristic of interest as the explanatory variable. Second, variables with a P value of <0.05 in the univariate analysis of poor clinical outcomes were included in a multivariate logistic regression performed with the backward elimination method.

RESULTS

From our central database, 68 patients with ischemic stroke and major posterior system vessel occlusion between 2015 and 2022 were screened. After excluding missing data, nine patients who did not undergo the thrombectomy procedure and nine patients with isolated posterior cerebral artery occlusion, a total of 59 patients, were included in this study (Figure 1).

Thirty-nine patients had i-BAO (66%), and 20 patients had t-BAO (33%). Table 1 shows the demographic, imaging, and stroke characteristics of the study groups. The patients with i-BAO and t-BAO had a mean age of 59.08±12.53 years and 56.30±12.94, respectively. Patients with i-BAO had a median admission NIHSS score of 22 (IQR, 16-25), whereas those with t-BAO had a median admission NIHSS score of 22 (IQR,17-27). Most patients with i-BAO were men (75%), whereas more than half of the patients with t-BAO were men (56.4%). Atrial fibrillation was more prevalent in the i-BAO patients. (p=0.006). There was a statistically significant difference in the stroke subtypes between the groups (p=0.001). Fifteen patients with i-BAO (38.5%) had cardioembolism, nine (22%) had intracranial atherosclerosis, and seventeen (43%) had occlusion of the distal segments of the basilar artery. Thirteen patients with t-BAO (65%) had large-vessel atherosclerosis, four (20%) had intracranial atherosclerosis, and ten (50%) had occluded proximal segments of the basilar artery.

Table 2 summarizes the periprocedural details of endovascular treatment. Symptom-onset hospital admission, door puncture, procedure, and symptom canalization times were longer in the tandem occlusion group than in the isolated basilar occlusion group. The time from symptom onset to hospital admission was 270 (IQR,108-318) minutes in the t-BAO group and 60 (IQR,44-218) minutes in the i-BAO group

Table 1: Demographics, imaging, and stroke characteristics at baseline

Characteristics	Overall (N=59)	i-BAO (n=39)	t-BAO (n=20)	p-value
Age, means (SD)	58.14±12.63	59.08±12.53	56.30±12.94	0.429[a]
Male, n (%)	37 (62.7)	22 (56.4)	15 (75.0)	0.162[b]
Medical history, n (%)				
Atrial fibrillation	16 (27,1)	15(38,5)	1(5,0)	**0.006**[b]
Hypercholesterolemia	29 (49.2)	18 (46.2)	11 (55.0)	0.520[b]
Hypertension	34 (57.6)	22 (56.4)	12 (60.0)	0.792[b]
Current Smoking	27 (45.8)	15 (38.5)	12 (60.0)	0.116[b]
Diabetes Mellitus	12 (20.3)	8 (20.5)	4 (20.0)	1.000[b]
Coronary artery disease	11 (18.6)	8 (20.5)	3 (15.0)	0.734[b]
Previous stroke	14 (23.7)	10 (25.6)	4 (20.0)	0.753[b]
Previous antiaggregant use	12 (20.3)	9 (23.1)	3 (15.0)	0,734[b]
Systolic blood pressure median (IQR)	151 (140-180)	160 (140-180)	150 (132-180)	0.355[c]
Glucose median (IQR)	138 (119-183)	153 (119-183)	136 (114-191)	0.665[c]
NIHSS median (IQR)	22 (17-25)	22 (16-25)	22 (17-27)	0.791[c]
Cause of stroke, n (%)				**0.001**[b]
Large artery atherosclerosis	33 (55.9)	20 (51.3)	13 (65)	
Cardio-embolism	16 (27.1)	15 (38.5)	0	
Other	5 (8.5)	0	5 (25.0)	
Undetermined etiology	5 (8.5)	4 (10,3)	2 (10.0)	
Intracranial atherosclerosis	13 (22.0)	9 (23.1)	4 (20.0)	1.000[b]
Occluded segments, n (%)				0,052[b]
V4 segment of vertebral artery	5 (8.5)	2 (5.1)	3 (15.0)	
Proximal	20 (33.9)	10 (25.6)	10 (50.0)	
Mid-segment	14 (23.7)	10 (25.6)	4 (20.0)	
Distal	20 (33.9)	17 (43.6)	3 (15.0)	
pc-ASPECT score, median (IQR)	8 (8-10)	9 (8-10)	8 (7-9)	0.122 [c]
BATMAN score, median (IQR)	4 (3-6)	4 (3-6)	4 (3-6)	0.987 [c]
Vertebral artery hypoplasia, n (%)	24 (41.4)	19 (50.0)	5 (25)	0.066 [b]

a: Mann-Whitney U test; b: Pearson's chi-square or Fisher's exact test. C: Yates' Chi-square test. IQR, interquartile range. ICAS, intracranial atherosclerosis; NIHSS, National Institutes of Health Stroke Scale; pc-ASPECT, posterior circulation Alberta Stroke Program Early CT Score; BATMAN: the Basilar Artery on Computed Tomography Angiography score

Table 2: Angiographic characteristics and endovascular procedure

Characteristics	Overall (N=59)	i-BAO (n=39)	t-BAO (n=20)	p-value
Median duration (IQR), min				
Onset to door	141.5 (46-271)	60 (44-218)	270 (108-318)	**0.015**[a]
Door to puncture	100 (73-125)	91 (72-108)	105 (80-150)	0.079[a]
Procedure time	55 (25-71)	53 (25-71)	60 (25-79)	0,711[a]
Onset to recanalization	303 (186-4119)	240 (177-381)	384 (278-833)	**0,03**[a]
Intravenous rt-PA, n (%)	18 (30.5)	14 (35.9)	4 (20.0)	0.209[b]
Anesthesia, n (%)				0.734[b]
General anesthesia	47 (79.7)	30 (79.6)	17 (85.0)	
Conscious sedation	12 (20.3)	9 (23.1)	3 (15.0)	
Technique, n (%)				0.108[b]
Aspiration	36 (64.2)	29 (74.3)	7 (41.1)	
Stent retriever	14 (23.2)	7 (17.9)	7 (41.1)	
Combined	6 (10.7)	3 (7.6)	3 (17.6)	
No. of passes, median (IQR)	2 (1-3)	1.5 (1-3)	2.5 (2-3)	**0.047**[a]
Angioplasty, n (%)	21 (34)	10 (27)	8 (50)	0.105[b]
Balloon angioplasty	15 (28,3)	8 (53,3)	7 (46,7)	0.182[b]
Balloon angioplasty+ Stenting	10 (18.9)	6 (16.2)	4 (25.0)	0.476[b]
VA access route, n (%)				
Ipsilateral (dirty)			7 (41.2)	
Contralateral (clean)			10 (58.8)	
Distal embolization, n (%)	18 (31.0)	9 (23.1)	9 (47.4)	0.061[b]

a: Mann-Whitney U test; b: Pearson's chi-square or Fisher's exact test; IQR: Interquartile range.

(p=0.015). The t-BAO group showed a trend towards prolonged procedure time, although the difference was not statistically significant (60 min vs. 53 min, p=0.71). The recanalization time was also longer in the tandem group in relation to these two groups (384 min. vs. 240 min. p= 0.03). In both groups, a high proportion of angiographic procedures were performed under general anesthesia (79.6% vs. 85%). Among the techniques used for thrombectomy, aspiration with a distal access catheter (CA) was more common in the isolated basilar occlusion group (73.7% vs. 43.8%). In contrast, stent retrievers (SR) were more common in the tandem group (37.5% vs. 18.4%). The t-BAO group had a higher number of intraprocedural passes (2.5 (IQR 2-3) vs. 1.5 (IQR 1-3)) and a higher rate of distal emboli detected on the last angiographic imaging (47.4% vs. 23.1%). Successful recanalization (≥mTıcı2b) and first pass rate were lower in the t-BAO group but not statistically significant (76.4% vs. 89.7% p=0.249; 23.5% vs. 48.7%, p=0.09, respectively). The third-month mortality rate was significantly higher in the t-BAO group than in the i-BAO group (66.7% vs. 38.5%, p=0.047). A similar number of hemorrhagic and procedural complications were observed in both groups. Of the five (8.9%) patients with arterial dissection, one patient had a fatal subarachnoid hemorrhage, while the other four patients were asymptomatic. Table 3 shows the angiographic and clinical outcomes and adverse events in both groups.

Access was achieved in 17 patients with t-BAO. Of these patients, seven (41.2%) had access through the affected vertebral artery (dirty route). In comparison, ten (58.8%) had access through the contralateral vertebral artery (clean route). Of the 12 tandem patients without vertebral artery hypoplasia (70.5%), only two (16.6%) were on a dirty road. Six out of the seven patients treated via the "dirty route" necessitated balloon angioplasty to navigate past the proximal occlusion.

In contrast, thrombectomy was achieved using the combined technique without the need for angioplasty in one patient. Three patients who underwent angioplasty also received an intravenous tirofiban infusion. Of the ten patients who underwent thrombectomy via the "clean road," two also underwent balloon angioplasty. Recanalization was not achieved in one of these patients who had intracranial atherosclerosis despite angioplasty. Subsequently, this patient

Table 3: Clinical outcomes and adverse events

Characteristics	Overall (N=59)	i-BAO (n=39)	t-BAO (n=20)	p-value
Successful recanalization≥mTıcı2b, n (%)	48 (85.7)	35 (89.7)	13 (76.4)	0.249 b
FPE (mTICI2b-3), n (%)	23 (41)	19 (50.0)	4 (23.5)	0.090 b
mRS 0-2 after 90 days, n (%)	21 (35.6)	16 (41.0)	5 (25.0)	0.224 b
mRS 0-3 after 90 days, n (%)	25 (42.4)	18 (46.2)	7 (35.0)	0.412 b
Mortality at 90 days, n (%)	27 (47.4)	15 (38.5)	12 (66.7)	**0.047** b
sICH (ECASS III), n (%)	7 (12,5)	4 (10.8)	3 (15.8)	0,486 b
Class 1c PH1	3 (5.4)	1 (2.7)	2 (10.5)	
Class 2 PH2	4 (7.1)	3 (8.1)	1 (5.3)	
Re-occlusion first 24 hours, n (%)	3 (5.3)	-	3 (5.3)	
Posterior decompression, n (%)	3 (5.3)	1 (2.6)	2 (11.7)	
Arterial dissection, n (%)	5 (8.9)	2 (5.1)	3 (17,6)	
Arterial perforation, n (%)	1 (1.7)	-	1 (5)	

a: Mann-Whitney U test; b: Pearson's chi-square or Fisher's exact test. mTICI, modified Thrombolysis in Cerebral Infarction; FPE, first-pass effect; mRS, modified Rankin Scale; sICH, symptomatic intracerebral hemorrhage; ECASS III, Heidelberg Bleeding Classification and European Cooperative Acute Stroke Study

underwent basilar artery intracranial stenting following tirofiban infusion. In the i-BAO group, eight patients with intracranial atherosclerosis underwent balloon angioplasty, and one patient required additional intracranial stenting of the basilar artery. Stent occlusion occurred in two patients in whom the "dirty road" approach was chosen, and proximal vertebral artery stenting was performed. In one patient with the "clean road," basilar artery re-occlusion developed within 24 hours.

The third-month poor outcome rate (mRS 4-6) was 57.6%. Table 4 shows an analysis of the factors associated with poor outcomes. Univariate tests identified an increased risk for each of the following: age, pc-ASPECT score<8, onset to recanalization, procedure time, and number of passes ≥3. The multivariate logistic regression analysis revealed that the number of passes of ≥3 was an independent risk factor for poor clinical outcome at three months (OR= 14; 95% CI, 2.596-77.208).

DISCUSSION

Our study on BAO found that i-BAO patients had higher rates of successful recanalization and first-pass success compared to t-BAO patients. Time-related factors were crucial, with a significant reduction in symptom onset to hospital admission time in i-BAO group compared to t-BAO group. t-BAO patients experienced longer procedure and recanalization times, which may have influenced overall treatment outcomes. Patients with t-BAOs had higher mortality rates. Factors associated with unfavorable outcomes include age, pc-ASPECT score of less than 8, duration between onset and recanalization, procedure time, and number of passes equal to or greater than 3.

This study retrospectively collected data from all patients with acute basilar occlusion who were treated with mechanical thrombectomy between 2015 and 2022. In recent years, researchers have shown that vertebral artery stenosis may cause basilar occlusion due to artery-to-artery embolism. Therefore, they thought it might be appropriate to evaluate the tandem occlusion group from a different perspective due to the anatomical variations in the posterior system.[12,16,17] Patients with BAO were divided into two subgroups to evaluate the clinical and angiographic results of tandem lesions and their technical aspects. Our cohort comprised 39 (66.6%) patients with i-BAO and 20 (33.3%) patients with t-BAO. Our findings were consistent with the 16-34% tandem incidence reported in previous studies.[18,19]

The prognosis of posterior circulation tandem occlusion may be largely related to early recanalization of the basilar artery.[12] Proximal VA occlusion during mechanical thrombectomy may lead to technical difficulties in basilar artery recanalization. Therefore, tandem occlusions may result in longer procedural time and worse clinical outcomes than i-BAO. Despite the reported successful recanalization rates ranging from 73.3% to 100% in the tandem occlusion group, there have been instances of high mortality (20% to 47.8%) and low clinical outcome rates with an mRS score of 0-2 at three months (15.8% to

Table 4: Regresion analyses for poor outcome at 3 months (mRS 4–6)

	Univariate		
Variables set	**OR**	**95 % CI**	**p-value**
Age	1.026	1.000-1.087	0.248
Gender			
Man	1.746	0.573-5.323	0.327
Occluded intracranial artery segments			
Mid-segment	2.000	0.476-8.395	0.344
Proximal	2.600	0.598-11.310	0.203
V4 segment of vertebral artery	3.000	0.248-36.325	0.388
Baseline NIHSS	1.070	1000-1.175	0.144
p-ASPECT			
<8	10.800	1.259-92.672	**0.030**
BATMAN score			
Bad <6	2.095	0.652-6.736	0.214
Anesthesia type			
General	2.737	0.606-12.350	0.190
Tandem Occlusion			
Yes	1.667	0.504-5.508	0.402
No of passes			
≥3	16.292	3.215-82.563	**0.001**
Procedure time	1.028	1.003-1.054	**0.027**
Onset to revascularization	1.004	1.000-1.009	**0.035**
	Multivariate*		
No of passes			
1-2	1		
≥3	**14.000**	**2.596-77.208**	**0.002**

* Backward: Wald method

53.3%) (Table 5).[7,13,20] Successful recanalization (76.4%) and good clinical outcomes (25%) were consistent with those reported in the literature. However, we observed the highest mortality rate to date (66.7%), confirming that patients with tandem occlusion have poor prognosis despite recanalization. This high mortality rate can be explained by the observed delayed reperfusion times and severity of BAO, which are poor prognostic factors.

The research establishes a clear connection between a higher number of passes with thrombectomy devices and a decrease in positive clinical outcomes.[21] Conversely, successful recanalization is associated with higher rates of favorable outcomes. As expected, our analysis indicates increased odds of positive clinical outcomes The results reveal a third-month poor outcome rate (mRS 4-6) of 57.6%, with multivariate logistic regression identifying the number of passes ≥3 as an independent risk factor for unfavorable clinical outcomes at three months (OR=14; 95% CI, 2.596-77.208). These findings offer valuable insights into the nuanced characteristics of isolated (i-BAO) and tandem (t-BAO) basilar artery occlusions, holding significant implications for prognostic indicators and treatment approaches.

In cases where neither vertebral artery exhibits hypoplasia, choosing a vertebral artery without stenosis or occlusion can lead to faster access and recanalization. However, this choice can also affect normal blood flow in the periprocedural basilar artery. Opting for the occluded or severe stenosis (≥70%) vertebral artery raises concerns, including potential delays associated with angioplasty and the risk of post-angioplasty hemorrhage when antiplatelet agents are used. Nevertheless, this choice may help prevent recurrent strokes caused by tandem vertebral artery lesions.[19] Our technical details showed that the “clean road” was preferred over the “dirty road” in tandem occlusions (58.8%

Table 5: Review of the studies on tandem occlusion management and outcomes

First Author year	No of patients	*Age, Male %	Access¶ route %	*No of passes	¥Type of Device %	mTICI ≥2b%	*Procedure time (min)	Clinical outcome at 90 days %
Cohen, *et al.*[12]	7	57(51-63) 85.7%	DR:71.4 CR:28.6	4.1(2-8)	SR: 100 Balloon:33.3 Balloon+Stent:71	100	68	mRS 0-2:28.6 mRS 0-3:57.1 Mortality:28.5
Baik, *et al.*[19]	28	72.5(20-90) 56%	DR:57 CR:43	NA	SR: 54 CA: 36 Balloon:33.3 Balloon+Stent: 17	86	66	mRS 0-2:28.5 Mortality:25
Siebert, *et al.*[13]	38	66(56-74) 81.6%	DR:77.4 CR:22.5	2 ± 2.35	SR: 84.2 CA: 15.8 Baloon:33.3 Balloon+Stent:52.6	86.3	91	mRS 0-2:15.8 Mortality36.8
Piechowiak, *et al.*[7]	15	62.6(37-90) 80%	DR:73.3 CR:26.7	NA	SR: 93.3 CA: 6 Balloon+Stent:53.3	100	57	mRS 0-2:53.3 Mortality:20
Sun *et al*. 2020 [20]	23	62.2±9.1 82.6%	DR:82.6 CR:17.4	2.5(1-3)	SR: 60.9 CA: NA Only Balloon:8.7 Balloon+Stent:78.3	60.9	108	mRS 0-2:26.1 mRS 0-3:30.4 Mortality:47.8
Weinberg, *et al.*[24]	17	55.7±11.8 64.7%	DR:100 CR:0	2.24 ± 2.02	SR/CA: 11.8 SR+CA:70.6 Balloon+Stent:29.4	76.5	59.3	mRS 0-2:41.2 Mortality:41.2
Elhorany, *et al.*[25]	15	62.4±12.2 73.3%	DR:73.3 CR:26.7	NA	SR/CA: NA Balloon:26.7 Balloon+Stent: 0	73.3	102	mRS 0-2:26.7 Mortality:46.7
Present Study	20	56.3±12.94 75%	DR:41.2 CR:58.8	2.5 (2-3)	SR/CA: 37.5/43.8 SR+CA:18.8 Balloon:33.3 Balloon+Stent:25	76.4	60	mRS 0-2:25 mRS 0-3:35 Mortality:66.7

mTICI: modified Thrombolysis in Cerebral Infarction; NA: not available ; mRS, modified Rankin scale
*Median or mean age, number of passes and procedure time
¶ DR: Dirty Road, ipsilateral stenotic or occluded vertebral artery, CR: Clean Road, patent vertebral artery approach
¥ SR: stent retriever CA: contact aspiration

vs. 41.2%). The rate of choosing the clean road approach was slightly higher in this study compared to the 17.4%-43% preference for this approach in similar studies.[9,19,20]

Recanalization of BAO is an important predictor of good clinical outcomes in tandem occlusions.[22] A meta-analysis that examined successful recanalization data for the two approaches in tandem patients revealed that the clean-road technique showed slightly better recanalization rates. However, the difference was not statistically significant.[23] In addition, thrombectomy was performed using an aspiration catheter (CA) , stent retriever (SR) , or a combination of both techniques (CA, 43.8%; SR, 37.5%; SR+CA, 18.8%). We found that operators preferred the easy-to-apply "clean road" approach and aspiration technique to achieve rapid basilar artery recanalization. The limited evidence and experience supporting mechanical thrombectomy for early treatment of posterior tandem occlusions may have influenced these decisions when these cases were treated.

One of the four patients (5.3%) treated with stent-assisted angioplasty of a tandem VA lesion developed a type-2 hematoma. Three patients (17.6%) developed vertebral artery dissection that did not require treatment, possibly due to aggressive navigation. Three patients (17.6%) developed basilar artery re-occlusion within the first 24 h after thrombectomy. These peri- and post-procedural complication rates were comparable to recently published data.[7,24] Our results showed that clean and dirty roads can be used depending on the anatomy and pathology of the patient. The role of interventional treatment strategies in symptomatic vertebrobasilar stenotic diseases has not yet been established.

Our study had some limitations. These include the retrospective design of the data collection, a relatively small sample size, and self-assessed angiographic evaluation without core laboratory review. The study's single-center design also restricts our ability to control for external factors that may have influenced the study outcomes. Variations in practice patterns, patient demographics, and local policies could all potentially impact the internal validity of our findings. Additionally, the use of techniques and devices was left to the discretion of the operator, which may have introduced bias into the results. Finally, it's worth noting that newer techniques and devices for mechanical thrombectomy were developed during the study period, and we were unable to analyze and compare the optimal treatment for BAO.

In conclusion, strategically choosing the vertebral artery access route in tandem with vertebrobasilar occlusion can result in favorable reperfusion outcomes. Mechanical thrombectomy is associated with higher mortality rates in patients with t-BAO. Nonetheless, additional research involving a larger multicenter series is necessary to validate our findings and establish appropriate selection criteria for managing these patients. Given the rarity of t-BAO, heterogeneity of clinical presentation, and poor natural history, conducting clinical trials remains challenging. Therefore, observational data are crucial for designing future clinical trials.

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