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Posterior circulation tandem occlusions: Classification and techniques

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ABSTRACT

Background: Posterior circulation tandem occlusions are poorly characterized in current literature. Data regarding endovascular approaches and outcomes in this patient subgroup is extremely limited.

Methods: We conducted a retrospective analysis of a prospectively maintained database and identified 17 patients with posterior circulation tandem occlusions who underwent mechanical thrombectomy between 2014 and 2019.

Results: Of 17 patients with posterior circulation tandem occlusion, the mean age was 55.76 ± 11.8 with 35.3% female. The mean NIHSS score on presentation was 17.2 ± 9.2. Tissue plasminogen activator was administered in 7 (41.2%) patients, stent-retrievers alone were used in 2 (11.8%), aspiration catheters alone were used in 2 (11.8%), a combination was used 12 (70.6%), and a self-expandable stent in 5 (29.4%). The mean number of device passes was 2.24 ± 2.02, recanalization failure occurred in 4 (23.5%) patients, the mean time from stroke onset to puncture was 6.9 ± 2.4 h, and the mean time from puncture to recanalization was 59.3 ± 26.6 min. Postprocedural symptomatic ICH occurred in 1 (5.9 %) patient, periprocedural ICH/SAH occurred in 2 (11.8%), periprocedural distal emboli occurred in 0 (0%), periprocedural vessel dissection occurred in 1 (5.9%), and periprocedural vessel perforation occurred in 1 (5.9%) patient. TICI score≥2b was achieved in 13 (76.5%) patients. An improvement in NIHSS≥3 at discharge occurred in 10 (58.8%) patients, and good outcomes (mRS score ≤ 2) occurred in 7 (41.2%). The mean length of stay was 11.6 ± 12.2 days, and the mortality rate was 41.2%.

Conclusion: Endovascular intervention with mechanical thrombectomy is safe and feasible in patients with posterior circulation tandem occlusions.

1. Introduction

Acute basilar artery occlusion (BAO) generally results in major morbidity and mortality [1]. Recent meta-analyses regarding the treatment of acute BAO found that mechanical thrombectomy (MT) resulted in lower mortality rates and higher rates of favorable outcomes compared to intravenous or intra-arterial thrombolysis alone [2,3]. Compter et al. [4] found that 44% of patients presenting with acute BAO had a concomitant intracranial or extracranial vertebral artery (VA) occlusion, yet this patient subgroup is underrepresented in these studies and current literature. Tandem occlusions of the anterior circulation with a carotid occlusion at the neck and intracranial large vessel occlusion is an established entity, while posterior circulation tandem occlusions are not well established in the literature. The prognosis of posterior circulation tandem occlusions is largely characterized by the BAO [5], but recanalization of the BA may be technically challenging in the setting of a proximal VA occlusion [6]. The HERMEs Collaboration, a meta-analysis of several independent randomized control trials, demonstrated the benefit of MT in patients with anterior circulation tandem occlusions [7]. However, the safety and efficacy of MT in

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posterior circulation tandem occlusions remains uncertain.

Tandem occlusions of the posterior circulation are poorly defined and characterized in current literature. Not until recently was there evidence supporting VA ostium stenosis as a source of vertebrobasilar embolic stroke. [5] Additionally, data regarding endovascular approaches and outcomes in this subgroup of patients is extremely limited. A few recent studies, albeit small case series, have shown that revascularization of posterior circulation tandem occlusions via MT is feasible [5,6,8,9]. In the present study, we analyzed the feasibility and outcomes of MT in patients presenting with posterior circulation tandem occlusion. We also defined the spectrum of tandem occlusions within the posterior circulation via 3 case illustrations: tandem occlusion of extracranial VA and basilar artery (BA) ("true" posterior circulation tandem occlusion), tandem occlusion of intracranial VA and BA (vertebrobasilar "J" occlusion), and posterior circulation pseudo-occlusion.

2. Methods

2.1. Study design

The study protocol was approved by our Institutional Review Board, and the need for informed consent was waived. The authors declare that all supporting data is present within the article. We conducted a retrospective analysis of a prospectively maintained database and identified 17 consecutive patients with posterior circulation tandem occlusions who underwent mechanical thrombectomy at our tertiary referral center for acute ischemic stroke from June 2014 through November 2019. Data collection was performed on patient age and sex, cerebrovascular risk factors, National Institutes of Health Stroke Scale (NIHSS) score at admission, stroke location, use of intravenous and/or arterial tissue plasminogen activator, time from stroke onset to groin puncture (TTP), time from groin puncture to intracranial recanalization (TTR)/procedure time, number of device passes needed for successful flow restoration, Thrombolysis in Cerebral Infarction (TICI) scores, perioperative complications (subarachnoid hemorrhage [SAH]/intracranial hemorrhage [ICH], vessel dissection and perforation, distal embolus), postoperative symptomatic ICH (sICH), NIHSS score at discharge, modified Rankin Scale (mRS) score at 3 month follow-up, and mortality. Symptomatic ICH was defined as parenchymal hemorrhage leading to neurologic deterioration as reflected by NIHSS score worsening of at least 4 points. We accessed patients' electronic medical record and collected relevant data related to their procedure for data analysis.

2.2. Technical procedure

MT was performed under conscious sedation or general anesthesia. Vessel recanalization was achieved with stent retriever approaches using a Solitaire FR device (Medtronic, Minneapolis, Minnesota, USA) or Trevo device (Stryker, Kalamazoo, Michigan, USA) and/or aspiration thrombectomy using a Penumbra aspiration catheter (Penumbra Inc., Alameda, California, USA) or React aspiration catheter (Medtronic, Minneapolis, Minnesota, USA).

2.3. Data analysis

Data are presented as mean and range for continuous variables, and as a frequency for categorical variables.

3. Results

3.1. Demographics (Table 1)

Of 17 patients with posterior circulation tandem occlusion, the mean age was 55.76 (range 32–82) and 35.3% were female.

Table 1
Baseline demographics. Abbreviations: BMI, Body Mass Index; SD, Standard Deviation.

Baseline Demographics	Total # of Procedures 17 (%)
Age ($n = 17$)	
Mean (SD, Range)	55.76 (11.8, 32–82)
Gender ($n = 17$)	
Male	11 (64.7)
Female	6 (35.3)
BMI (kg/m^2)	
Mean (SD, Range)	28.4 (5.9, 22–44.3)
Smoking	9 (52.9)
Previous Stroke	3 (17.6)
Cardiovascular disease	4 (23.5)
Hypertension	11 (64.7)
Diabetes Mellitus	3 (17.6)
Hyperlipidemia	7 (41.2)
Atrial Fibrillation	1 (5.9)

3.2. Stroke characteristics and treatment details (table 2)

The mean NIHSS score on presentation was 17.2 (range 3–36). Vessels involved were the basilar artery in 17 (100%) patients, right vertebral artery in 8 (47.1%) patients, and left vertebral artery in 9 (52.9%). Tissue plasminogen activator was administered in 7 (41.2%) patients, stent retrievers alone were used in 2 (11.8%) patients, aspiration catheters alone were used in 2 (11.8%) patients, a combination of stent retrievers and aspiration catheters was used 12 (70.6%) patients, and a self-expandable stent was placed in 5 (29.4%) patients. The mean number of device passes was 2.24 (range 0–9), and recanalization failure occurred in 4 (23.5%) patients. The mean time from stroke onset to groin puncture was 6.9 h (range 4–12), and the mean time from groin puncture to recanalization was 59.3 min (range 16–98).

3.3. Procedural and postprocedural complications (table 3)

Postprocedural symptomatic ICH occurred in 1 (5.9%) patient, periprocedural ICH/subarachnoid hemorrhage occurred in 2 (11.8%) patients, periprocedural distal emboli occurred in 0 (0%) patients, periprocedural vessel dissection occurred in 1 (5.9%) patient, and periprocedural vessel perforation occurred in 1 (5.9%) patient.

Table 2
Stroke characteristics and treatment details. Abbreviations: NIHSS, National Institutes of Health Stroke Scale; SD, Standard Deviation; tPA, Tissue Plasminogen Activator.

Stroke Characteristics and Treatment Details		Total # of Procedures 17 (%)
NIHSS (0–42)		
Mean (SD, Range)		17.2 (9.2, 3–36)
tPA		7 (41.2)
Vessels Involved	Left Vertebral	9 (52.9)
	Right Vertebral	8 (47.1)
	Basilar	17 (100)
Type of Device	Stent Retriever	2 (11.8)
	Aspiration	2 (11.8)
	Both	12 (70.6)
Self-Expandable Stent		5 (29.4)
Recanalization Failure		4 (23.5)
Number of Device Passes		
Mean (SD, Range)		2.24 (2.02, 0–9)
Number of Passes	1	5 (29.4)
	2	8 (47.1)
	3+	3 (17.6)
Time from Stroke Onset to Puncture (hours)		
Mean (SD, Range)		6.9 (2.4, 4–12)
Time from Puncture to Recanalization (minutes)		59.3 (26.6, 16–98)
Mean (SD, Range)		

Table 3
Procedural and postprocedural complications. Abbreviations: ICH, Intracranial Hemorrhage; SAH, Subarachnoid Hemorrhage; sICH, Symptomatic Intracranial Hemorrhage.

Procedural and Postprocedural Complications	Total # of Procedures 17 (%)
Periprocedural ICH/SAH	2 (11.8)
Periprocedural distal emboli	0 (0)
Periprocedural vessel dissection	1 (5.9)
Periprocedural vessel perforation	1 (5.9)
Postprocedural sICH	1 (5.9)

3.4. Recanalization and functional status (Table 4)

Successful recanalization (TICI score $\geq$ 2b) was achieved in 13 (76.5%) patients. An improvement of NIHSS score of at least 3 points at discharge was seen in 10 (58.8%) patients, and a good outcome (mRS score $\leq$ 2) occurred in 7 (41.2%). The mean length of stay was 11.6 days (range 1-36), and the mortality rate was 41.2%.

Case 1. ("True") Tandem occlusion of extracranial vertebral artery and basilar artery

The patient presented to the emergency department (ED) after an episode of right arm and leg weakness and confusion. Computed tomography (CT) head showed no abnormalities, but magnetic resonance imaging (MRI)/magnetic resonance angiography (MRA) brain showed a left medial temporal lobe diffusion weighted imaging restriction and right VA irregularity. The next morning the patient became comatose, hypotensive, tachycardic and hypoxic. Motor exam showed extensor posturing in all extremities. NIHSS was 36. CT angiography (CTA) showed BA thrombosis. The patient was taken for emergent revascularization.

The right femoral artery was accessed. A Neuronmax 088 80 cm (Penumbra Inc., Alameda, California, USA) and a select catheter was advanced into the arch and the right subclavian artery was accessed. The right VA was found to be occluded (Fig. 1A), which was revascularized with NC Trek balloon (Abbott, Chicago, Illinois, USA) angioplasty (Fig. 1B). Proceeding angiographic runs revealed BAO, which was treated with aspiration thrombectomy using a Penumbra Jet7 Flex catheter (Fig. 1C). Further angiographic runs showed bilateral posterior cerebral artery (PCA) occlusions (Fig. 1D). The right PCA occlusion was treated with aspiration alone, while the left PCA occlusion was treated with 2 passes of a Trevo 4 × 30 mm stent retriever and suction from a Jet7 Flex catheter (Fig. 1E). Final angiographic run showed complete revascularization (Fig. 1F). Finally, a Resolute Onyx 4.5 × 18 mm balloon-mounted drug-eluting stent (Medtronic, Minneapolis, Minnesota, USA) was placed at the right VA origin (Fig. 1G). The patient was bolused with Aggrastat and Plavix300 mg prior to stent deployment. An Aggrastat drip was also started but was discontinued 6 h after the patient received the Plavix loading dose.

MRI the next day showed multiple infarcts in the pons and cerebellum (Fig. 2). The patient received a percutaneous endoscopic gastrostomy tube and was discharged to rehabilitation with dysphagia, dysarthria, and left-sided hemiparesis. NIHSS was 7.

Table 4
Functional outcome and mortality. Abbreviations: mRS, Modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; SD, Standard Deviation; TICI, Thrombolysis in Cerebral Infarction.

Functional Outcome and Mortality	Total # of Procedures 17 (%)
TICI $\geq$ 2b	13 (76.5)
Improvement $\geq$3 NIHSS score on discharge	10 (58.8)
mRS $\leq$ 2	7 (41.2)
Length of Stay (days)	
Mean (SD, Range)	11.6 (12.2, 1−36)
Mortality	7 (41.2)

Case 2. Tandem occlusion of intracranial vertebral artery and basilar artery ("J" Occlusion)

The patient presented to the ED after sudden onset visual disturbance and left-sided weakness. CT/CTA revealed right cerebellum infarct. The right VA was diffusely irregular and highly stenotic with dissection of the distal V2 segment. There was loss of contrast opacification of the intracranial VA to the proximal BA. However, the proximal BA thrombus was nonocclusive, and the BA was filling. The patient was then transferred to our institution. The decision was made against intervention given the brainstem infarct had already occurred and the BA was filling. NIHSS was 4 at discharge.

Three days after discharge the patient woke with worsening left hemiplegia, right facial palsy, left gaze preference, and global aphasia (NIHSS 17). Imaging showed infarct evolution and progressive occlusion of the right intracranial VA and BA. The patient was taken for emergent endovascular revascularization.

The right radial artery was accessed. A 6-Fr Cook shuttle (Cook Medical LLC, Bloomington, Indianapolis, USA) was advanced into the right subclavian artery. Angiographic runs revealed stenosis at the right VA origin as the likely cause of the stroke (Fig. 3A). A microcatheter was advanced distal to the stenosis, and subsequent runs confirmed location within the true lumen and filling of the right V2 and V3 segments (Fig. 3B and C). Angioplasty of the right VA origin was performed with an Emerge balloon (Boston Scientific, Marlborough, Massachusetts, USA) (Fig. 3D), which enabled advancement of the React aspiration catheter into the right V2 segment for aspiration thrombectomy (Fig. 3E). The React aspiration catheter was advanced into the V4, and subsequent angiographic runs demonstrated complete recanalization (TICI 3) of the posterior circulation with retrograde flow in the left VA (Fig. 3F). This was followed by the placement of 2 atlas stents (Stryker, Kalamazoo, Michigan, USA) (4.5 × 30 mm, 4 × 24 mm) at the right VA origin to address the proximal stenosis and dissection (Fig. 3G).

MRI the next day showed evolving cerebellar and brainstem infarcts (Fig. 4). The patient was discharged to rehabilitation with 5/5 strength throughout but had dysarthria, right facial palsy, and right cranial nerve VI palsy. At 3 month follow-up, mRS was 2.

Case 3. Posterior Circulation Pseudo-occlusion

The patient presented with acute onset dizziness, diplopia, and dysarthria. MRI/MRA showed acute pontine infarct. The patient was then transferred to our institution with NIHSS 0. CTA head/neck showed extensive calcification of the left V4 segment with multifocal stenosis and occlusion of the right VA distal to the right PICA origin. The patient was discharged home neurologically intact with Plavix75 mg, Aspirin 81 mg, Metoprolol, and Atorvastatin 80 mg.

The patient returned 1 month later with right gaze palsy, generalized weakness, gait disturbance, nausea/vomiting, and dysarthria. Last known normal was over 4 h ago. NIHSS was 3. CTA head/neck showed left V4 high-grade stenosis versus occlusion and new non-visualization of the proximal BA (thrombus versus slow flow). The patient was taken for emergent revascularization.

The femoral artery was accessed. A Cook shuttle was advanced over a select catheter and used to select the left VA. Angiographic runs showed slow flow in V3 and occlusion of V4 (Fig. 5A). A React aspiration catheter was advanced into the intracranial VA removing clot proximal to the vertebrobasilar junction stenosis (Fig. 5B). The microcatheter was advanced distal to the stenosis, and microcatheter runs demonstrated filling within the upper BA (Fig. 5C). A Solitaire stent retriever (6 × 40 mm) was deployed and pulled back under aspiration (Fig. 5D). Subsequent angiographic runs demonstrated complete recanalization of the VA and BA with persistent high-grade stenosis (Fig. 5E). Finally, a 4 × 30 mm Enterprise stent (Codman Inc., Raynham, MA, USA) was deployed followed by angioplasty with a Scepter C balloon (MicroVention, Aliso Viejo, California, USA) then an Emerge balloon

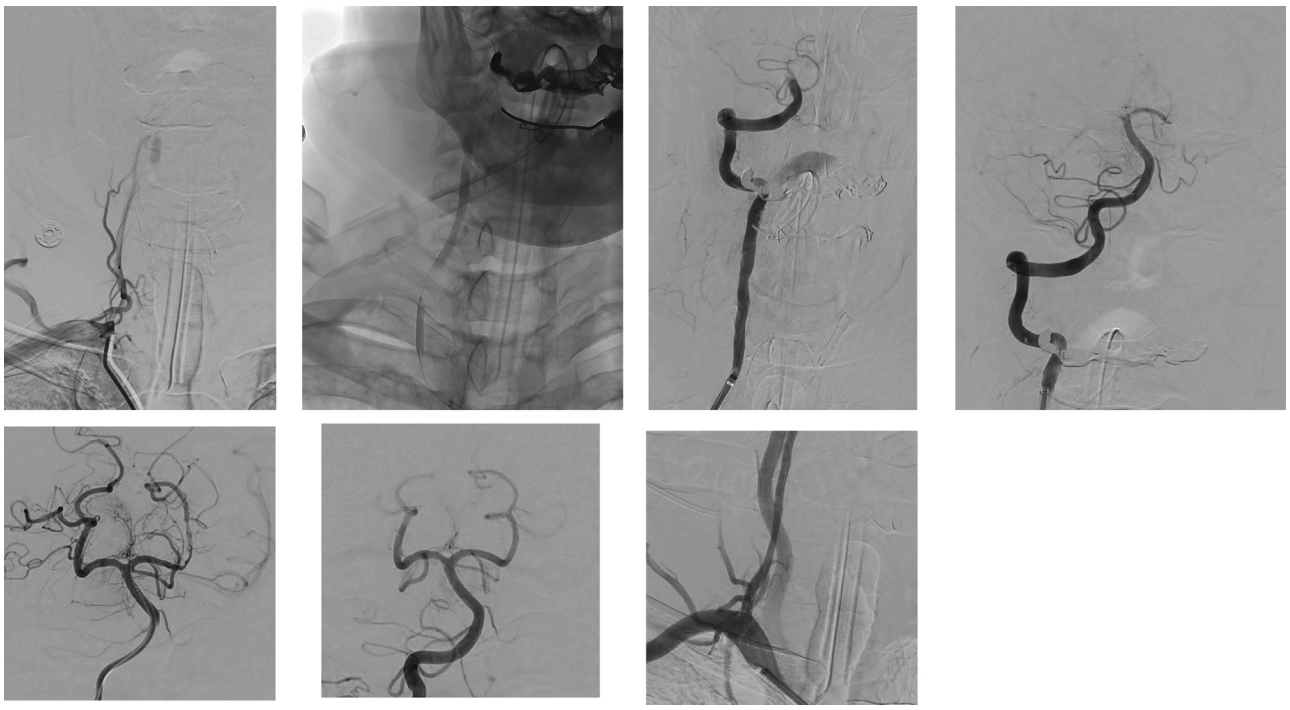

Fig. 1. Digital subtraction angiography (DSA) AP view of emergent revascularization. *A)* Occlusion of the right VA; *B)* Balloon angioplasty of the right VA; *C)* BA occlusion treated with aspiration thrombectomy; *D)* Bilateral PCA occlusions; *E)* Left PCA revascularization with a combination of stent retrieval and aspiration thrombectomy; *F)* Final angiographic run showed complete revascularization; *G)* Right VA origin stent placement. Abbreviations: BA, Basilar Artery; DSA, Digital Subtraction Angiography; PCA, Posterior Cerebral Artery; VA, Vertebral Artery.

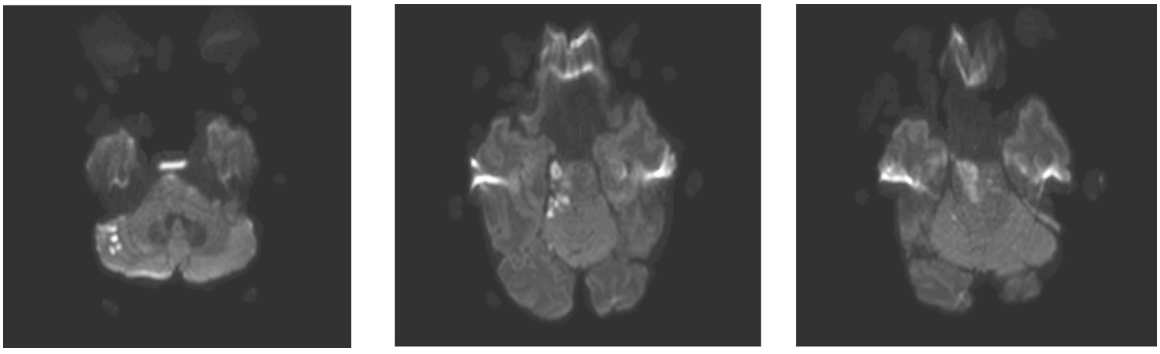

Fig. 2. *(A-C)* Axial view of follow-up diffusion weighted MRI at 24 h showed multiple infarcts in the pons and cerebellum. Abbreviations: MRI, Magnetic Resonance Imaging.

(2 × 8 mm), which resulted in improvement of the stenotic lesion (Fig. 5F). The patient was also given bolus of Aggrastat due to concern for Plavix resistance. Result of intervention: TICI 3 with persisting 50% stenosis of vertebrobasilar junction (Fig. 5G).

MRI the next day showed foci of acute infarcts in bilateral cerebellar hemispheres (Fig. 6). At 3 month follow-up, the patient was neurologically intact with no dysarthria (mRS 0).

4. Discussion

In the present study, we aimed to demonstrate the safety and feasibility of MT in posterior circulation tandem occlusions as well as define the spectrum of posterior circulation tandem occlusions. Amongst 17 patients, the mean NIHSS at presentation was 17.2, TICI $\geq$ 2b was achieved in 76.5%, mean TTP was 6.9 h, mean TTR was 59.3 min, good outcomes (mRS 0−2) were achieved in 41.2%, and the mortality rate was 41.2%. Our results are consistent with recently published data on rates of good outcomes and mortality, which further supports endovascular intervention with MT in this patient subgroup.

Posterior circulation tandem occlusions are rarely reported. The prognosis of posterior circulation tandem occlusions is largely characterized by the BAO, [5] but recanalization of the BA may be technically challenging in the setting of a proximal VA occlusion [6]. Only a few small case series exist in current literature that address the technical aspects of MT and outcome in this patient subgroup [5,6,8,10,11]. In this study, we presented 3 cases to illustrate the spectrum of posterior circulation tandem occlusion subtypes. Case 1 is a ("true") posterior circulation tandem occlusion: an extracranial VA occlusion with concomitant acute embolic BAO, which is analogous to anterior circulation tandem occlusion. Case 2 illustrates a tandem occlusion of intracranial VA and BA, which is analogous to carotid T, I, and L occlusions. We refer to it as a vertebrobasilar "J" occlusion. Case 3 illustrates a posterior circulation pseudo-occlusion, which is analogous to carotid pseudo-occlusions. MT is a feasible intervention for the spectrum of posterior circulation tandem occlusions with the optimal approach depending on vascular anatomy and occlusive lesions.

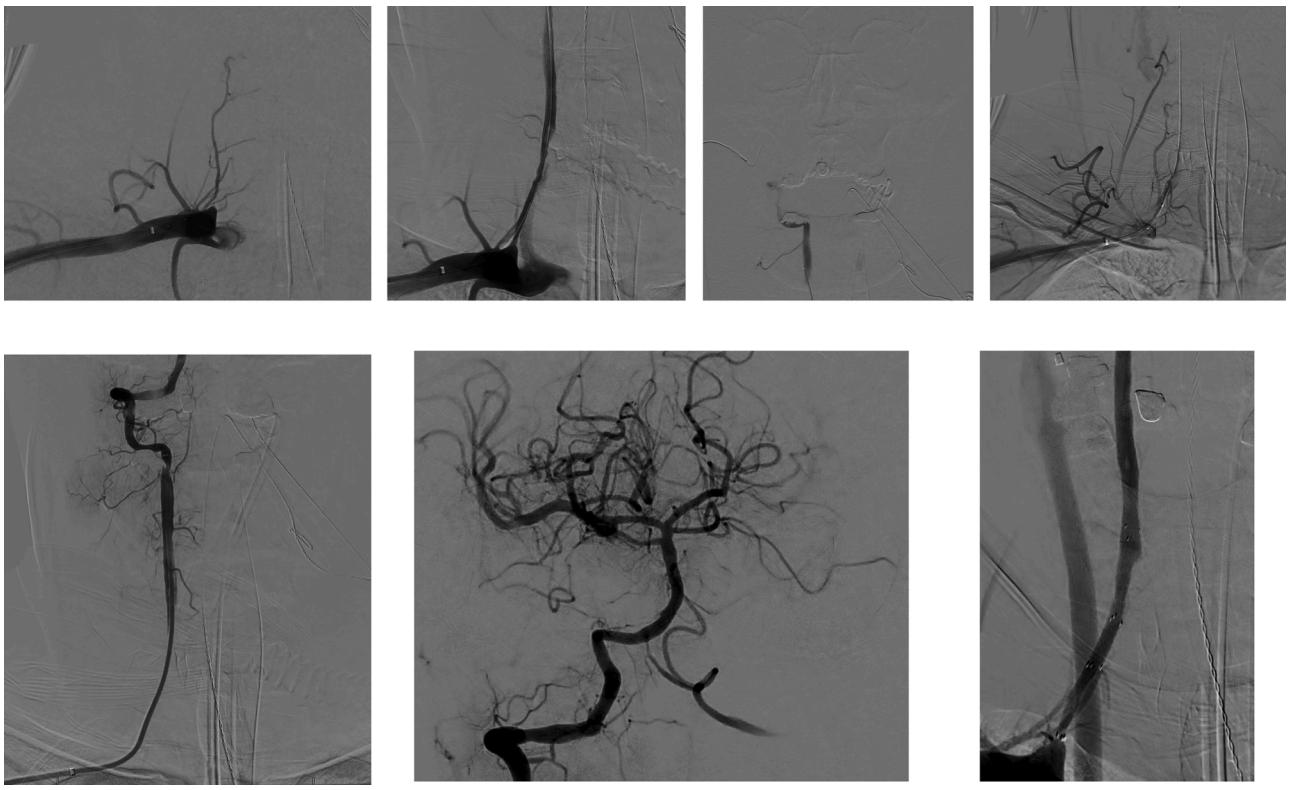

Fig. 3. Digital subtraction angiography (DSA) AP view of emergent revascularization. *A)* Stenosis of the right VA origin; *B,C)* Microcatheter runs distal to the stenosis confirmed location within the true lumen and demonstrated filling of the V2 and V3 segments; *D)* Angioplasty of the right VA origin; *E)* Aspiration catheter advanced distal to the right VA origin stenosis and into V4; *F)* Complete recanalization of the posterior circulation post-aspiration thrombectomy; *G)* Placement of 2 stents at the right VA origin. Abbreviations: DSA, Digital Subtraction Angiography; VA, Vertebral Artery.

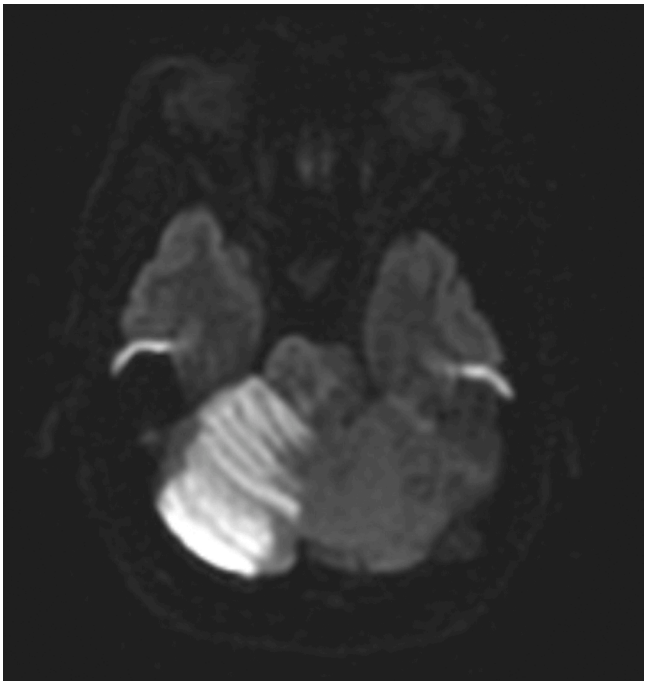

Fig. 4. Axial view of follow-up diffusion weighted MRI at 24 h showed evolving cerebellar and brainstem infarcts. Abbreviations: MRI, Magnetic Resonance Imaging.

Cohen et al. [5] described 2 potential endovascular approaches based on vascular access in this patient subgroup. The clean-road pathway utilizes the patent VA to access the BA, which is the fastest and safest approach to perform MT in the BA. Additionally, the contralaterally occluded VA may also enhance the aspiration effect [5], but may impair normal blood flow to the BA during intervention [12]. A stenotic or non-dominant contralateral VA may limit the use of this pathway [8]. The dirty-road pathway requires navigating the stenotic or occluded VA, which is technically challenging and associated with additional risks compared to the clean-road pathway [5]]. Cohen et al. [5] describes 2 techniques, each with advantages and disadvantages, using the dirty road pathway which differ in the sequence of occlusion revascularization. The antegrade approach addresses the proximal VA atherosclerotic occlusion first via stent placement at the VA ostium followed by BA thrombectomy. Primary stent placement may stabilize the proximal plaque or clot, while the distal occlusion provides protection against embolic showering [13]. Additionally, restoration of flow may aid in thrombolysis of the distal occlusion [14]. However, this approach increases TTR of the posterior fossa structures, increases hemorrhage risk associated with reperfusion time delay, and requires performing thrombectomy through the proximal stent [5,12]. Cohen et al. [5] also described a retrograde approach that begins with VA balloon angioplasty followed by intracranial BA thrombectomy and then proximal VA stent-assisted angioplasty. The retrograde technique has been reported to decrease TTR and improve patient outcomes in tandem occlusions of the anterior circulation [15]. However, it is associated with an increased risk of VA to BA re-embolization during VA ostial stent placement [5,12]. In this study, the BA was accessed via the dirty-road pathway and revascularization attempted using a retrograde approach in all cases; there were no occurrences of periprocedural distal emboli.

Despite successful revascularization rates of 85.7–100% with MT reported in previous studies, posterior circulation tandem occlusions are

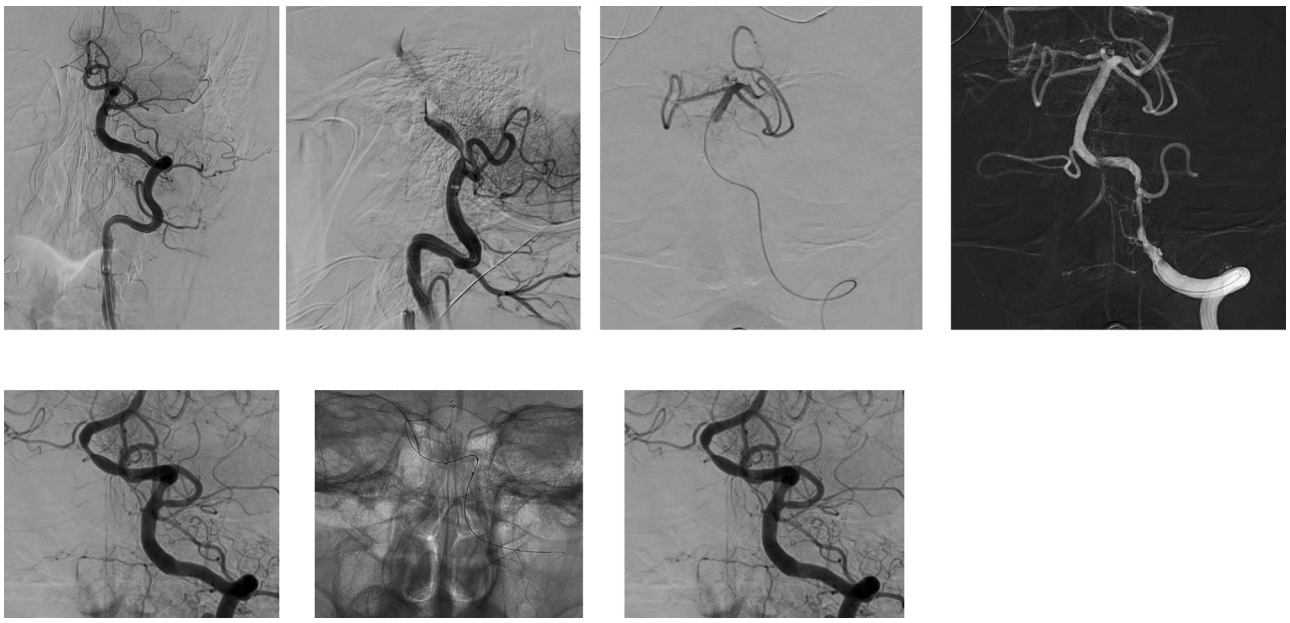

Fig. 5. Digital subtraction angiography (DSA) AP view of emergent revascularization. *A)* Slow flow in the V3 segment and occlusion of the V4 segment of the right VA; *B)* Aspiration catheter advanced into the intracranial VA; *C)* Microcatheter run distal to the stenosis demonstrated filling of the upper basilar artery; *D)* Mechanical thrombectomy performed via Solumbra technique; *E)* Complete recanalization of the posterior circulation with persistent high-grade stenosis; *F)* Stent deployment followed by angioplasty of the stenotic lesion; *G)* Successful revascularization with improvement of the stenotic lesion. Abbreviations: DSA, Digital Subtraction Angiography; VA, Vertebral Artery.

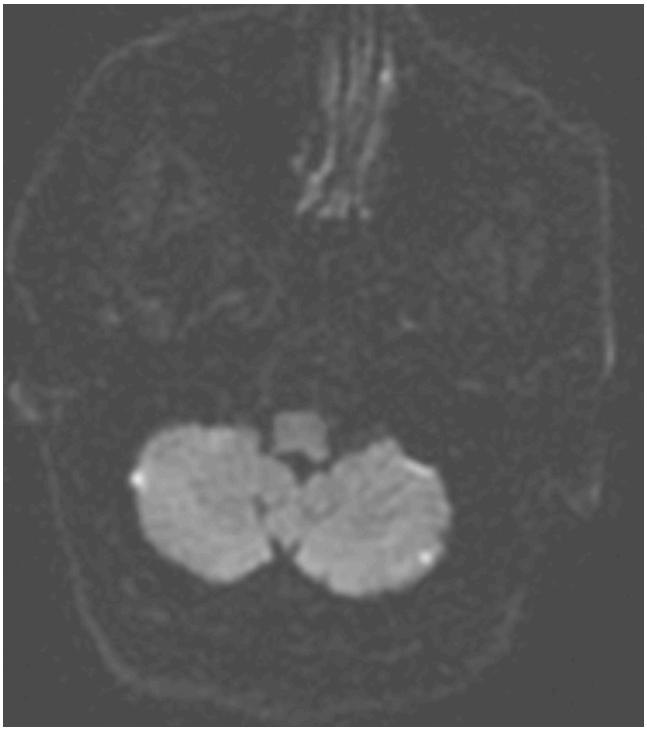

Fig. 6. Axial view of follow-up diffusion weighted MRI at 24 h showed foci of acute infarcts in bilateral cerebellar hemispheres. Abbreviations: MRI, Magnetic Resonance Imaging.

associated with mortality rates of 20–42.9% and good outcomes (mRS 0−2) in only 26.6–53.3% (Table 5). These findings are consistent with the rates of mortality (41.2%) and good outcomes (41.2%) seen in the present study. Compter et al. [4] found that patients with BAO and bilateral VA occlusion had an increased risk of poor outcome due to impaired collateral developed and lower recanalization rates. However, previous studies also reported low rates of complications associated with MT in posterior circulation tandem occlusion including distal emboli and symptomatic intracerebral hemorrhage [5,6,8,9,12]. Additionally, Siebert et al. [11] concluded that MT is feasible, safe, and effective for the treatment of acute BAO due to VA stenosis or occlusion with thromboembolism.

Endovascular revascularization of tandem lesions is associated with increased technical complexity and difficulty compared to isolated BAO [8]. Theoretically, the increased complexity of endovascular intervention for tandem occlusions should increase time intervals such as TTR resulting in higher morbidity and mortality [9]. Recent studies comparing tandem occlusions to isolated acute BAO have found conflicting results [9,12]. Piechowiak et al. [9] found no statistically significant difference in time intervals, rate of good outcomes, or mortality rate between the following subgroups: tandem VBO, isolated BAO with intracranial stenosis (ICS), and isolated BAO without ICS. Baik et al. [12] found a statistically significant increase in procedure time and decrease in good outcomes at 3 months for patients with tandem occlusions compared to patients with embolic BAO without VA steno-occlusion despite similar recanalization rates. However, there was no statistically significant difference in mortality between any patient subgroups. Of note, embolic BAO from tandem VA lesions was associated with occlusion location in the distal BA [9,12]. Although not all studies agree, poor outcomes despite high recanalization rates may be attributed to increased procedure times, persistent occlusions of BA branches, and/or lack of collateral flow to BA perforators [5,6,12]. In this study, the mean TTR/procedure time was 59.3 min, which is consistent with recently published studies. The major challenge encountered during intervention was accessing and navigating an occluded and diffusely stenotic VA. Engineering advances in thrombectomy devices have the potential to improve patient outcomes by decreasing time-to-recanalization and increasing vascular access.

The optimal approach to endovascular intervention of posterior circulation tandem occlusions is unknown [12]. Each technique has its own advantages and disadvantages [5]. Technique selection is largely dependent of preference of the neurointerventionalists and patient vascular anatomy. Despite variations in MT techniques between

Table 5
Literature summaries for posterior circulation tandem occlusion management with endovascular techniques. Abbreviations: mRS, Modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; TICI, Thrombolysis in Cerebral Infarction; TTP, Time to Puncture; TTR, Time to Recanalization.

	Patients	Mean Age	Mean NIHSS	TICI ≥ 2b (%)	Mean TTP (hours)	Mean TTR (min)	Mean mRS	Good Outcome, mRS 0−2 (%)	Mortality (%)
Ecker et al, 2014. [6]	6	49.5	18.5	100	–	–	3.2	50	33.3
Cohen et al, 2016. [5]	7	57.7	22.1	100	8.6[a]	66.4	3.7	28.6	28.6
Yang et al, 2018. [8]	7	57.4	22	100	9.1	124.1	3.7	42.9	42.9
Piechowiak et al, 2019. [9]	15	62.7	23.1	100	5.56	57	3.07	53.3	20
Baik et al, 2019. [12]	28	70.4	18*	85.7	3.75*	66*	5*	28.6	25
Present Study, 2020.	17	55.8	17.2	76.5	6.9	59.3	3.7	41.2	41.2

[a] Time from symptom onset to arrival at the interventional neuroradiology suite.
* Median.

previous studies, reported outcomes are consistent: despite high rates of revascularization (TICI ≥ 2b), posterior circulation tandem occlusions are associated with high rates of morbidity and mortality (Table 5) [5,6,8,9,12]. Mattle et al. [16] found that recanalization is the most important prognostic factor and improves survival in BAO, but good outcomes are not guaranteed. Overall, endovascular treatment of tandem VBO is safe and feasible with a relatively high rate of good outcomes compared to other treatment modalities [5,6,9,12].

The limitations of this study include the small sample size, lack of long-term patient follow-up, and lack of randomized-controlled design. This was a single-center study of endovascular procedures for the treatment of CBS performed by neurointerventionalists; therefore, our data may lack generalization.

5. Conclusion

Endovascular interventions with mechanical thrombectomy is safe and feasible in patients with posterior circulation tandem occlusion. We hope that this study brings attention to the lack of current literature regarding posterior circulation tandem occlusions and prompts investigation into the development of optimal endovascular management.

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Data sharing statement

The relevant anonymized patient level data are available on reasonable request from the authors.

CRediT authorship contribution statement

Joshua H. Weinberg: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft. **Ahmad Sweid:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft. **Kalyan Sajja:** Conceptualization, Data curation, Formal analysis, Writing - original draft. **Rawad Abbas:** Data curation, Formal analysis. **Ashlee Asada:** Data curation, Formal analysis. **Osman Kozak:** Writing - review & editing, Validation. **Larami Mackenzie:** Writing - review & editing, Validation. **Hana Choe:** Writing - review & editing, Validation. **Michael Reid Gooch:** Writing - review & editing, Validation. **Nabeel Herial:** Investigation, Methodology. **Stavropoula Tjoumakaris:** Writing - review & editing, Validation. **Hekmat Zarzour:** Investigation, Methodology, Writing - review & editing, Validation. **Robert H. Rosenwasser:** Writing - review & editing, Validation. **Pascal Jabbour:** Conceptualization, Investigation, Methodology, Writing - original draft, Writing - review & editing, Validation.

Declaration of Competing Interest

The authors report no declarations of interest.

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