The Neurohospitalist
2015, Vol. 5(3) 142-150
© The Author(s) 2015
Reprints and permission:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1941874415583847
nhos.sagepub.com
SAGE

Basilar Occlusion Syndromes: An Update

Stacie L. Demel, DO, PhD[1], and Joseph P. Broderick, MD[1]

Abstract

Basilar artery occlusions (BAOs) are a subset of posterior circulation strokes. Particular issues relevant to BAOs include variable and stuttering symptoms at onset resulting in delays in diagnosis, high morbidity and mortality, and uncertain best management. Despite better imaging techniques, diagnosis, and therefore treatment, is often delayed. We will present the most common signs and symptoms of posterior circulation strokes. Data on optimal treatment strategies are gathered from multiple case series, registries, and one randomized trial, which was stopped early. Possible etiologies of BAOs, acute, and subacute treatment strategies and special topics in neuroimaging of the posterior fossa are discussed. This review may be helpful to neurohospitalists who are managing patients with acute stroke as well as emergency room physicians and neurologists.

Keywords

basilar artery occlusion, basilar artery thrombosis, intra-arterial treatment, intravenous thrombolysis, stroke

Introduction

Basilar artery occlusion (BAO) is a potentially fatal diagnosis, yet it is one of the most challenging conditions for clinicians to diagnose and manage. Posterior circulation strokes account for about 15% to 20% of all ischemic strokes. The BAO is a subset of this category, representing 1% to 4% of all ischemic strokes. Unlike hemispheric ischemia, where there is usually sudden onset of focal symptoms, BAO syndromes may mimic other nonstroke conditions, resulting in a delay in neurological evaluation.[1] A more sophisticated neurological examination may help to decipher a posterior circulation syndrome from other clinical diagnoses. Clinical features localizing to the brainstem or cerebellum such as truncal ataxia, nystagmus, extraocular movement abnormalities, and hearing loss, may help to differentiate ischemia in the posterior circulation from other clinical diagnoses. Yet even when the appropriate diagnosis is made, the best management is not well defined. Within 2 weeks of each other, our stroke team saw and treated 2 BAOs with similar presentations but with markedly different outcomes (Figure 1). These cases demonstrate several points: (1) Diagnosing a BAO syndrome can be difficult for family, first responders, and physicians. (2) The best treatment for patients with acute BAO is uncertain but there are several reasonable options based upon current data.

We discuss presentation, causes, and current opinions for treatment of BAO with the neurohospitalist's perspective in mind. Many of these topics have been addressed in a recent review in *Lancet Neurology* by Mattle et al.[12]

Posterior Circulation Anatomy

The posterior cerebral circulation is the blood supply to the posterior portion of the brain including the brainstem, thalami, cerebellum, and occipital lobes. Bilateral vertebral arteries originate from the subclavian arteries and join at the pontomedullary junction to form a singular basilar artery (BA). The BA can be divided into three segments: a proximal, middle, and distal segment. The distal tip of the BA divides into bilateral posterior cerebral arteries (PCAs), which supply the occipital lobes, the inferior temporal lobes, and the medial parietal lobes via major arterial branches and the thalamus and upper midbrain via perforating arteries that arise from the PCAs. Other important branches of the BA include the superior cerebellar arteries (SCAs), the anterior inferior cerebellar arteries, and pontine perforating arteries. The posterior inferior cerebellar arteries usually originate from the vertebral arteries. The location of arterial occlusion relates closely with symptoms.

[1] Department of Neurology and Rehabilitation Medicine, University of Cincinnati, Cincinnati, OH, USA

Corresponding Author:
Stacie L. Demel, Department of Neurology and Rehabilitation Medicine, University of Cincinnati, 260 Stetson Street, Suite 2300, Cincinnati, OH 45219, USA.
Email: demelse@ucmail.uc.edu

	Case 1	Case 2
Clinical presentation	20 year old male presented to University Hospital after several hours of dizziness, emesis x1 which progressed to weakness, unsteady gait (needing assistance to get into shower at 5:30 PM) lethargy and collapse (7PM). Upon presentation to the ED, he had a disconjugate gaze and posturing of his bilateral arms and legs. Emergent CT/CTA was obtained which confirmed a BAO. Stroke team was notified at that point (9 PM)	55 year old male presented to OSH with vertigo. He was discharged from the ED with meclizine. He returned at 1 AM the following day with left facial droop, slurred speech, decreased responsiveness and intermittent limb weakness. The stroke team was consulted and CTA recommended. CTA at 4:30 AM showed BAO. Patient was transferred to the University Hospital for endovascular treatment. Patient progressed to coma prior to intervention
Pre-hospital course	Initial presentation at University Hospital	Transfer from outside hospital
CTA findings	Distal BAO. Intact PCAs from posterior communicating arteries bilaterally	15 mm mid to distal basilar occlusion. Left fetal PCA (supplied from anterior circulation)
Stroke risk factors	None	Coronary artery disease
Time from first symptoms to stroke team contact	~8 hours	~24 hours
Time from onset to recanalization	~9 hours 45 min	~30 hours
Endovascular techniques used	Manual aspiration with 5 Max reperfusion catheter followed by mechanical thrombectomy (Solitaire Stent Retriever)	Mechanical thrombectomy (Solitaire Stent Retriever); balloon angioplasty of high-grade BA stenosis, IA t-PA and IA verapamil
Angiographic outcome	TICI 3 recanalization	TICI 3 recanalization with persistent high grade mid-basilar stenosis (red arrow)
Acute complications	None	Subarachnoid hemorrhage; coma
Short-term outcome	Discharged to rehab. Deficits include ataxia, left arm and leg dysmetria, slurred speech and pseudo-bulbar affect. NIHSS at 1 month = 0	Death

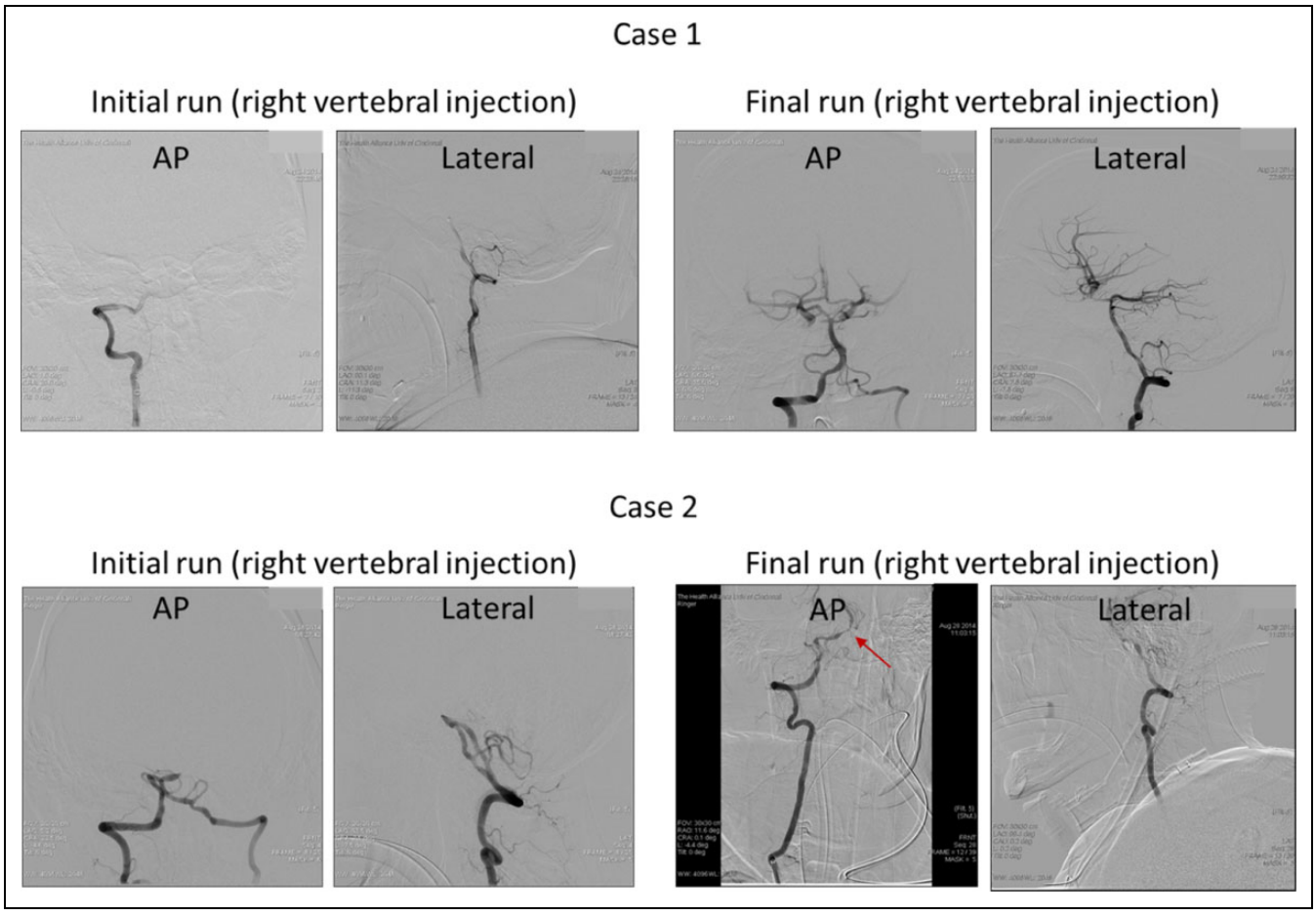

Figure 1. Clinical presentation and angiographic comparison of 2 cases of basilar artery occlusion seen at the University Hospital within 1 week of each other meant to illustrate similarities and differences of etiology, symptoms at onset, and outcomes. The arrow points out a persistent high-grade mid-basilar stenosis after recanalization in case 2.

Basilar Occlusion Syndromes

The BAO syndrome presents as a subset of the larger category of posterior circulation strokes. Compared to anterior circulation stroke syndromes, posterior circulation ischemia may have a longer prodrome and an evolution that is important to recognize. The latency between first prodromal symptoms and stroke onset can be from days to months before stroke onset and may increase in frequency as the stroke approaches.[13,14] Most common prodromal symptoms are vertigo and nausea, followed by headache and neck pain.[15,16] "Herald hemiparesis" refers to the transient, lateralized motor weakness that may precede the stroke.

Dizziness and vertigo, common early symptoms of BAO, are nonspecific, accounting for about 4 million emergency department visits annually in the United States. Distinguishing between central and peripheral vertigo is clinically important as delayed recognition of vascular vertigo leads to missed opportunities for thrombolysis and/or thrombectomy and may increase risk of death and disability.

Head impulse, nystagmus type, and test of skew (HINTS) is a sensitive clinical decision tool, more often used by specialists, which can be used to help distinguish between central and peripheral vertigo. It has been shown to outperform magnetic resonance imaging (MRI) in diagnosing stroke within the first 2 days of acute dizziness symptoms.[2] Use of a stroke risk-stratification tool such as the ABCD2 score, which assigns points (0-7) based on 5 clinical factors: age 60 years or older = 1; blood pressure $\geq$ 140/90 = 1; clinical features (unilateral weakness = 2, speech disturbance without weakness = 1, and any other symptom = 0); duration of symptoms (<10 minutes = 0, 10-59 minutes = 1, and $\geq$60 minutes = 2); and diabetes = 1, may also help to stratify higher risk patients. 1.0% of dizzy patients with an ABCD2 score of 3 or less ultimately received a diagnosis of stroke compared with 6.8% of patients with a score of 4 or 5 and 27% with a score of 6 or 7.[3] Time to follow-up and neuroimaging were variable between patients.

The neurological examination should be used to look for additional localizing signs and symptoms. A patient with dizziness plus one other neurological symptom is much more likely to have a vascular etiology of their symptoms than a patient with isolated vertigo. Fewer than 1% of patients with vertebrobasilar ischemia (VBI) in the New England Medical Center Posterior Circulation Registry had only 1 presenting symptom or sign.[4] Oculomotor palsies, oropharyngeal dysfunction, truncal and appendicular ataxia, and limb weakness are the most common signs.[16] Other findings in VBI include abnormal eye movements,[5] asymmetric pupils, dysmetria, respiratory disturbance, and altered level of consciousness. Vertical or alternating horizontal nystagmus in primary gaze is of central etiology until proven otherwise. Descending unilateral or bilateral long upper motor tracts and crossing cerebellar fibers located in the paramedian pons are frequently affected with accompanying combinations of weakness and ataxia.

The severity of presentation can vary from isolated cranial nerve palsies to tetraplegia, locked-in state, or coma. Acute BAO may mimic other neurological syndromes such as benign paroxysmal positional vertigo, delirium, or coma. Other misleading presentations of acute BAO include either unilateral or bilateral shaking, twitching, jerking, or posturing which can potentially be mistaken for epileptic events.[17] Symptoms may be bilateral or "crossed" (ie, left face weakness with right arm and leg weakness), which can present a diagnostic challenge if suspicion for posterior circulation stroke is not high.

One of the most devastating locations for a BAO is a mid-basilar occlusion with bilateral pontine ischemia. These patients may appear to be comatose but can be fully conscious and paralyzed with only limited vertical eye movements. This "locked-in syndrome" has a high mortality rate of approximately 75% in the acute phase.[18] Another BAO syndrome involves occlusion at the distal top of the BA where the SCAs and PCAs represent the final terminal branches. This "top of the basilar" syndrome may cause ischemia of the midbrain, thalami, inferior temporal lobes, and occipital lobes. Occlusion of paramedian perforator branches, which originate from the distal BA, results in midbrain and thalamic ischemia. Examination findings may include vertical gaze and convergence disorders, slowed smooth pursuit movements, skew deviation,[19] see-saw, and convergence-retraction nystagmus. Pupillary light reflex is often affected such that pupils react to light slowly and incompletely or not at all. If SCAs are involved, then dizziness, vomiting, dysarthria, ipsilateral or bilateral dysmetria, and gait ataxia may be observed with ischemia of the superior cerebellum. An embolus to one PCA can result in contralateral vision loss, whereby infarction of both PCA territories can cause cortical blindness, disorientation, and inability to form new memories.

Infarction of the middle midbrain can result in nuclear third nerve palsy or fascicular third nerve palsy, which can be associated with crossed hemiplegia, ipsilateral, or contralateral hemiataxia. An infarct in the lower midbrain can cause internuclear ophthalmoplegia (INO), fourth nerve palsy, and bilateral ataxia. Long anteromedial perforators arise from the mid-basilar portion of the artery. Occlusion of the mid-BA that supply the pons and lower midbrain can also result in prominent eye findings including primary-position, down-beating nystagmus, ipsilateral gaze paralysis (ipsilateral or complete), and INO (both unilateral and bilateral).

Infarcts in the paramedian pons cause pure unilateral motor strokes with or without incoordination (ataxic hemiparesis). Ocular bobbing can be seen in pontine strokes. Less common are lateral pontine syndromes like Gasperinin syndrome, which comprises abducens palsy plus complete anterior inferior cerebellar artery syndrome.

Mechanisms for BAOs

The most common causes of posterior circulation ischemia are similar to causes of anterior circulation strokes and include

embolism, large-artery atherosclerosis, penetrating small-artery disease, and arterial dissection. Intrinsic atherosclerotic BA stenosis is the most common cause and occurs most often in the sixth and seventh decade of life. The BAO secondary to embolism from the heart or vertebral arteries is another significant cause. Patients with embolic etiology are younger than those with atherosclerotic disease.[14]

Dissection of a vertebral artery can either expand directly into the wall of the BA resulting in low-flow or no-flow state, or cause formation of a thrombus that can embolize distally. Traumatic vertebral artery dissection is one of the most common causes of acute BAO in young patients and should be suspected in patients presenting with cervical pain with or without headache and neurological deterioration.[20] Rarer causes which are more specific to the posterior circulation include cervical spine or skull base fracture, cervical instability,[21,22] arteritis, meningitis, aneurysms, hereditary arteriopathies, and neurosyphilis.[23] Behcet vasculitis more commonly involves the posterior circulation.[24] A large number of posterior circulation strokes remain cryptogenic.

Special Topics in Imaging of BAO and Posterior Fossa

Although a noncontrast head computed tomography (CT) is sensitive to detect an intracranial hemorrhage, it is not particularly sensitive for diagnosis of acute ischemic stroke, especially in the posterior fossa. A hyperdense BA sign, presumed to represent acute thrombus or clot, can be seen on a noncontrast head CT in 50% to 70% of patients with BA thrombosis (Figure 2B).[26] Overall, the sensitivity, specificity, and reliability of this finding are low and in most cases should not be used to direct patient care.[27] However, in patients where there is a high pretest probability of posterior circulation stroke, the presence of a hyperdense BA is a specific predictor of BAO.[28]

When a hypodensity is seen in the posterior circulation territory on the CT scan, the posterior circulation Acute Stroke Prognosis Early CT score (pc-ASPECTS), developed and validated by Volker Puetz, can be used to quantify early ischemia. This scoring system allots the posterior circulation 10 points in total with points subtracted for ischemic changes. One point is subtracted for changes in the left or right thalamus, cerebellum, or PCA territory and 2 points are subtracted for any hypodensity in the midbrain or pons,[9] as shown in Figure 2A. The same scoring system used on source images from a CT angiogram has a higher sensitivity for predicting final infarct size and those who will have poor functional outcome, despite recanalization of the BA.[9,29]

An MRI of the brain is more sensitive than a noncontrast head CT for detection of acute stroke. The diffusion-weighted imaging (DWI) sequence paired with an apparent diffusion coefficient map are the most sensitive sequences for acute stroke. However, it is estimated that 6% to 10% of all strokes are initially DWI negative[30-32] with more false-negative MRIs occurring in cases of posterior circulation stroke. 50% of patients with a stroke who present with isolated vertigo will have a falsely negative MRI up to 48 hours after onset.[25] A recent article by Simonsen et al found DWI negative strokes were twice as likely in the posterior circulation (34% vs 15%), but the sensitivity of DWI seems variable within the literature.[31,32] The sensitivity of MRI increases with time from symptom onset to imaging. Therefore, a posterior circulation stroke should not be ruled out with an early negative MRI, especially with persistent neurological deficits. The Pc-ASPECT score of 8 or more on MRI (or CT angiogram) is an independent predictor of favorable outcomes,[33] whereas cerebral blood volume pc-ASPECTS <8 may indicate patients with high case fatality.[34]

With regard to vascular imaging, computed tomography angiography (CTA) and MRA have greater sensitivity than transcranial Doppler and Doppler studies of the vertebral arteries in the neck, which can only grossly comment on the presence and direction of flow in the vertebral arteries. The gold standard for vascular imaging is cerebral angiogram and should be considered when initial, noninvasive imaging is nondiagnostic or conflicting.

Acute Treatment of BAO

There is no consensus for the best acute management of BAOs. If suspected, the first critical step is to verify that the patient can protect his or her airway, as acute BAO symptoms can progress to decreased alertness, decreased respiratory drive, and coma. The treating clinician should consider augmenting blood pressure to increase cerebral perfusion by lying the head of bed flat. A noncontrast head CT and CT angiography should be the next step in diagnostic testing. If the head CT shows no hemorrhage and symptom onset is within 4.5 hours, IV tissue-type plasminogen activator (t-PA) is standard of care. The high morbidity and mortality in patients with BAO who do not recanalize[7] may lead to consideration of endovascular treatment to revascularize the BA by intra-arterial thrombolysis or thrombectomy. However, no large, definitive, randomized, clinical trials have compared thrombectomy using clot retrieval devices following best medical therapy (IV t-PA within 4.5 hours or best medical therapy after 4.5 hours) as compared to best medical therapy alone.

Case series and retrospective studies provide some insight into the natural history of BAOs and the importance of recanalization. Prior to 2006, data were solely from case series or minimal data from acute stroke trials. In Interventional Management of Stroke III, a randomized, controlled study comparing IV t-PA to IV t-PA + endovascular treatment, there were only 5 patients enrolled with occlusions within the posterior circulation.[35] There was no outcome difference between the 2 groups in this small subset of patients. The Australian Urokinase Stroke Trial (1996-2003) was the 1 randomized, controlled trial directly comparing best medical

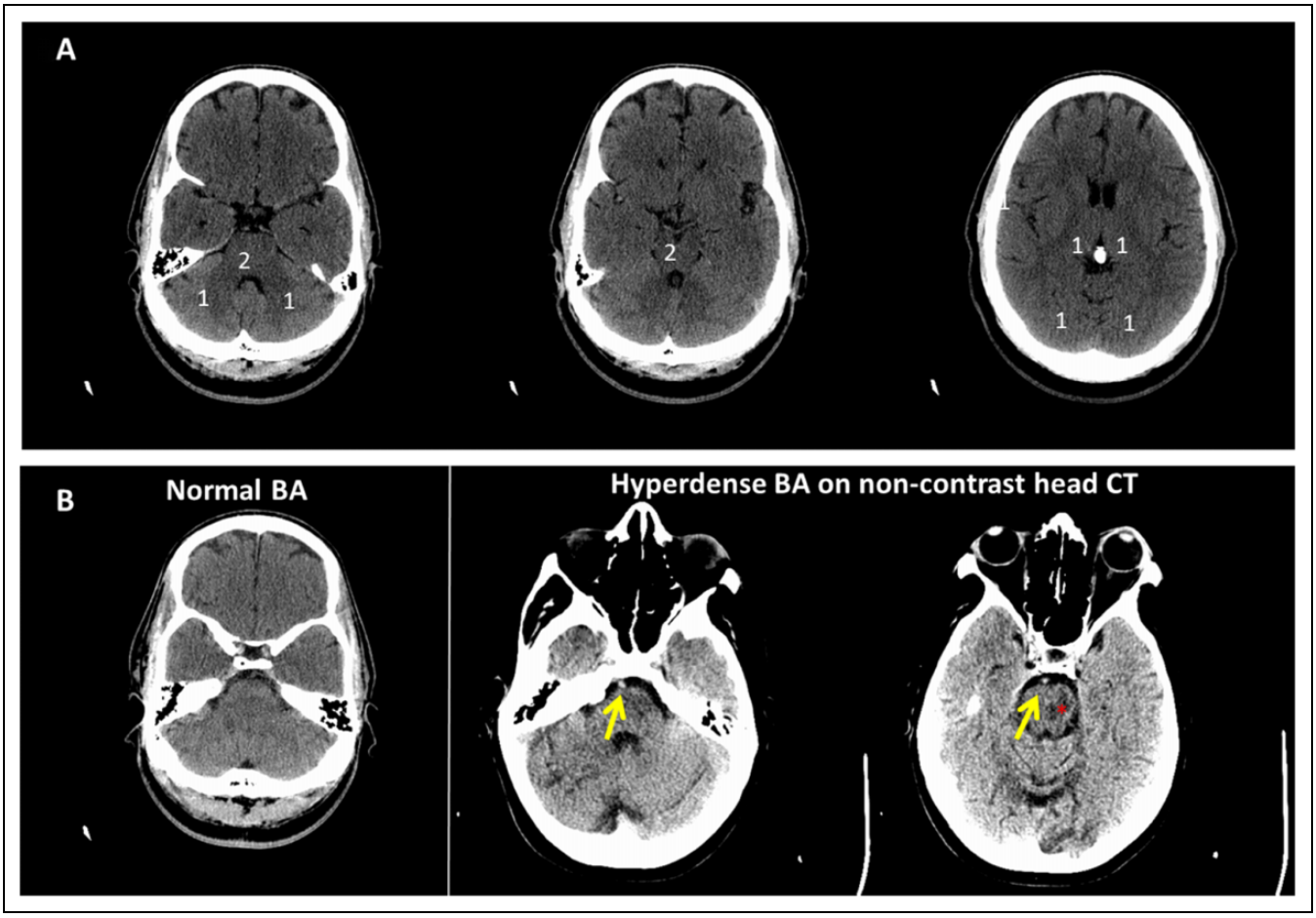

Figure 2. Axial sections through representative noncontrast head CT scans demonstrating: (A) normal head CT with superimposed posterior circulation Acute Stroke Prognosis Early CT (pc-ASPECT) scoring territories. A scan with no hypodensity would receive a score of 10; 1 to 2 points are subtracted for hypodensity in each of the areas represented. One point is subtracted for hypodensity in the right and left cerebellum, thalamus, and occipital lobe and 2 points are subtracted for any hypodensity in the pons or midbrain. B, Left panel demonstrates a normal posterior fossa and normodense basilar artery. The middle and right panels depict a hyperdense basilar artery (arrow). Early ischemic changes in the left midbrain are noted (*). CT indicates computed tomography.

therapy to intra-arterial urokinase but was stopped early due to slow recruitment and the withdrawal of urokinase from clinical use.[36] Prior to study withdrawal, 16 patients were randomized into 2 arms. In all, 8 patients received heparin and warfarin and 8 received urokinase, heparin, and warfarin. Of the 8 patients, 7 were dead or disabled in the anticoagulation arm and 4 of the 8 patients in the urokinase arm were dead or disabled at 6 months ($P = .28$). Median time to treatment was approximately 12 hours in either group, and time did not seem to affect outcome.

New technology for intra-arterial treatment (IAT) of stroke (ie, stent retrievers) is available and currently being used for clot removal in the posterior circulation. A meta-analysis of uncontrolled studies comparing IAT to IV t-PA (N = 420; 76 IV t-PA, 344 endovascular) showed no difference in death or dependency between groups.[37] In all, 77.6% of IV t-PA-treated patients and 75.6% of IAT patients who presented with BAO had poor outcomes, despite higher recanalization rates in the IAT group (65% vs 53%). Rates of hemorrhagic infarction were not significantly different between groups. Recanalization was a factor associated with good outcome (38% in patients with some recanalization vs 2% in those without any recanalization).[37] In addition, a recently published multicenter registry, ENDOSTROKE, enrolled 148 patients with angiographic proven BAOs between January 2011 and June 2013. In all, 84% of patients were treated with a stent retriever either as the only device or in combination with others. In all, 34% of patients had good clinical outcomes (independence) while mortality was 35%. In this cohort of patients, lower National Institutes of Health Stroke Scale (NIHSS) score, use of MRI, and better collateralization status independently predicted good clinical outcome. Recanalization was achieved in 79% but was not found to be a predictor of good outcome.[38]

The Basilar Artery International Cooperation Study (BASICS) was a nonrandomized prospective registry that

assessed clinical outcomes of patients with confirmed BAO between November 2002 and October 2007.[7] In this registry, most patients received endovascular therapy (±IV t-PA). The authors found no overall differences between IV t-PA alone and endovascular therapy (±IV t-PA), although IV t-PA alone was associated with better clinical outcomes as compared to endovascular therapy in patients with mild to moderate symptoms. Patients with moderate and severe symptoms did better if they received endovascular therapy or IV t-PA compared to antiplatelets or anticoagulation only. Due to nonrandomization, the treatment strategy in these patients is influenced by time, patient age, comorbid status, and stroke severity. The BASICS Trial is an ongoing randomized, controlled, multicenter, open label, and phase III interventional trial with blinded outcome assessment of efficacy and safety of additional IAT after IVT in patients with BAO.[39] The trial has been limited by slow enrollment.

Despite any direct evidence that endovascular treatment of BAO is beneficial, proponents of the endovascular therapy argue that the natural history of the disease has a poor prognosis, and reperfusion is a predictor of good outcome. Most interventionalists will perform endovascular therapy up to 6 hours from symptom onset, dependent on the severity of the patient's symptoms. Because BAO symptoms often progress to devastating neurological outcomes, some interventionalists may consider revascularization up to 24 hours after symptom onset. Successful recanalization has been performed in patients with symptoms present for up to 50 hours.[40] Strbian and colleagues conclude that recanalization of BAO up to 48 hours was seldom futile and produced good outcomes in 50% of patients independent of time to treatment.[8] However, the question remains, how much does recanalization improve outcomes and at what point are attempts to recanalize futile? Ultimately a randomized trial is warranted to determine the appropriate treatment at various time windows after stroke onset.

In-Hospital Management of BAO

After initial stabilization of the patient with a BAO, neurologists or neurohospitalists should direct a work up to determine the stroke etiology. One should obtain an MRI brain to evaluate lesion burden and edema and an MRA (or CTA) head and neck to evaluate for atherosclerotic disease, dissection, luminal narrowing, or occlusion. An echocardiogram with a bubble study should be obtained to evaluate for potential cardiac sources of emboli such as a valvular vegetation, intracardiac mass, ventricular thrombus, or patent foramen ovale. Patients should be placed on continuous cardiac monitoring to evaluate for atrial fibrillation, a finding that would change secondary stroke prevention management. Laboratory testing including CBC, fasting lipids, coagulation panel, and glycated hemoglobin A1c should be obtained. More extensive work up should be obtained on a case-by-case basis, especially in young patients without typical risk factors.

Close attention should be made to relation of symptoms to blood pressure. Patients with BAOs may be particularly sensitive to changes in blood pressure. In the first 24 to 48 hours, the blood pressure should be allowed to autoregulate. One should consider using fluids or pressors if symptoms are blood pressure dependent. Patients should be carefully monitored for cerebellar edema causing compression of the fourth ventricle and/or herniation, which generally peaks 3 to 5 days after infarction. Secondary prevention should be guided by stroke etiology. Although antithrombotics are indicated, the American Heart Association guidelines state that there is no clear indication for anticoagulation in acute stroke, with limited exceptions (ie, cardiac thrombus), which are to be considered on a case-by-case basis.[41] Outside of these guidelines, heparin drip can be considered if the patient is outside the window for acute treatment and infarct burden is minimal. The heparin drip in these difficult cases may prevent clot propagation. The size of the infarct will determine the time frame in which it is safe to initiate anticoagulation in patients in whom atrial fibrillation is detected. Although safe with small infarcts, moderate and large infarcts are subject to hemorrhagic transformation in the first 1 to 2 weeks. In general, statins should be initiated when patient can safely swallow.

Outcomes

When acute BAO was first described by Kubik and Adams by postmortem analysis, it was assumed to have a 100% mortality rate.[42] More recent reports of BAO outcomes have varied greatly due to increased detection with modern imaging techniques and better recognition of posterior stroke symptoms. In the New England registry of posterior circulation strokes, a prospective, single institution registry, only 29% of patients died or were left with a major deficit. Outcomes were dependent on the etiology of the occlusion. Those patients with embolic etiology had a 2.4-fold higher risk of poor outcome compared with patients with diffuse or localized atherosclerosis.[14] Overall, the mortality rate in their study was lower compared to previously reported findings of mortality rates of 45% to 86%.[37,43,44]

There are some data to help guide clinicians as to which patients with BAO will have better outcomes. In a prospective study of 184 consecutive patients with angiography-proven BAO, predictors of poor outcomes included greater age, higher NIHSS score, lack of recanalization, history of atrial fibrillation, and symptomatic intracranial hemorrhage.[8] A pc-ASPECTS >8 is independently associated with better outcomes.[8,9]

Successful recanalization appears to be the single most important predictor of a good outcome.[10] The thrombolysis in cerebral infarction (TICI) score is a widely used method to describe angiographic findings after endovascular treatment of acute ischemic stroke. Although definitions vary within the literature, TICI 2b (>50% reperfusion of vascular territory

Table 1. Summary of Uncertainties and Controversies in Presentation, Diagnosis, and Treatment.

Topic	Discussion	References
When should vertigo be concerning for a central etiology	Normal head impulse test	2
	Risk stratification (ABCD2 > 3)	3
	Dizziness + any other neurological symptom or examination finding	4,5
Treating within <4.5 hours from symptom onset	IV t-PA, if no contraindications; endovascular treatment	6
How to treat BAO outside of 4.5-hour window		
Endovascular treatment	If examination is poor (high NIHSS score) consider endovascular treatment with IA t-PA and/or embolectomy (up to 48 hours).	7,8
	Advanced imaging with CTA or MRI may help with decision making where small core with high NIHSS score may suggest greater potential benefit.	9,8
	Outcomes after IA thrombolysis vs IA thrombectomy are inconclusive, but IA thrombectomy devises have better outcomes in the anterior circulation	10,11
Anticoagulation as bridging therapy or definitive therapy	Inconclusive and lacking data. Decisions to treat with heparin drip and/or anticoagulation should be made on a case-by-case basis	

Abbreviations: BAO, basilar artery occlusion; CTA, computed tomography angiography; IA, intra-arterial; MRI, magnetic resonance imaging; t-PA, tissue-type plasminogen activator; NIHSS, National Institutes of Health Stroke Scale.

according to the original TICI[45] and >67% of the vascular territory in the modified TICI[46]) and TICI 3 (100% reperfusion) are generally regarded to represent a successful angiographic outcome. Lindsberg and Mattle found that only 2% of patients who did not recanalize the BA had good outcomes versus 38% who did.[37] In the Helsinski Stroke Thrombolysis Registry, 14% of patients who did not recanalize had good outcomes compared to 86% who did recanalize.[47] In a small case series of 6 consecutive BAO's treated at a single institution, 5 of the 6 patients treated with endovascular treatment had a TICI score of 3 and the other had TICI 2b resultant recanalization, and all but 1 patient was independent with activities of daily living at 90 days.[48] In lieu of randomized controlled trials, a recent meta-analysis by Kumar et al showed that recanalization was associated with a 1.5-fold reduction in dependency and 2.0-fold reduction in mortality.[10] Despite apparent improvements in outcomes over time, the best therapy to achieve recanalization is unknown.

Predictors of recanalization include clot location and clot length. Top of the basilar clot location[47] and shorter thrombus length[49] have increased probability of recanalization. Strbian reported that thrombi shorter than 100 mm had a 70% to 80% probability of recanalization. The probability of recanalization decreased in a clot length-dependent fashion, such that thrombi >30 mm long had only a 20% to 30% chance of opening with IV t-PA. In this study, patients with complete or partial recanalization had significantly less morbidity at 3 months and less mortality at 3 months and 1 year.[49] In addition to recanalization, other clinical and radiological variables associated with survival of BAO after systemic thrombolysis include younger age, atherothrombotic etiology, short occlusion length, and good collaterals.[50] As the technology of thrombectomy devices has improved, recanalization rates and time to recanalization have also improved.[51] Clinical outcomes data with these new devices for BA occlusion are ongoing.

Summary

The morbidity and mortality of BAO remain high, despite advances in stroke prevention and treatment in ischemic stroke (please also refer to Table 1). There should be a high index of suspicion for a BAO in a patient with dizziness plus *any* other neurological deficit, particularly fluctuating level of consciousness, diplopia (or abnormal eye movements on examination), or unsteady gait. After airway stabilization if needed, the best treatment and optimal treatment time for BAO are not known but reperfusion approaches involving IV t-PA and/or endovascular therapy are appropriate within 4.5 hours. Data for endovascular treatment beyond 4.5 hours are based more on case series but could be considered on an individual basis, particularly in those patients with very severe deficits and imaging that shows mild or minimal ischemic changes. Randomized trials have been difficult because of relatively low incidence rates and lack of equipoise. Further research should focus on quicker diagnosis, appropriate imaging, and optimal treatment for this patient population.

Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Research monies to the Department of Neurology from Genentech for PRISMS Trial (to JPB).

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

1. Sarraj A, Medrek S, Albright K, et al. Posterior circulation stroke is associated with prolonged door-to-needle time [published online March 22, 2013]. *Int J Stroke*. 2013.

2. Newman-Toker DE, Kattah JC, Alvernia JE, Wang DZ. Normal head impulse test differentiates acute cerebellar strokes from vestibular neuritis. *Neurology*. 2008;70(24 pt2):2378-2385
3. Navi BB, Kamel H, Shah MP, et al. Application of the ABCD2 score to identify cerebrovascular causes of dizziness in the emergency department. *Stroke*. 2012;43(6):1484-1489.
4. Caplan L, Chung CS, Wityk R, et al. New England medical center posterior circulation stroke registry: I. Methods, data base, distribution of brain lesions, stroke mechanisms, and outcomes. *J Clin Neurol*. 2005;1(1):14-30.
5. Moncayo J, Bogousslavsky J. Vertebro-basilar syndromes causing oculo-motor disorders. *Curr Opin Neurol*. 2003;16(1): 45-50.
6. Lees KR, Bluhmki E, von Kummer R, et al. Time to treatment with intravenous alteplase and outcome in stroke: an updated pooled analysis of ECASS, ATLANTIS, NINDS, and EPITHET trials. *Lancet*. 2010;375(9727):1695-1703.
7. Schonewille WJ, Wijman CA, Michel P, et al. Treatment and outcomes of acute basilar artery occlusion in the Basilar Artery International Cooperation Study (BASICS): a prospective registry study. *Lancet Neurol*. 2009;8(8):724-730.
8. Strbian D, Sairanen T, Silvennoinen H, Salonen O, Kaste M, Lindsberg PJ. Thrombolysis of basilar artery occlusion: impact of baseline ischemia and time. *Ann Neurol*. 2013;73(6):688-694.
9. Puetz V, Sylaja PN, Coutts SB, et al. Extent of hypoattenuation on CT angiography source images predicts functional outcome in patients with basilar artery occlusion. *Stroke*. 2008;39(9): 2485-2490.
10. Kumar G, Shahripour RB, Alexandrov AV. Recanalization of acute basilar artery occlusion improves outcomes: a meta-analysis [published online September 30, 2014]. *J Neurointerv Surg*. 2014.
11. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med*. 2015;372(1):11-20.
12. Mattle HP, Arnold M, Lindsberg PJ, Schonewille WJ, Schroth G. Basilar artery occlusion. *Lancet Neurol*. 2011;10(11):1002-1014.
13. Ferbert A, Bruckmann H, Drummen R. Clinical features of proven basilar artery occlusion. *Stroke*. 1990;21(8):1135-1142.
14. Voetsch B, DeWitt LD, Pessin MS, Caplan LR. Basilar artery occlusive disease in the New England Medical Center Posterior Circulation Registry. *Arch Neurol*. 2004;61(4):496-504.
15. Grad A, Baloh RW. Vertigo of vascular origin. Clinical and electronystagmographic features in 84 cases. *Arch Neurol*. 1989; 46(3):281-284.
16. Savitz SI, Caplan LR. Vertebrobasilar disease. *N Engl J Med*. 2005;352(25):2618-2626.
17. Ropper AH. 'Convulsions' in basilar artery occlusion. *Neurology*. 1988;38(9):1500-1501.
18. Nikic PM, Jovanovic D, Paspalj D, Georgievski-Brkic B, Savic M. Clinical characteristics and outcome in the acute phase of ischemic locked-in syndrome: case series of twenty patients with ischemic LIS. *Eur Neurol*. 2013;69(4):207-212.
19. Caplan LR. "Top of the basilar" syndrome. *Neurology*. 1980; 30(1):72-79.
20. Kuan CY, Hung KL. Vertebral artery dissection complicated by basilar artery occlusion. *Pediatr Neonatol*. 2014;55(4):316-319.
21. Oshima K, Sakaura H, Iwasaki M, Nakura A, Fujii R, Yoshikawa H. Repeated vertebrobasilar thromboembolism in a patient with severe upper cervical instability because of rheumatoid arthritis. *Spine J*. 2011;11(2):e1-e5.
22. Sugrue PA, Hage ZA, Surdell DL, Foroohar M, Liu J, Bendok BR. Basilar artery occlusion following C1 lateral mass fracture managed by mechanical and pharmacological thrombolysis. *Neurocrit Care*. 2009;11(2):255-260.
23. Bauerle J, Zitzmann A, Egger K, Meckel S, Weiller C, Harloff A. The great imitator-still today! A case of meningovascular syphilis affecting the posterior circulation. *J Stroke Cerebrovasc Dis*. 2015;24(1):e1-e3.
24. Akman-Demir G, Serdaroglu P, Tasci B. Clinical patterns of neurological involvement in Behcet's disease: evaluation of 200 patients. *Brain*. 1999;122(pt 11):2171-2182.
25. Saber Tehrani AS, Kattah JC, Mantokoudis G, et al. Small strokes causing severe vertigo: frequency of false-negative MRIs and nonlacunar mechanisms. *Neurology*. 2014;83(2):169-173.
26. Mortimer AM, Saunders T, Cook JL. Cross-sectional imaging for diagnosis and clinical outcome prediction of acute basilar artery thrombosis. *Clin Rad*. 2011;66(6):551-558.
27. Connell L, Koerte IK, Laubender RP, et al. Hyperdense basilar artery sign-a reliable sign of basilar artery occlusion. *Neuroradiology*. 2012;54(4):321-327.
28. Goldmakher GV, Camargo EC, Furie KL, et al. Hyperdense basilar artery sign on unenhanced CT predicts thrombus and outcome in acute posterior circulation stroke. *Stroke*. 2009;40(1): 134-139.
29. Puetz V, Sylaja PN, Hill MD, et al. CT angiography source images predict final infarct extent in patients with basilar artery occlusion. *AJNR Am J Neuroradiol*. 2009;30(10):1877-1883.
30. Bulut HT, Yildirim A, Ekmekci B, Eskut N, Gunbey HP. False-negative diffusion-weighted imaging in acute stroke and its frequency in anterior and posterior circulation ischemia. *J Comput Assist Tomogr*. 2014;38(5):627-633.
31. Oppenheim C, Stanescu R, Dormont D, et al. False-negative diffusion-weighted MR findings in acute ischemic stroke. *AJNR Am J Neuroradiol*. 2000;21(8):1434-1440.
32. Simonsen CZ, Madsen MH, Schmitz ML, Mikkelsen IK, Fisher M, Andersen G. Sensitivity of diffusion- and perfusion-weighted imaging for diagnosing acute ischemic stroke is 97.5%. *Stroke*. 2015;46(1):98-101.
33. Nagel S, Herweh C, Kohrmann M, et al. MRI in patients with acute basilar artery occlusion—DWI lesion scoring is an independent predictor of outcome. *Int J Stroke*. 2012;7(4): 282-288.
34. Pallesen LP, Gerber J, Dzialowski I, et al. Diagnostic and prognostic impact of pc-ASPECTS applied to perfusion CT in the Basilar Artery International Cooperation Study [published online June 18, 2014]. *J Neuroimag*. 2014.
35. Broderick JP, Palesch YY, Demchuk AM, et al. Endovascular therapy after intravenous t-PA versus t-PA alone for stroke. *N Engl J Med*. 2013;368(10):893-903.

36. Macleod MR, Davis SM, Mitchell PJ, et al. Results of a multicentre, randomised controlled trial of intra-arterial urokinase in the treatment of acute posterior circulation ischaemic stroke. *Cerebrovasc Dis*. 2005;20(1):12-17.
37. Lindsberg PJ, Mattle HP. Therapy of basilar artery occlusion: a systematic analysis comparing intra-arterial and intravenous thrombolysis. *Stroke*. 2006;37(3):922-928.
38. Singer OC, Berkefeld J, Nolte CH, et al. Mechanical recanalization in basilar artery occlusion: the ENDOSTROKE study. *Ann Neurol*. 2015;77(3):415-424.
39. van der Hoeven EJ, Schonewille WJ, Vos JA, et al. The Basilar Artery International Cooperation Study (BASICS): study protocol for a randomised controlled trial. *Trials*. 2013;14:200.
40. Grigoriadis S, Gomori JM, Grigoriadis N, Cohen JE. Clinically successful late recanalization of basilar artery occlusion in childhood: what are the odds? Case report and review of the literature. *J Neurol Sci*. 2007;260(1-2):256-260.
41. Kernan WN, Ovbiagele B, Black HR, et al. Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2014;45(7):2160-2236.
42. Kubik CS, Adams RD. Occlusion of the basilar artery; a clinical and pathological study. *Brain*. 1946;69(2):73-121.
43. Schonewille WJ, Algra A, Serena J, Molina CA, Kappelle LJ. Outcome in patients with basilar artery occlusion treated conventionally. *J Neurol Neurosurg Psychiatry*. 2005;76(9):1238-1241.
44. Labauge R, Pages M, Marty-Double C, Blard JM, Boukobza M, Salvaing P. Occlusion of the basilar artery. A review with 17 personal cases (author's transl) [in French]. *Rev Neurol (Paris)*. 1981;137(10):545-571.
45. Higashida RT, Furlan AJ, Roberts H, et al. Trial design and reporting standards for intra-arterial cerebral thrombolysis for acute ischemic stroke. *Stroke*. 2003;34(8):e109-e137.
46. Tomsick T, Broderick J, Carrozella J, et al. Revascularization results in the Interventional Management of Stroke II trial. *AJNR Am J Neuroradiol*. 2008;29(3):582-587.
47. Sairanen T, Strbian D, Soinne L, et al. Intravenous thrombolysis of basilar artery occlusion: predictors of recanalization and outcome. *Stroke*. 2011;42(8):2175-2179.
48. Jankowitz BT, Aleu A, Lin R, et al. Endovascular treatment of basilar artery occlusion by manual aspiration thrombectomy. *J Neurointerv Surg*. 2010;2(2):110-114.
49. Strbian D, Sairanen T, Silvennoinen H, Salonen O, Lindsberg PJ. Intravenous thrombolysis of basilar artery occlusion: thrombus length versus recanalization success. *Stroke*. 2014;45(6):1733-1738.
50. Brandt T, von Kummer R, Muller-Kuppers M, Hacke W. Thrombolytic therapy of acute basilar artery occlusion. Variables affecting recanalization and outcome. *Stroke*. 1996;27(5):875-881.
51. Son S, Choi DS, Oh MK, et al. Comparison of Solitaire thrombectomy and Penumbra suction thrombectomy in patients with acute ischemic stroke caused by basilar artery occlusion [published online November 19, 2014]. *J Neurointerv Surg*. 2014.