11 Thrombolysis and Thrombectomy

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Summary

Posterior circulation stroke (PCS) comprises a minority of overall acute ischemic stroke (AIS) cases; however, it is associated with a disproportionally higher level of morbidity and mortality. Because its presenting symptoms may be ambiguous and insidious in onset, the diagnosis of PCS may require a stronger clinical acumen compared to that of anterior circulation stroke (ACS). However, like ACS, once recognized, acute reperfusion therapy such as thrombolytics or mechanical thrombectomy (MT) must be initiated immediately in eligible patients. Outcome data are relatively sparse for systemic thrombolysis or MT in PCS treatment compared to ACS; however, it is well established that in PCS due to basilar artery occlusion (BAO), the constellation of persistent vessel occlusion and moderate-to-severe clinical deficit at presentation is uniformly associated with death or severe disability. Multiple case series and reviews have demonstrated systemic and intra-arterial thrombolysis as promising recanalization methods for PCS. Furthermore, the advent of recent class I evidence of efficacy for MT in ACS, has established endovascular therapy (with or without IV thrombolysis depending on patient eligibility) as the standard of care for PCS due to BAO in many centers across the world. Just like in the case of ACS, where current guidelines recommend the recently expanded but still rigid time criteria for treatment selection, a growing body of literature suggests that time constraints should not limit treatment for select patients with BAO given that lack of treatment resulting in a uniformly poor outcome. While time is increasingly less considered, the primordial factor for patient selection in stroke populations, in each individual patient, the earlier reperfusion occurs, the higher the chance of a good outcome. Therefore, optimizing triage and transport to appropriate centers remains critical to achieving sustained growth in the number of eligible patients with better clinical outcomes. In addition, new-generation MT devices and adjunctive approaches to endovascular therapy, including neuroprotection, will be the next frontier in comprehensive acute PCS management.

Background

While posterior circulation stroke (PCS) accounts for only 20–30% of all acute ischemic stroke (AIS), it is associated with significant morbidity

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and mortality [1]. Stroke due to occlusion of proximal large vessels in the posterior circulation, involving the basilar artery (BA), both intracranial vertebral arteries (VAs), or one intracranial VA with atretic contralateral VA, carries a particularly poor prognosis. When all such untreated patients are considered, nearly 65% of patients can be left with severe deficits, and 40% will not survive [2]. Furthermore, in patients presenting with moderate-to-severe deficits, without reperfusion therapy, rates of good outcomes can be as low as 2% [3]. While the National Institute of Health Stroke Scale (NIHSS) is a less accurate measure of the severity of the neurological deficit in PCS compared to its ACS counterpart, an NIHSS ≥10 is highly associated with death or severe disability without reperfusion therapy [4].

Clinical Symptomatology and Clot Location

Similar to ACS, prompt recognition and institution of treatment aimed to reperfuse the ischemic brain is essential. Recognition of PCS symptoms, however, may be more difficult given the more complex nuances of patient's presenting symptoms, particularly as the NIHSS is not as reliable for these strokes [5–7]. Unlike an ACS that may present with specific symptoms suggestive of impairment of certain brain regions, such as hemiparesis, hemisensory loss, hemifield cut, aphasia, or neglect, the symptoms of a PCS can be nonspecific with dizziness, headache, or slight incoordination. These relatively ambiguous symptoms may present as recurrent transient ischemic attacks (TIAs), which represent the prodromal symptoms of a full-blown BA occlusion (BAO) syndrome in 25–60% of cases, when untreated [8, 9].

The mode of symptom presentation may indicate the pathophysiologic mechanism of BAO. Typically, the prodromal, stuttering symptoms occur in patients with proximal BA occlusions, which are more likely to be related with atherothrombosis whereas the abrupt, sudden symptoms associated with mid/distal BA occlusion are more frequently associated with embolic mechanisms [10–12]. These distal embolic occlusions have higher recanalization rates compared to their proximal, atherosclerotic counterparts [3, 13–15].

Thrombolytic Therapy

Historical Context

The potential benefit of thrombolytic therapy in acute PCS was recognized as early as 1958. In their series of 3 patients treated with intravenous (IV) fibrinolysin, Sussman and Fitch made several important observations. They understood that time to treatment was essential, based on the finding that angiographic proof of recanalization within 6 hours correlated with a favorable prognosis. They also reported that while a surgical approach can satisfactorily recanalize an occluded vessel, by the time this is achieved, the tissue at risk will likely be irreversibly damaged [16].

Despite numerous early case reports of successful IV thrombolytic therapy for AIS, this treatment became standard of care only after 1995 landmark National Institute of Neurological Disorders and Stroke (NINDS) IV tissue plasminogen activator (t-PA) trial, which established the benefit of t-PA in acute AIS when treated within 3 h of last seen well (LSW) [17]. Later, the use of IV t-PA was established out to 4.5 h from LSW [18].

While IV thrombolysis remains the standard of care for AIS, its utilization in BAO is low. It has been reported that among all patients who receive thrombolysis, only 5% have BAO [19]. Furthermore, the aforementioned pivotal t-PA trials either had a low proportion of PCS (5% in NINDS) or did not delineate how many PCS were included (ECASS III). More recently, single-arm studies have investigated outcomes in PCS treated with IV t-PA. A retrospective study of 116 patients treated with IV t-PA over 13 years reported rates of recanalization of 65% with trends toward favorable outcomes [15]. Another retrospective study reported 53% recanalization rates associated with 22% favorable outcomes and 50% mortality [3]. Lastly, the prospective

Basilar Artery International Cooperation Study (BASICS) group captured data on 121 patients treated with IV t-PA who achieved nearly 70% recanalization rates with 16% mortality; however, it is worth noting that a third of these patients received rescue intra-arterial (IA) thrombolysis [4]. Rates of symptomatic intracerebral hemorrhage (sICH) in these groups ranged from 6% to 16%, which is higher than that observed with IV t-PA treatment in ACS. However, two studies reported lower rates of sICH in PCS compared to ACS [20, 21]. When comparing outcomes with IV thrombolysis in PCS with ACS, a large single-center study found a higher rate of favorable outcomes in the former than in the latter [21]. Overall, despite the lack of evidence from randomized control trials (RCTs) of IV thrombolysis in stroke due to BAO, studies suggest that IV t-PA is relatively safe and likely to be efficacious for this subgroup of patients.

Intra-Arterial Thrombolysis

In addition to systemic thrombolysis, local IA thrombolysis has been used to treat AIS with thrombolytics such as streptokinase, urokinase, or prourokinase. The first RCTs assessing the feasibility of IA thrombolytic treatment were Prolyse in Acute Cerebral Thromboembolism (PROACT) and PROACT II. The latter included patients with AIS due to occlusion of the M1 or M2 MCA segment who could be treated within 6 hours of LSW. Investigators compared clinical outcomes in patients treated with IA prourokinase administered within the thrombus to standard medical therapy [22, 23]. Despite the increased risk of sICH, PROACT II found a significant benefit in favor of IA therapy [23]. The primary clinical outcome at 90 days (modified Rankin Scale [mRS] score ≤ 2) was achieved in 40% of the treatment group and 25% of the controls, $p = 0.043$ [23]. The positive results of PROACT II in the context of the particularly dismal natural history of stroke due to BAO have led to cessation of equipoise such that there have been virtually no RCTs examining the benefit of IA lytics for this type of stroke. One RCT of IA streptokinase conducted in Australia enrolled only 16 patients before being stopped due to slow enrollment and lack of funding [24]. In this study, 4 of the 8 patients in the IA streptokinase group achieved a favorable outcome (mRS 0–3), while only one favorable outcome was observed in the 8 control patients. Since Zeumer et al. firstly described IA streptokinase therapy for BAO in a young woman in 1982 [25], several papers published have attested to the feasibility, relative safety, and higher than expected outcomes of this approach compared to historical controls [3, 4, 26–31].

Mechanical (Nonpharmacological) Endovascular Treatment

Evolution of Endovascular Treatment

Narrow time windows and the risk of hemorrhage associated with thrombolytic agents prompted the design and application of mechanical thrombectomy (MT) devices. Endovascular clot retrieval provides the potential for rapid flow restoration, with a decreased incidence of clot fragmentation and distal embolism [32]. Catheter-based, retrieval/aspiration systems began to be used in AIS patients who were either ineligible for or had failed IV t-PA administration; initially, they were largely used in conjunction with thrombolytic infusion.

MERCI Device

The first device to receive U.S. Food and Drug Administration (FDA) approval for clot retrieval was the MERCI device [33]. Results from the single-arm Mechanical Embolus Removal in Cerebral Ischemia (MERCI) trial demonstrated the efficacy of the MERCI system in restoring the patency of occluded intracranial vessels within 8 hours of AIS [34]; 48% of occluded vessels were recanalized, a rate significantly higher than that of the control arm in the PROACT II trial (18%) [23, 32]. After adjuvant therapy (IA t-PA, angioplasty, snare), the rate of recanalization reached to 60.3%. Furthermore, successful revascularization was found to be an independent predictor of decreased mortality and favorable neurological outcome at 90 days [34]. Similar results were noted in the Multi MERCI trial, which included patients treated with IV t-PA prior to MT and used a modified version of the original MERCI device [35]. These trials are mainly of historical importance as the MERCI device is no longer used in clinical practice.

Penumbra Aspiration System

The Penumbra System (Penumbra Inc., Alameda, CA) is an aspiration device through which the thrombus can be retrieved from the occluded vessel. The aspiration device is advanced coaxially to the level of the thrombus through a guide catheter, and an aspiration pump or aspiration syringe is connected to the reperfusion catheter. Based on the results of the Penumbra Pivotal trial demonstrating a recanalization rate of thrombolysis in myocardial infarction (TIMI) 2–3 of 81.6% and rates of mRS 0–2 of 20%, coupled with a rate of sICH of 11.2%, the Penumbra device received FDA approval in 2008 [36]. Ever since, newer-generation reperfusion catheters with an increasingly larger diameter and improved navigability have been designed, which have substantially improved procedural results with this device [37].

Stentrievers

Retrievable stent thrombectomy devices (stentrievers) are self-expanding stent-like structures attached to a microwire that are designed to capture the thrombus. These devices emerged as favorable methods for MT in stroke after the first two such devices (Solitaire and Trevo) showed overwhelmingly superior rates of recanalization and better clinical outcomes in a head-to-head comparison against the MERCI device [38, 39].

Another technique, manual aspiration thrombectomy, has also been used in the treatment of large vessel occlusion. This technique was initially described for use in the extracranial posterior circulation and later in the BA [40–42]. Single-arm studies supported the use of manual aspiration as part of a multimodality recanalization strategy [43].

Early Evidence for Endovascular Treatment

Many of the early trials on MT excluded PCS [22, 23, 44–47]. MERCI and Multi MERCI enrolled a total of 26 patients with BAO and 1 patient with VA plus bilateral posterior cerebral artery occlusions [34, 35]. While lacking a control group, a consistent finding of all the early MT trials was that favorable outcomes were seen in significantly higher proportions in patients who achieved recanalization compared to those without [48]. The first large randomized endovascular stroke trial, the Endovascular Therapy after Intravenous t-PA versus t-PA Alone for Stroke (IMS III) trial, included only 4 patients with BAO. This trial was stopped prior to completing enrollment of the planned sample size due to futility [49]. In the Penumbra Pivotal trial, only 11 patients with vertebrobasilar occlusion were included [36]. As such, limited conclusions can be drawn regarding the efficacy of MT with early-generation devices from these small numbers of patients. A summary of various endovascular trials including patients with posterior circulation stroke is shown in Table 11.1.

BASICS represents an international, multicenter prospective registry that enrolled patients presenting with BAO confirmed by CTA or MRA. Patients were treated with best medical management, including IV t-PA (within 4.5 h of the estimated time of BAO) or antithrombotics, or best medical management plus IA therapy [4]. IA therapy had to be initiated within 6 h, and the strategy used was at the discretion of the treating neurointerventionalist, including IA thrombolysis (with urokinase) or IA stenting. Analysis of the BASICS registry data revealed no statistically significant difference in poor outcome (defined

Table 11.1 Summary of trials including patients with posterior circulation large vessel occlusion

Trial	Patients treated	Time window	Recanalization	Mortality at 90 days
MERCI Multi MERCI	27	<8 h	21 (78%) TIMI II or more	12 (44%)
Penumbra pivotal	11	<8 h	Unknown	Unknown
SWIFT	2 (roll in) 1 (SOLITAIRE) 1 (MERCI0	<8 h	Unknown	Unknown
TREVO 2	7 (TREVO) 5 (MERCI)	<8 h	Unknown	Unknown
IMS III	4	Procedure start <5 h, end <7 h	Unknown	Unknown
BASICS	288	No limit	207 (72%) TIMI II or more	Unknown
ENDOSTROKE registry	148	No limit	111 (79%) TICI 2b-3	43 (35%)
BEST	66	<8 h	47 (71.4%) TICI 2b-3	22 (33.3%)

as mRS 4–6 at 1 month) between patients treated with IV thrombolysis or antithrombotics alone compared to intra-arterial therapy (55% of patients) [4]. A portion of patients (10%) included in the registry had no treatment, either because symptoms were mild while already on antithrombotics or because further treatment was considered futile. Overall, 68% of patients had a poor outcome, with a mortality rate of 36%. However, successful recanalization with IA therapy was associated with higher likelihood of favorable outcomes. In this nonrandomized study, there was also a suspected bias toward more aggressive treatment in patients with a more severe presentation, which is a confounder of worse outcome [4]. Another limitation of this registry is that modern stentrievers were not available at the time of the study.

Modern Endovascular Trials

In 2015, five prospective RCTs showed overwhelming benefit for MT performed largely with stentrievers in patients with AIS due to LVO presenting in the early time window [50–54]. Another positive trial was published in 2016 [55]. However, none of these studies included patients with BAO. Subsequent trials showing arguably stronger benefit of MT than that observed in the early time window trials were seen in patients presenting from 6 to 24 h with evidence of substantial areas of salvageable brain on neuroimaging. However, these trials also did not include BAO [56, 57].

Observational data from the Endovascular Stroke Treatment Registry (ENDOSTROKE), an international registry of patients aged 18 or older who underwent attempted MT, showed that only 34% of patients with BAO and attempted MT had a good clinical outcome at 3 months, despite 79% recanalization rate of thrombolysis in cerebral infarction (TICI) 2b-3 [58]. This confirms previously held beliefs that, at comparable recanalization rates, clinical outcomes with MT for BAO are poorer than those seen in ACS. Factors predictive of favorable outcomes included young age and low NIHSS at presentation [58]. This suggests that acute stroke due to BAO continues to remain a formidable challenge requiring a multifaceted approach as recanalization alone may be insufficient in achieving a good outcome.

There is limited randomized controlled data on BAO treatment with MT (Table 11.1). Acute Basilar Artery Occlusion: Endovascular Interventions versus Standard Medical Treatment (BEST) was a RCT evaluating endovascular treatment of BAO compared to standard care (including IV t-PA in eligible patients) within 8 h of estimated occlusion time [59]. The trial was stopped early due to excessive crossovers and a progressive drop in recruitment, underscoring again the ethical challenges associated with conducting BAO trials. The trial aimed to demonstrate that MT for BAO (when performed within 8 h of estimated occlusion time) yields a higher rate of favorable clinical outcomes expressed as an mRS score of 0–3 compared to standard medical therapy. The study enrolled 131 patients, 66 allocated to intervention and 65 allocated to control, including patients treated with IV t-PA (30%) as part of standard medical therapy. The intention-to-treat analysis of BEST failed to show a statistically significant benefit in favor of MT (rates of mRS 0–3 in MT were 42.4% vs 32.3 in controls, $p = 0.232$, which was attributed to the high number (21.5%) of crossovers from medical therapy to MT in the medical group). When analyzed "per protocol," a significant difference in the primary outcome between MT and control patients was found (44.4% vs 25.5%, respectively, $p = 0.036$). A nonstatistically significant increase in sICH was noted in the MT group compared to the control group (7.9% compared to 0%, $p = 0.064$). Despite lack of class I evidence, due to the very poor likelihood of favorable clinical outcomes in patients with BAO without recanalization, MT is currently offered at most endovascular centers as a part of routine care protocols.

Selection Criteria for Endovascular Treatment

Selection based on imaging played an important role in the success of the landmark MT trials, especially in those patients enrolled in the extended time window. Just like with the ACS, key questions that imaging aims to answer in PCS are: is it an ischemic or hemorrhagic stroke? is there a large vessel occlusion? what is the extent of infarcted tissue? and what is the extent of "at-risk" (penumbral) tissue? With regard to MT for ACS, our understanding of imaging's role as a patient selection tool for MT has been continuously evolving. It has long been believed that patients with large baseline infarcts should not be treated because of futility or even harm in the form of reperfusion injury, resulting in sICH or malignant edema. However, data from a large pooled analysis of nearly 1800 patients directly contradicts this concept by showing that in the early time window, even patients with large baseline infarcts still stand to benefit from MT [60]. Furthermore, baseline infarct size, regardless of imaging modalities through which it is being measured, while a strong prognostic factor, is not capable of identifying which patients benefit and which patients do not benefit from MT. Whether the same findings apply to BAO stroke remains to be established.

Similar to the ACS, CTA is a reliable method for identifying vascular occlusions in the PCS [61]. However, detection of early ischemic changes based on noncontrast CT is more difficult in the PCS compared to ACS. Using areas of hypoattenuation on CTA source images improves the accuracy of infarct size estimation [62]. The posterior circulation Acute Stroke Prognosis Early CT Score (pc-ASPECTs) allots 10 points to the normal posterior circulation and deducts one point for early region with early ischemic changes on CTA source images [63]. One point is subtracted for early ischemic changes in the right or left thalamus, cerebellar hemispheres, or posterior cerebral artery territory. Two points are deducted for early ischemic changes in the midbrain or pons. Just like its anterior equivalent, pc-ASPECTS appears to be a powerful prognostic factor. In a case series of patients treated with endovascular therapy for BAO, of patients with recanalization of the BA, 70% of those with a pc-ASPECTS score of ≥8 had a favorable outcome, compared to those with scores <8 having 9% favorable outcomes (RR 12.1; 95% CI 1.7 to 84.9) [63]. Because of the low rates of favorable outcomes noted in patients with low pc-ASPECTS, this score has been proposed as a way to improve selection of patients for future trials. However, the absence of a control group in the case series describing the association of pre-intervention pc-ASPECTS with clinical outcomes does not rule out the possibility that clinical benefit may still exist in patients with low pc-ASPECTS scores who undergo MT compared to those who do not.

Another method of quantifying early ischemic changes in the PCS is the Pons Midbrain Index [64]. This system involves scoring each side of the pons and midbrain from 0 to 2 on the CTA source images; 0, no hypoattenuation; 1, equal or less than 50% hypoattenuation; or 2, more than 50% hypoattenuation. A study conducted on patients from the BASICS registry revealed that those with a Pons Midbrain Index of <3 were less likely to die and more likely to have a favorable outcome compared to those patients with a comparatively higher index [65].

Multiple scoring systems for brainstem DWI lesions on MRI have also been proposed to quantify infarct burden in patients with BAO, including using pc-ASPECTS with MRI [66, 67]. Regardless of the scoring system used, the absence of extensive infarct on MRI is associated with a favorable outcome with mechanical MT [68]. In addition to infarct volume, infarct topography is of crucial importance with regard to prognosis in these patients. Based on a retrospective review of patients treated with MT for BAO who underwent a postprocedure MRI, one group reported that the only significant predictors of favorable outcome (mRS 0–2) were age (OR 0.84, 95% CI 0.74–0.91, p = 0,018) and infarct volume in the brainstem (OR 0.25, 95% CI 0.11–0.61, p = 0,002) [69]. Time to treatment and infarct volume were not associated with clinical outcomes for strokes outside of the brainstem. Another study also demonstrated a lack of association between time to treatment and clinical outcomes, specifically in patients with BAO who underwent MT for BAO [70]. Identical to the rates of favorable (33%) outcomes seen in a similarly large case series of patients treated in earlier time window (median time to treatment 300 min), rates of favorable outcomes in the study conducted by Starr et al. were 33% and time to treatment was not associated with the likelihood of a favorable outcome [71]. Rangaraju et al. described the Pittsburgh Outcomes in Thrombectomy for anterior circulation stroke (POST) score as a prognostic tool that aims to inform physicians and family members of the likelihood of a favorable outcome after MT for BAO and thus aid in the post-MT care decision-making process [72]. However, this score has been validated for patients with ACS only.

Using strict time criteria as selection criteria for treatment of BAO has been called into question by multiple authors. The presentation of BAO can be insidious and protean, making an accurate determination of symptom onset timing very challenging [8]. Studies have shown that patients with BAO treated more than 24 h from LSW can have clinical outcomes and rates of sICH that are comparable to those seen in patients treated early [70, 71]. The highly developed collateral arterial network in the posterior circulation, reverse filling of the BA, and a layer of plasma flow between the clot and artery wall have been proposed to maintain brainstem viability for longer time after BAO compared to occlusions in the anterior circulation [73]. On the contrary, Grevik et al. analyzed a cohort of 619 patients with BAO from BASICS and found that time to treatment is an independent predictor of outcome, along with age, baseline NIHSS, hyperlipidemia, and minor prodromal stroke symptoms. Although the therapeutic time window may be longer in BAO patients than in ACS patients, the importance of prompt and active therapy to save the penumbra area should also be emphasized in BAO treatment.

Technical Considerations

The anatomy of the vertebrobasilar circulation can pose technical challenges in MT. The caliber of the vessels in the posterior circulation is generally smaller than that of large arteries in the anterior circulation, requiring careful consideration when selecting catheters and devices [74]. There are also a number of anatomical variations in the posterior circulation, such as VA termination at the posterior inferior cerebellar artery [75]. Some anatomical characteristics may represent an advantage. For example, the lesser tortuosity of the VA compared to the internal carotid artery makes direct thromboaspiration feasible in the

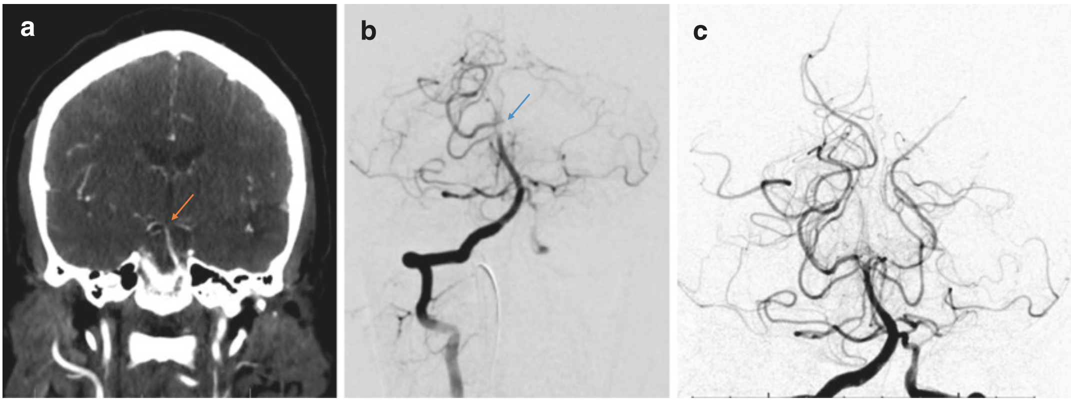

Fig. 11.1 A middle-aged woman with a history of atrial fibrillation on anticoagulation was admitted to the hospital for workup of new-onset, recurrent seizures. During her hospitalization, she was found to be unresponsive during a routine nursing check, which prompted a stroke code activation. NIHSS performed by the Stroke team was calculated at 29. STAT CTA demonstrated a basilar tip occlusion (**a**, arrow). She went for emergent endovascular thrombectomy, where the first base catheter run demonstrated the basilar tip occlusion (**b**, arrow). She underwent thromboaspiration and achieved TICI 2B recanalization (**c**)

vertebrobasilar system [41–43]. An example is demonstrated in Fig. 11.1.

A subgroup of patients with PCS has tandem BAO and VA occlusions (intracranially or extracranially), making access to the BAO more challenging, especially when the contralateral VA is hypoplastic or occluded. Access can be through the patent VA, or the occluded VA, which depending on the location and etiology of the occlusion (e.g., atherosclerotic) may require stenting or angioplasty. The choice of the approach should be tailored to the individual anatomic and clinical considerations [76, 77]. Some studies suggest that once base catheter access is achieved in the VA and the BA is accessed via microcatheter, contralateral VA low flow, from either an occlusion or hypoplasia, is associated with better recanalization and lower risk of distal embolization [75]. This may be due to the lack of flow reversal when the contralateral VA is patent during aspiration. When standard access is not possible, for instance, if the VA ostium is occluded and thus not visible, alternative approaches to access the BA have been employed. These approaches include obtaining retrograde access through the posterior communicating artery, using thyrocervical collaterals in a chronically occluded VA, or using a hypoplastic contralateral VA access to pass a microwire retrograde through the occluded VA ostium to delineate its location [78–80].

Treatment of VA ostium high-grade stenosis or occlusion is also a consideration when the occluded VA represents the only access site to the BAO. Since occlusion of the VA results in a low flow state, and because of the high propensity for re-occlusion with angioplasty alone, stenting should be the preferred choice. There are generally two approaches, consisting either of stenting the vessel prior to accessing the distal lesion or more commonly of placing a stent at the end of the procedure after the distal reperfusion is complete [76]. The former approach has the main advantage of allowing intracranial access and is required when access cannot be established otherwise. It may also allow placement of larger bore guide catheters that may not be able to be navigated through a severe ostial stenosis [81]. The latter approach more rapidly restores flow to the ischemic tissue, avoids the risk of dislodgement of the stent with passage of a large sheath through the stent, and can be done after the intracranial work is complete [80]. Both approaches require the use of dual antiplatelet therapy (periprocedurally, this can be in the form of IV GP IIb/IIIa inhibitors), which can be of concern, especially in patients with large cerebellar infarcts who may require open surgical decompressive surgery. Thus, if the likelihood of posterior fossa decompression is deemed to be high, VA angioplasty may be the best alternative. Because of the relatively high incidence of atherosclerotic lesions underlying the occlusion compared to anterior circulation occlusions, especially in the proximal segment of the BA, consideration should be given to acute angioplasty or (preferably) stenting, especially when MT yields either no recanalization or recanalization with residual high-grade stenosis. This can be accomplished with self-expanding stents, balloon-mounted stents, or detachable stentrievers (Solitaire AB) [82, 83]. This angioplasty with or without stenting is often performed in Asian countries where intracranial atherosclerotic occlusion is relatively common [84]. An example is demonstrated in Fig. 11.2.

Treatment for LVOs with balloon-mounted stents as a second-line approach after MT in patients with presumed intracranial atherosclerosis has been shown to have reperfusion rates and clinical outcomes comparable to MT [82]. However, the rates of sICH and mortality were higher than those seen with traditional MT devices in this cohort of high-risk patients, a significant proportion of whom had BAO. While the advent of modern intermediate catheters has made delivery of balloon-mounted stents in the BA feasible with high reliability, the need for immediate antiplatelet agent administration to prevent stent thrombosis, with their ensuing hemorrhagic risk, especially in those patients who receive IV t-PA, is potential limitation of this technology. Larger randomized studies are needed to assess the safety and efficacy of this treatment modality.

Future Directions

Ongoing clinical trials, including the Basilar Artery Occlusion Chinese Endovascular Trial (BAOCHE) and BASIC, hope to address some of the gaps in evidence for endovascular treatment of BAO [85, 86]. Trials examining neuro-

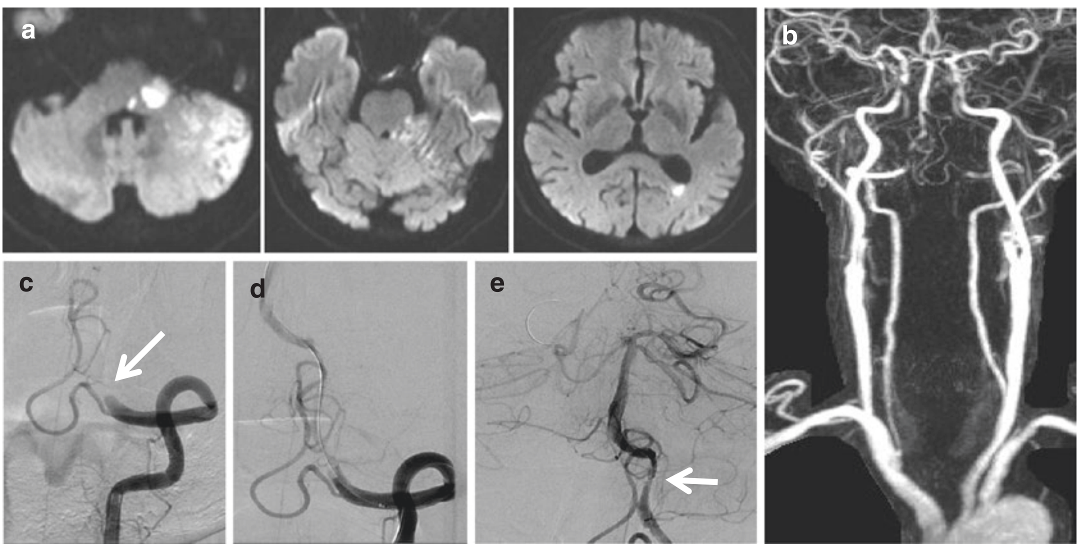

Fig. 11.2 A 65-year-old man with a history of hypertension and diabetes mellitus developed recurrent episodes of dizziness for a few days, followed by sudden vertigo, dysarthria, and gait ataxia. Diffusion-weighted MRI showed acute infarcts in the right pons, cerebellar peduncle, cerebellum, and occipital area (**a**). MR angiogram showed bilateral steno-occlusion in the distal vertebral arteries (VAs) (**b**). Initially, he was alert, but he became drowsy and his symptoms progressed. He went for emergent endovascular thrombectomy. Catheter angiogram showed occlusion of the right distal VA (**c**, arrow). Thrombectomy was performed with a stentriever, and residual stenosis was managed with angioplasty and intracranial stent application (**d**) to maintain patency of the dominant left vertebral artery (**e**). He became alert and was discharged with mild dysarthria only

protectants, which include the Field Randomization of NA-1 Therapy in Early Responders and No-NO, are also underway [87]. It is hoped that neuroprotectant drugs may result in prolongation of the therapeutic time window by transforming "fast progressors" into "slow progressors." Other potentially beneficial effects of neuroprotectant agents include mitigation of reperfusion injury and apoptosis and inflammation [88, 89]. Technological solutions are being proposed to address the challenges of endovascular treatment for PCS. For example, stentrievers are being developed with the ability to detach should the lesion require stenting. This could be particularly useful for the PCS where there is a higher likelihood of underlying intracranial atherosclerotic disease [90]. Transporting patients to the appropriate medical center is necessary to facilitate timely treatment, particularly with PCS where there is a higher rate of misdiagnosis [91]. Finally, improvement in systems of care is needed to increase access to timely endovascular treatment for patients with large vessel occlusion including those with BAO.

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