Outcomes and Prognosis

15

Nitish Kumar, Vamshi K. S. Balasetti, Farhan Siddiq, Brandi R. French, Camilo R. Gomez, and Adnan I. Qureshi

Introduction

Ischemic stroke (i.e., infarction) occurring as a result of disorders affecting the vertebrobasilar system, results in ischemic injury to the brainstem, the cerebellum, and/or the posterior portions of the cerebral hemispheres [1]. Historically, these types of cerebrovascular events account for approximately 30% of all ischemic strokes [2]. The recognition of posterior circulation transient ischemic attack or stroke is more difficult to make compared to anterior circulation, mostly because of the complexity of the vertebrobasilar system. Current guidelines for the management of posterior circulation are similar to anterior circulation stroke, although several differences exist in their presentations, disease mechanism, and their outcomes [3–7]. The prognosis of posterior circulation differs depending on stenosis/occlusion, and vertebrobasilar stenosis, for example, increases the risk by three times [8–10]. Moreover, the etiology of stroke also affects the functional outcomes, as shown by Chung et al., where large artery atherosclerosis and cardioembolic etiologies carry worse functional outcome at discharge and 3 months, respectively, in a posterior circulation stroke [11].

N. Kumar (✉) · V. K. S. Balasetti · B. R. French
C. R. Gomez · A. I. Qureshi
The Department of Neurology, University of Missouri Columbia School of Medicine, Columbia, MO, USA
e-mail: vbzzn@health.missouri.edu; frenchb@health.missouri.edu; crgomez@missouri.edu

F. Siddiq
The Division of Neurosurgery, University of Missouri Columbia School of Medicine, Columbia, MO, USA
e-mail: farhansiddiq@missouri.edu

Mechanism of Vertebrobasilar Ischemic Stroke

The most common causes of posterior circulation ischemia are cardioembolism, large artery atherosclerosis, and small artery disease. Atherosclerosis often occurs at or near the origin of the vertebral artery [3]. Caplan et al. in 2004 proposed that the mechanism of ischemic stroke in anterior and posterior circulation is different. The conclusion was based on a study of 407 patients between 1988 and 1996 from New England Medical Center-Posterior Circulation Registry. Patients with posterior circulation ischemic events had a lower frequency of cardioembolic etiology (24%) compared with large artery disease (32%). In patients with anterior circulation ischemic events, a higher frequency of cardioembolic etiology was detected (38%) compared with large artery disease (9%) [2].

Posterior circulation ischemic stroke incidence rates are different for asymptomatic and symptomatic vertebrobasilar disease. In New England Medical Center-Posterior Circulation Registry, 9% of the 407 patients had complete occlusion vertebral artery occlusion and 2.7%

© Springer Nature Singapore Pte Ltd. 2021

J. S. Kim (ed.), *Posterior Circulation Stroke*, https://doi.org/10.1007/978-981-15-6739-1_15

had bilateral vertebral artery occlusion [2]. Atherosclerotic stenosis ≥50% in either the vertebral artery is found in approximately 25% of the patients with vertebrobasilar transient ischemic attack or stroke. The stenosis is most frequently located in the proximal vertebral artery [10]. Patients with symptomatic vertebrobasilar stenosis are at risk of stroke occurrence despite the medical therapy occurring in 10–15% of the patients in 2 years [12]. In one study, 7.6% of the patients with asymptomatic vertebral artery stenosis >50% were followed for mean 4.6 years; posterior circulation stroke occurred in <0.1% of the patients. The risk of stroke was higher for patients with vertebral artery stenosis than in patients without vertebral artery stenosis [5]. A study from Taiwan analyzed 286 patients who presented with posterior circulation stroke and found that basilar artery branch occlusive disease (28%) and large artery dissection (25.9%) were the two most common etiologies, followed by large artery atherosclerotic stenosis or occlusion (26%), cardioembolism (18.5%), and small vessel disease (7%) [11].

Early Outcomes: First 90 Days

Recurrent Stroke

A meta-analysis published in 2003 demonstrated a higher risk of recurrent ischemic strokes in the posterior circulation in the first 7 days (acute phase) in patients with vertebrobasilar stenosis (odds ratio 1.47, 95% confidence interval (CI) 1.1–2.0, $p = 0.014$) [9]. Conversely, they also found that the risk of recurrent stroke was low (odds ratio 0.74, 95% confidence interval 0.7–0.8) after the first 7 days. This was further confirmed in recent studies: Oxford Vascular Study and 1 hospital register-based study (St. George's Study) [8]. Both studies demonstrated that vertebrobasilar stenosis was a major predictor of recurrent stroke, particularly in the first month. A pooled individual patient analysis from the Oxford Vascular Study and St. George's Study demonstrated that 90-day risk of stroke from the first event was 24.6% in patients with vertebrobasilar stenosis versus 7.2% in patients without any stenosis. This was further supported by another study that showed that risk of recurrence stroke and the risk of any vertebrobasilar disease recurrence (including both transient ischemic stroke and stroke) at 90 days was up to 3 times higher in patients with stenosis compared with those without stenosis [12].

Schonewille et al. did a prospective, observational study from the "The Basilar Artery International Cooperative Study" registry of 619 consecutive patients who presented with an acute symptomatic and radiologically conformed basilar artery occlusion [13]. Patients were divided into three groups based on the treatment they received: (1) antithrombotic treatment only, which comprised antiplatelets or systemic anticoagulation; (2) primary intravenous therapy including subsequent intra-arterial thrombolysis; and (3) intra-arterial therapy including thrombolysis, mechanical thrombectomy, stenting, or a combination of these approaches. The outcome was assessed at 1 month, and poor outcome was defined as a modified Rankin scale score of 4 or 5, or death. They reported that overall, 68% (492/592) of analyzed patients had a poor outcome at 30 days. They also showed that compared to antiplatelet or anticoagulant therapy, patients with a severe deficit had a lower risk of poor outcomes when received intravenous therapy (adjusted relative risk 0.88, confidence interval 0.76–1.01) or when received intra-arterial therapy (adjusted relative risk 0.94, confidence interval 0.86–1.02).

A systematic analysis from Finland by Lindsberg et al. looked at the outcome of basilar artery occlusion patients treated with intra-arterial thrombolysis or intravenous thrombolysis. Modified Rankin scale score 0–2, Barthel Index 95 to 100, or Glasgow Outcome Scale 5 was considered as good outcomes [14]. Approximately 3-month outcome was provided. Of 420 patients, 76/420 were treated with intravenous therapy and 344/420 were treated with intra-arterial therapy. Death or dependency was similar in both groups ($p = 0.82$) reportedly in 78% (59/76) of patients treated with intravenous therapy and 76%

(260/344) of patients treated with intra-arterial therapy. Even though recanalization rate was higher in intra-arterial group (65%, 225/344) compared to intravenous group (53%,40/76, $p = 0.05$), survival rates (50% vs 45%, $p = 0.48$) were equal. A similar rate of good outcomes (24% vs 22%, $p = 0.82$) was seen in both groups. Without recanalization, the likelihood of good outcome was close to 2%.

A systematic review and meta-analysis were done by Schonewille et al. and colleagues to analyze the efficacy of different methods of acute basilar artery occlusion. They reviewed 102 articles to analyze the treatment options. The weighted pooled rate of mortality was 43.16% (95% confidence interval 38.35–48.03%) in the intravenous thrombolysis group, 45.56% (95% confidence interval 39.88–51.28%) in the intra-arterial thrombolysis group, and 31.40% (95% confidence interval 28.31–34.56%) in the endovascular thrombectomy group. The weighted pooled rate of modified Rankin score 0–2 at 3 months was 31.40% (95% confidence interval 28.31–34.56%) in the intravenous thrombolysis group, 28.29% (95% confidence interval 23.16–33.69%) in the intra-arterial thrombolysis group, and 35.22% (95% confidence interval 32.39–38.09%) in the endovascular thrombectomy group [13].

A study from Switzerland looked at the 106 patients treated between 1992 and 2010 with intra-arterial thrombolysis. At 3 months, clinical outcome was good (modified Rankin scale score, 0–2) in 33% of the patients and 11.3% had a moderate outcome (modified Rankin scale score, 3). Mortality was 40.6% [14].

Death or Disability

A Korean study looked at 7718 patients for minor anterior circulation and minor posterior circulation stroke and disability at 3-month follow-up. Disability (modified Rankin scale score 2–6) was seen in 32.3% of the patients with minor posterior circulation stroke (compared to 30.3% of minor anterior circulation stroke, $p = 0.07$) and death in 1.3% of the patients (compared to 1.5% of minor anterior circulation stroke, $p = 0.82$) [15].

Prospective data of 116 patients with posterior circulation stroke who were admitted to a single Qatar hospital were collected from 2005 through 2008 with mean duration from symptom onset to presentation of 29 h reported the following: 71% of the patients were discharged home while 10% died, and modified Rankin scale score at discharge was ≤2 in 53% and ≥4% in 13% of the patients. The modified Rankin scale score was ≤2 in 68% of the patients at 30-day follow-up. Almost 90% of the patients were alive with a modified Rankin scale score of ≤2 seen in 73% of the patients [16].

Predictors of Outcome

Chung et al. looked at the etiologies of posterior circulation stroke and their association with outcome. They also suggested age >70 years, National Institute of Health Stroke Scale >9, and certain stroke etiologies (large artery atherosclerosis and cardioembolism) as predictors of poor functional outcomes (defined by modified Rankin scale score >5), which are associated with poor functional outcomes at the discharge and 3 months [11, 17].

Etiologies of posterior circulation stroke affecting the outcomes were further supported in a study by Glass et al., which found that outcomes of posterior circulation stroke differed depending on vascular occlusive lesion, brain infarct location, and stroke mechanism [18].

Occlusion of the basilar artery led to the worst outcome (>50% of the patients had poor outcomes at 30 days, defined by death or severe disability) [18]. Basilar artery occlusive disease was responsible for the greatest risk of mortality and disability followed by intracranial vertebral, extracranial vertebral, and posterior cerebral artery. Schonewille et al. reported outcomes in patients with posterior circulation stroke at 28 days: almost 80% of the basilar artery occlusion patients had poor outcomes with a case fatality rate of 40%, and 65% of the survivors had severe residual deficits. They also identified 3

potential predictors of outcomes in patients treated by conventional methods (antiplatelets or anticoagulants or both): age (young vs old), stroke severity, and presenting symptoms (fluctuating vs maximum deficits from the onset) with younger age (<60 years), less severe stroke and fluctuating symptoms favoring better outcomes [19]. One study looked at 87 patients with predominantly minor stroke and occlusive basilar disease documented based on transcranial Doppler, magnetic resonance angiography, or conventional angiography and found an overall case fatality rate of about 2.3%. The low case fatality rate in this study could be due to a higher number of patients with minor deficits being diagnosed with vertebrobasilar disease [20].

A Chinese study combined the National Institutes of Health stroke scale score and posterior circulation Alberta stroke program early computed tomography score through diffusion-weighted imaging in 125 patients with posterior circulation stroke. Patients with higher baseline National Institutes of Health stroke scale score (6.3±7.4) and lower posterior circulation Alberta stroke program early computed tomography score (≤7) in the first 36 h of stroke onset had unfavorable outcomes (modified Rankin scale score at 90 days 3–6). Age >70 years and the presence of diabetes mellitus were significant predictors of unfavorable outcomes [21].

Tsao et al. looked at 21 consecutive patients retrospectively who received either intravenous or intra-arterial tissue plasminogen activator for posterior circulation ischemic stroke at University of California between 1993 and 2001. Results showed that high presenting Glasgow coma scale score ≥ 9 was predictive of good patient outcome (modified Rankin scale score at 3 months =/<2) [22].

Another study looked at the correlation between the severity of the neurologic deficit and posterior circulation stroke. Almost 1200 patients with anterior circulation stroke and 400 with posterior circulation strokes were included with median National Institutes of Health stroke scale scores of 7 and 2, respectively. Of the patients analyzed, 70% of the posterior circulation stroke patients had National Institutes of Health stroke scale score ≤4, and around 15% of them had a poor prognosis [23]. Sato et al. in his study of 100 patients showed that the National Institutes of Health stroke scale score appears to have limitations in predicting outcomes in posterior circulation stroke [24]. The cutoff score of the baseline National Institutes of Health stroke scale score for a favorable outcome was relatively low in patients with posterior circulation stroke compared to patients with anterior circulation stroke. The National Institutes of Health stroke scale score seems to be weighted toward anterior circulation stroke and tends to underestimate the severity of the posterior circulation stroke [23–25].

Adaptation of the National Institutes of Health stroke scale score for elements common to the posterior circulation stroke, such as vertigo, dizziness, or confusion, may increase its sensitivity [26].

Another study of 88 patients in Switzerland reported statistically significant association of certain admission clinical characteristics with an outcome in patients presenting with stroke or transient ischemic attacks in the basilar artery stenosis or occlusion. Dysarthria, pupillary disorders, lower cranial nerve involvement, and consciousness disorders at admission were strongly ($P < 0.001$) associated with poor outcomes, defined by severe disability or death. A multivariate analysis showed that the outcome was poor in 100% of cases with either consciousness disorders or other 3 clinical characteristics [27]. Interestingly, in the absence of these factors, a poor outcome (severe disability or death) was reported in only 11% of the patients.

Sommer et al. used propensity-score matching to balance patient characteristics and stroke severity between 4604 patients of posterior circulation and 4604 patients of anterior circulation stroke enrolled within the Austrian Stroke registry [28]. A total of 477 (10.3%) patients within the posterior circulation stroke group were treated with tissue plasminogen activator compared to 4433 (~19%) of anterior circulation stroke patients. Patients with posterior circulation stroke had 19% higher odds of poor functional outcome ($p < 0.0001$) as assessed by the modified Rankin

scale at 3 months. Patients who got tissue plasminogen activator did not show a significant difference in the functional outcome irrespective of infarct localization. However, more deficits in the posterior circulation stroke group were found to be driven by patients who could not receive tissue plasminogen activator and had presented after 4.5 h of the symptom onset. These patients had 34% odds of poor functional outcomes compared to anterior circulation stroke patients. These results were independent of stroke severity tissue plasminogen activator treatment, demographic, and vascular risk factors. This observation supported the findings of other few studies that showed the effectiveness of tissue plasminogen activator for stroke irrespective of localization [29–31]. The effect of time delays on the therapeutic outcomes of tissue plasminogen activator in posterior circulation stroke is further supported by the retrospective study of 95 patients done in China, which demonstrated that for patients with an onset-to-treatment time of 0–90 min, the rate of favorable outcome (defined by modified Rankin Scale<2) was 100% as opposed to 73.7% of favorable outcome for patients with an onset-to-treatment time of 181–237 min [32].

Only a few studies have looked at the direct relationship between the initial Glasgow coma scale score and clinical outcomes in the patients with posterior circulation stroke [33–35]. Schwarz et al. described 45 patients with posterior circulation stroke and found that those who had lower presenting Glasgow coma scale scores had worse clinical outcomes [35]. A few studies found tetraparesis and coma as independent predictors of poor outcomes [20, 36].

Late Outcomes: Beyond the First Year

Qureshi et al. and the group did a cohort study looking at the risk of recurrent stroke and death associated with vertebrobasilar stenosis and occlusion in 10,515 patients, diagnosed either by computed tomography, magnetic resonance angiography, or catheter angiogram [37]. Patients were selected from the Taiwan Stroke registry. They found 66% of the patients with none-to-mild stenosis and 29.8% with moderate-to-severe stenosis, and occlusion was identified in 3.8% of the patients. There was a significantly higher risk of recurrent stroke at 1 year (hazard ratio 1.21, 95% confidence interval 1.01–1.45) among the patients with moderate-to-severe vertebrobasilar stenosis. There was a nonsignificantly higher risk of recurrent stroke (hazard ratio 1.49, 95% confidence interval 0.99–2.22) and a significantly higher risk of death (hazard ratio 2.21, 95% CI 1.72–2.83), among the patients with vertebrobasilar occlusion.

Another retrospective study looked at 102 patients diagnosed with symptomatic vertebrobasilar stenosis and followed up with them for the development of stroke and disability/death for 15±15.9 months (range 1–60 months). Recurrent stroke and mortality were reported in 14% and 21% of the patients, respectively, during the follow-up period.

Stroke-free survival was 76% and 48% at 12 months (95% confidence interval, 66–83%) and at 60 months (95% confidence interval, 27–65%), respectively. The risk of recurrent stroke was 11% per year, and the risk of recurrent stroke and/or death was 24% per year. Older patients had decreased stroke-free survival. Treatment with either antiplatelet agents in 41% or coumadin in 32% improved stroke-free survival [38].

A study from Greece reported 10-year outcomes in posterior circulation stroke patients, and 185 patients were followed up during 1998–2009. They divided their patients into pure posterior cerebral artery infarction group (pure cortical and combined cortical and deep posterior cerebral artery infarct) and posterior cerebral artery infarction-plus group (including posterior cerebral artery stroke and ≥ 1 concomitant infarction outside posterior cerebral artery territory). Of them, 56% of the patients of cortical-only infarct had no or minor disability compared to 26–36% in the posterior cerebral artery-plus group at 6-month follow-up. The 10-year probability of death was 55% for the pure posterior cerebral artery group vs 73% for posterior cerebral artery-plus ($p = 0.001$), showing that posterior cerebral

artery strokes with concomitant infarction outside the posterior cerebral artery territory was associated with an increased risk of disability and long-term mortality [39].

In another study of 51 patients with posterior circulation stroke, 30-day and 3-year survival rates were found to be 96% and 73% for top of the basilar group vs 100% and 71% in the group with involvement of either single penetrating or branch artery involvement, respectively [40].

Ottomeyer et al. looked at the long-term functional outcome and quality of life of patients who presented with acute basilar artery occlusion and got multimodal recanalization therapy. Ninety-one patients were treated during December 2002 and December 2009 by such therapy that included intravenous thrombolysis with consecutive on-demand intra-arterial therapy or intra-arterial therapy alone. The overall recanalization rate was 89%. Long-term survival (median follow-up for 4.2 years) was achieved in approximately 41% of the patients. Among survivors, 74% of the patients had a favorable functional long-term outcome (defined as modified Rankin scale score ≤ 3) [41].

Lindsberg et al. studied 50 consecutive patients between 1995 and 2003 with proven basilar artery occlusion who were treated with intravenous thrombolysis with recombinant tissue plasminogen activator. Recanalization was studied in 43 patients and was verified in 26 patients (52%). In the first 3 months, 40% [20] of the patients died and 11 patients had good outcomes (modified Rankin scale score, 0–2); 12 (24%) were independent of activities of daily living (Barthel Index score, 95–100), and 6 (16%) patients were severely disabled (Barthel Index score, 0–50). After a median follow-up for 2.8 years, 15 (30%) patients reached good outcomes (modified Rankin scale score, 0–2) while 23 (46%) patients died [42].

Jung et al. looked at 3-month and long-term outcomes and their predictors in acute basilar occlusion treated with intra-arterial thrombolysis. Between 3-month and long-term follow-up, 40.8% survivors showed clinical improvement of at least 1 point on the modified Rankin scale score, 53.7% were functionally unchanged, and 5.7% showed functional worsening ($P < 0.0001$). Low baseline National Institutes of Health stroke scale score was identified as a predictor of good or moderate outcome (modified Rankin scale score, 0–3, $p < 0.0001$) and survival ($p = 0.001$) at 3 months. Younger age was identified as an additional predictor of survival ($p = 0.012$). Age was also an independent predictor ($p = 0.018$) for long-term clinical outcome [43].

Cognitive and Functional Outcomes

The information regarding the neuropsychiatric outcomes in patients with vertebrobasilar territory stroke is scarce, and patients with heterogenous arterial lesions were included [44–46].

A case–control study from Brazil compared the cognitive statuses of basilar artery occlusion disease survivors (28 patients) and healthy controls (27 patients). They also looked at the correlation of functional capacity outcomes (modified Rankin scale score) with the cognitive profiles of basilar artery occlusion disease patients. Functional capacity was moderately correlated with the presence of cognitive impairment, indicating that functional results were due to poorer scores on cognitive tests. They found that 75% of the patients (21/28) had no functional disability (modified Rankin scale score of 0–1) at 4.2 years after the stroke suggestive favorable outcomes. Only 25% (7/28) of the patients had mild-to-moderate functional disability (modified Rankin scale score 2–3). Compared to controls, basilar artery occlusion disease patients presented with impairments in selective, sustained, and set-shifting action, processing speed, visuospatial skills, mental flexibility, and monitoring rules. Significant deficits in verbal episodic memory (immediate and delayed recall) and visuospatial episodic memory (immediate and delayed recall and recognition) were noted [47].

Patients with posterior circulation infarctions were noted to have abnormal neuropsychiatric profiles. The impairments were noted in executive function, attention, memory, visuospatial ability, and language [17, 48, 49]. Neural links connecting anterior and posterior regions of the brain may be attributed [45, 46].

References

1. Bogousslavsky J, Van Melle G, Regli F. The Lausanne stroke registry: analysis of 1,000 consecutive patients with first stroke. Stroke. 1988;19(9):1083–92.
2. Caplan LR, Wityk RJ, Glass TA, Tapia J, Pazdera L, Chang HM, et al. New England Medical Center posterior circulation registry. Ann Neurol. 2004;56(3):389–98.
3. Markus HS, van der Worp HB, Rothwell PM. Posterior circulation ischaemic stroke and transient ischaemic attack: diagnosis, investigation, and secondary prevention. Lancet Neurol. 2013;12(10):989–98.
4. Merwick A, Werring D. Posterior circulation ischaemic stroke. BMJ. 2014;348:g3175.
5. Kim JS, Nah HW, Park SM, Kim SK, Cho KH, Lee J, et al. Risk factors and stroke mechanisms in atherosclerotic stroke: intracranial compared with extracranial and anterior compared with posterior circulation disease. Stroke. 2012;43(12):3313–8.
6. Caplan L. Posterior circulation ischemia: then, now, and tomorrow. The Thomas Willis Lecture-2000. Stroke. 2000;31(8):2011–23.
7. Paul NL, Simoni M, Rothwell PM. Transient isolated brainstem symptoms preceding posterior circulation stroke: a population-based study. Lancet Neurol. 2013;12(1):65–71.
8. Gulli G, Khan S, Markus HS. Vertebrobasilar stenosis predicts high early recurrent stroke risk in posterior circulation stroke and TIA. Stroke. 2009;40(8):2732–7.
9. Flossmann E, Rothwell PM. Prognosis of vertebrobasilar transient ischaemic attack and minor stroke. Brain. 2003;126(Pt 9):1940–54.
10. Marquardt L, Kuker W, Chandratheva A, Geraghty O, Rothwell PM. Incidence and prognosis of > or = 50% symptomatic vertebral or basilar artery stenosis: prospective population-based study. Brain. 2009;132(Pt 4):982–8.
11. Chung CP, Yong CS, Chang FC, Sheng WY, Huang HC, Tsai JY, et al. Stroke etiology is associated with outcome in posterior circulation stroke. Ann Clin Transl Neurol. 2015;2(5):510–7.
12. Gulli G, Marquardt L, Rothwell PM, Markus HS. Stroke risk after posterior circulation stroke/transient ischemic attack and its relationship to site of vertebrobasilar stenosis: pooled data analysis from prospective studies. Stroke. 2013;44(3):598–604.
13. Schonewille WJ, Wijman CA, Michel P, Rueckert CM, Weimar C, Mattle HP, 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):724–30.
14. Lindsberg PJ, Mattle HP. Therapy of basilar artery occlusion: a systematic analysis comparing intra-arterial and intravenous thrombolysis. Stroke. 2006;37(3):922–8.
15. Sheng K, Tong M. Therapy for acute basilar artery occlusion: a systematic review and meta-analysis. F1000Res. 2019;8:165.
16. Akhtar N, Kamran SI, Deleu D, D'Souza A, Miyares F, Elsotouhy A, et al. Ischaemic posterior circulation stroke in State of Qatar. Eur J Neurol. 2009;16(9):1004–9.
17. Park KC, Yoon SS, Rhee HY. Executive dysfunction associated with stroke in the posterior cerebral artery territory. J Clin Neurosci. 2011;18(2):203–8.
18. Glass TA, Hennessey PM, Pazdera L, Chang HM, Wityk RJ, Dewitt LD, et al. Outcome at 30 days in the new England Medical Center posterior circulation registry. Arch Neurol. 2002;59(3):369–76.
19. 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.
20. 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.
21. Lin SF, Chen CI, Hu HH, Bai CH. Predicting functional outcomes of posterior circulation acute ischemic stroke in first 36 h of stroke onset. J Neurol. 2018;265(4):926–32.
22. Tsao JW, Hemphill JC 3rd, Johnston SC, Smith WS, Bonovich DC. Initial Glasgow coma scale score predicts outcome following thrombolysis for posterior circulation stroke. Arch Neurol. 2005;62(7):1126–9.
23. Inoa V, Aron AW, Staff I, Fortunato G, Sansing LH. Lower NIH stroke scale scores are required to accurately predict a good prognosis in posterior circulation stroke. Cerebrovasc Dis. 2014;37(4):251–5.
24. Sato S, Toyoda K, Uehara T, Toratani N, Yokota C, Moriwaki H, et al. Baseline NIH stroke scale score predicting outcome in anterior and posterior circulation strokes. Neurology. 2008;70(24 Pt 2):2371–7.
25. Kasner SE. Clinical interpretation and use of stroke scales. Lancet Neurol. 2006;5(7):603–12.
26. Olivato S, Nizzoli S, Cavazzuti M, Casoni F, Nichelli PF, Zini A. E-NIHSS: an expanded National Institutes of Health stroke scale weighted for anterior and posterior circulation strokes. J Stroke Cerebrovasc Dis. 2016;25(12):2953–7.
27. Devuyst G, Bogousslavsky J, Meuli R, Moncayo J, de Freitas G, van Melle G. Stroke or transient ischemic attacks with basilar artery stenosis or occlusion: clinical patterns and outcome. Arch Neurol. 2002;59(4):567–73.
28. Sommer P, Posekany A, Serles W, Marko M, Scharer S, Fertl E, et al. Is functional outcome different in posterior and anterior circulation stroke? Stroke. 2018;49(11):2728–32.
29. Forster A, Gass A, Kern R, Griebe M, Hennerici MG, Szabo K. Thrombolysis in posterior circulation stroke: stroke subtypes and patterns, complications and outcome. Cerebrovasc Dis. 2011;32(4):349–53.
30. Sarikaya H, Arnold M, Engelter ST, Lyrer PA, Mattle HP, Georgiadis D, et al. Outcomes of intravenous thrombolysis in posterior versus anterior circulation stroke. Stroke. 2011;42(9):2498–502.
31. Dornak T, Kral M, Hazlinger M, Herzig R, Veverka T, Burval S, et al. Posterior vs. anterior circulation

infarction: demography, outcomes, and frequency of hemorrhage after thrombolysis. Int J Stroke. 2015;10(8):1224–8.
32. Huang Q, Song HQ, Ma QF, Song XW, Wu J. Effects of time delays on the therapeutic outcomes of intravenous thrombolysis for acute ischemic stroke in the posterior circulation: an observational study. Brain Behav. 2019;9(2):e01189.
33. Cross DT 3rd, Moran CJ, Akins PT, Angtuaco EE, Diringer MN. Relationship between clot location and outcome after basilar artery thrombolysis. AJNR Am J Neuroradiol. 1997;18(7):1221–8.
34. Cross DT 3rd, Moran CJ, Akins PT, Angtuaco EE, Derdeyn CP, Diringer MN. Collateral circulation and outcome after basilar artery thrombolysis. AJNR Am J Neuroradiol. 1998;19(8):1557–63.
35. Schwarz S, Egelhof T, Schwab S, Hacke W. Basilar artery embolism. Clinical syndrome and neuroradiologic patterns in patients without permanent occlusion of the basilar artery. Neurology. 1997;49(5):1346–52.
36. Grond M, Rudolf J, Schmulling S, Stenzel C, Neveling M, Heiss WD. Early intravenous thrombolysis with recombinant tissue-type plasminogen activator in vertebrobasilar ischemic stroke. Arch Neurol. 1998;55(4):466–9.
37. Qureshi AI, Qureshi MH, Lien LM, Lee JT, Jeng JS, Hu CJ, et al. One-year risk of recurrent stroke and death associated with vertebrobasilar artery stenosis and occlusion in a cohort of 10,515 patients. Cerebrovasc Dis. 2019;47(1–2):40–7.
38. Qureshi AI, Ziai WC, Yahia AM, Mohammad Y, Sen S, Agarwal P, et al. Stroke-free survival and its determinants in patients with symptomatic vertebrobasilar stenosis: a multicenter study. Neurosurgery. 2003;52(5):1033–9; discussion 9–40
39. Ntaios G, Spengos K, Vemmou AM, Savvari P, Koroboki E, Stranjalis G, et al. Long-term outcome in posterior cerebral artery stroke. Eur J Neurol. 2011;18(8):1074–80.
40. Nadeau S, Jordan J, Mishra S. Clinical presentation as a guide to early prognosis in vertebrobasilar stroke. Stroke. 1992;23(2):165–70.
41. Ottomeyer C, Zeller J, Fesl G, Holtmannspotter M, Opherk C, Bender A, et al. Multimodal recanalization therapy in acute basilar artery occlusion: long-term functional outcome and quality of life. Stroke. 2012;43(8):2130–5.
42. Lindsberg PJ, Soinne L, Tatlisumak T, Roine RO, Kallela M, Happola O, et al. Long-term outcome after intravenous thrombolysis of basilar artery occlusion. JAMA. 2004;292(15):1862–6.
43. Jung S, Mono ML, Fischer U, Galimanis A, Findling O, De Marchis GM, et al. Three-month and long-term outcomes and their predictors in acute basilar artery occlusion treated with intra-arterial thrombolysis. Stroke. 2011;42(7):1946–51.
44. Garrard P, Bradshaw D, Jager HR, Thompson AJ, Losseff N, Playford D. Cognitive dysfunction after isolated brain stem insult. An underdiagnosed cause of long term morbidity. J Neurol Neurosurg Psychiatry. 2002;73(2):191–4.
45. Hoffmann M, Schmitt F. Cognitive impairment in isolated subtentorial stroke. Acta Neurol Scand. 2004;109(1):14–24.
46. Hoffmann M, Cases LB. Etiology of frontal network syndromes in isolated subtentorial stroke. Behav Neurol. 2008;20(3):101–5.
47. Campanholo KR, Conforto AB, Rimkus CM, Miotto EC. Cognitive and functional impairment in stroke survivors with basilar artery occlusive disease. Behav Neurol. 2015;2015:971514.
48. Martinaud O, Pouliquen D, Gerardin E, Loubeyre M, Hirsbein D, Hannequin D, et al. Visual agnosia and posterior cerebral artery infarcts: an anatomical-clinical study. PLoS One. 2012;7(1):e30433.
49. Capitani E, Laiacona M, Pagani R, Capasso R, Zampetti P, Miceli G. Posterior cerebral artery infarcts and semantic category dissociations: a study of 28 patients. Brain. 2009;132(Pt 4):965–81.