



Predictors of Good Outcome After Endovascular Treatment for Patients with Vertebrobasilar Artery Occlusion due to Intracranial Atherosclerotic Stenosis

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Abstract

Purpose To investigate the predictors for good outcome of endovascular therapy (EVT) for patients with acute vertebrobasilar artery occlusion (VBAO) due to intracranial atherosclerosis stenosis (ICAS).

Methods From April 2012 to February 2018, patients with VBAO due to ICAS who received EVT were retrospectively analyzed. ICAS was defined as fixed stenosis of >70%, or a degree of fixed stenosis >50% in addition to either perfusion impairment or evidence to re-occlusion. Good outcome was defined as mRS ≤ 2 at 90 days. Both logistic regression and receiver operating characteristic curve (ROC) analyses were performed to explore the predictors.

Results Among 103 patients enrolled in the analysis, 40.8% achieved good outcome. Prior antiplatelet therapy (OR, 7.301; 95% CI, 1.761–30.265; $P=0.006$), EVT+IVT (OR, 7.343; 95% CI, 1.621–33.263; $P=0.010$), the pc-ASPECT on DWI (OR, 1.705; 95% CI, 1.127–2.580; $P=0.012$), BATMAN (OR, 1.395; 95% CI, 1.005–1.937; $P=0.047$), general anesthesia (OR, 0.081; 95% CI, 0.010–0.633; $P=0.017$), onset-to-recanalization time (≤ 542 min vs. >542 min) (OR, 0.194; 95% CI, 0.057–0.661; $P=0.009$) and the initial NIHSS (OR, 0.882; 95% CI, 0.820–0.949; $P=0.001$) were significantly associated with good outcome in logistic regression. Based on ROC analyses, initial NIHSS score (area under the curve [AUC]=0.816, $p < 0.001$; cutoff, 19.5; sensitivity, 78.7%; specificity, 72.5%) was significant predictors of good outcome.

Conclusions For patients with VBAO due to ICAS, prior antiplatelet therapy, EVT+IVT, local anesthesia, short onset-to-recanalization time, a low initial NIHSS, a high pc-ASPECT and BATMAN might be helpful to predict the good outcome at 90 days after EVT.

Keywords Acute ischemic stroke · Thrombectomy · Antiplatelet therapy · Pc-ASPECT · BATMAN

Introduction

Acute ischemic stroke caused by vertebrobasilar artery occlusion (VBAO) is associated with high mortality and disability rates, which have been reported to be up to 95% [1]. Some recent studies showed that endovascular treatment (EVT) may be a safe and effective method for recanaliza-

tion but a good clinical outcome at 90 days was approximately 30% despite successful recanalization [2–5], which is lower than that reported for large vessel occlusion in the anterior circulation [6].

As one of the most common subtypes, occlusion attributable to in situ intracranial atherosclerotic disease (ICAS) accounts for 17–60% of VBAO [7–9], and the rate of good outcome at 90 days tends to be lower than that due to embolisms [8]. So far, the prognostic factors that predict outcome after EVT in patients with acute VBAO are limited, especially for occlusion due to ICAS. The aim of this retrospective study was to investigate the prognostic factors for patients with VBAO due to ICAS who received EVT.

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Material and Methods

Patients

From April 2012 to February 2018 patients with VBAO undergoing EVT at this center were retrospectively analyzed. The inclusion criteria were (1) age ≥ 18 years, (2) presented with posterior circulation stroke symptoms and treated by EVT, (3) onset to puncture time < 24 h, (4) National Institute of Health stroke scale (NIHSS) pretreatment ≥ 4 , (5) modified Rankin scale (mRS) ≤ 1 before the qualifying stroke and (6) occlusion of V4 segment of vertebral artery or basilar artery due to ICAS. An ICAS was defined as (1) significant stenosis $> 70\%$ at the occlusion site, or (2) a degree of stenosis $> 50\%$ in addition to either flow and perfusion impairment on angiography or an evident reocclusion tendency even after adequate treatment with stent retrievers, according to Lee et al. [10]. Stenosis caused by vasospasm or iatrogenic dissection was excluded from the study population, which can be identified with delayed angiography or high-resolution magnetic resonance imaging (MRI).

This retrospective study was approved by the ethics committee of Beijing Tiantan Hospital and the institutional review board and the requirement for informed consent for study inclusion was waived because it was a retrospective study.

Treatment

All the patients received treatment according to the standard of care at this center in compliance with the guidelines or expert consensus. Patients with suspected stroke initially underwent a computed tomography (CT) scan which can provide the necessary information to make decisions about acute management. All the patients with posterior circulation artery occlusion should be diagnosed based on vascular imaging before the procedure. Intravenous thrombolysis (IVT) was performed before EVT in patients who were eligible. Loading dose aspirin (300 mg) and/or clopidogrel (300 mg) can be given before the treatment according to the doctors' decision.

The neurointerventionists decided that EVT was performed with the patient under local anesthesia or general anesthesia based on the patient's condition. Because this study was a retrospective analysis, operation strategies were decided at the operator's discretion without special restrictions. Thrombectomy with a Solitaire stent (ev3, Irvine, CA, USA) was recommended as the primary treatment. If the target segment stenosis resulted in inadequate distal perfusion or new thrombus formation at the residual stenosis location culminating in repeated reocclusion after thrombectomy, rescued retrievable stent detachment (Solitaire stent), balloon angioplasty (Gateway, Boston

Scientific Corporation, Natick, MA, USA) or stenting (balloon-mounted Apollo stent, MicroPort Medical, Shanghai, China or self-expandable Wingspan stent, Boston Scientific Corporation, Stryker, USA) can also be performed at the occlusion site to achieve successful reperfusion, defined as modified Thrombolysis in Cerebral Infarction score (mTICI) 2b/3 [11]. Glycoprotein IIb/IIIa inhibitor infusion (tirofiban) would be given, when acute thrombosis or significant residual stenosis was observed.

Nonenhanced CT was performed immediately after the procedure to exclude intracranial hemorrhage. A CT or MRI and transcranial Doppler, CT angiography, magnetic resonance angiography or digital subtraction angiography would be performed at 24 h, or at any time if patients' neurological function deteriorated, to evaluate the status of brain tissue and cerebral arteries. Cerebrospinal fluid drainage or decompressive suboccipital craniectomy with dural expansion might be performed in patients when neurological deterioration was observed from brainstem compression caused by severe edema or hemorrhage despite maximum medical treatment. Severe symptomatic intracranial hemorrhage was defined as intracranial hemorrhage according to 24-h imaging and neurologic deterioration was more than 4 points on the NIHSS [12]. If no intracranial hemorrhage was observed in 24-h imaging, patients would receive a loading dose of clopidogrel (300 mg) orally or via nasogastric tube, and dual antiplatelet treatment (aspirin 100 mg plus clopidogrel 75 mg) for at least 3 months before switching to aspirin or clopidogrel alone.

Clinics and Imaging Assessment

From prospectively collected clinical and imaging databases, the baseline characteristics, procedure details and outcomes were collected. The stroke neurologist at the emergency department assessed and recorded the past medical history, time of symptom onset, mRS before qualifying stroke, and pretreatment NIHSS score. Regular antiplatelet therapy before the qualifying stroke or loading dose of antiplatelet drugs before EVT was recognized as the existence of prior antiplatelet therapy. Pretreatment and follow-up imaging data were evaluated by two experienced neuroradiologists who were blinded to the clinical information and conclusions were reached in consensus. Diffusion-weighted imaging (DWI) ($b = 0$ and $b = 1000$ s/mm²) before treatment was evaluated with the post-circulation Alberta Stroke Program Early CT Score (pc-ASPECTS) [13]. To evaluate both the extent of the occlusion and the presence of collaterals, the basilar artery on computed tomography angiography (BATMAN) score was assessed based on digital subtraction angiography before EVT, according to the method of Alemseged et al. [14].

Fig. 1 Flow chart of patients inclusion

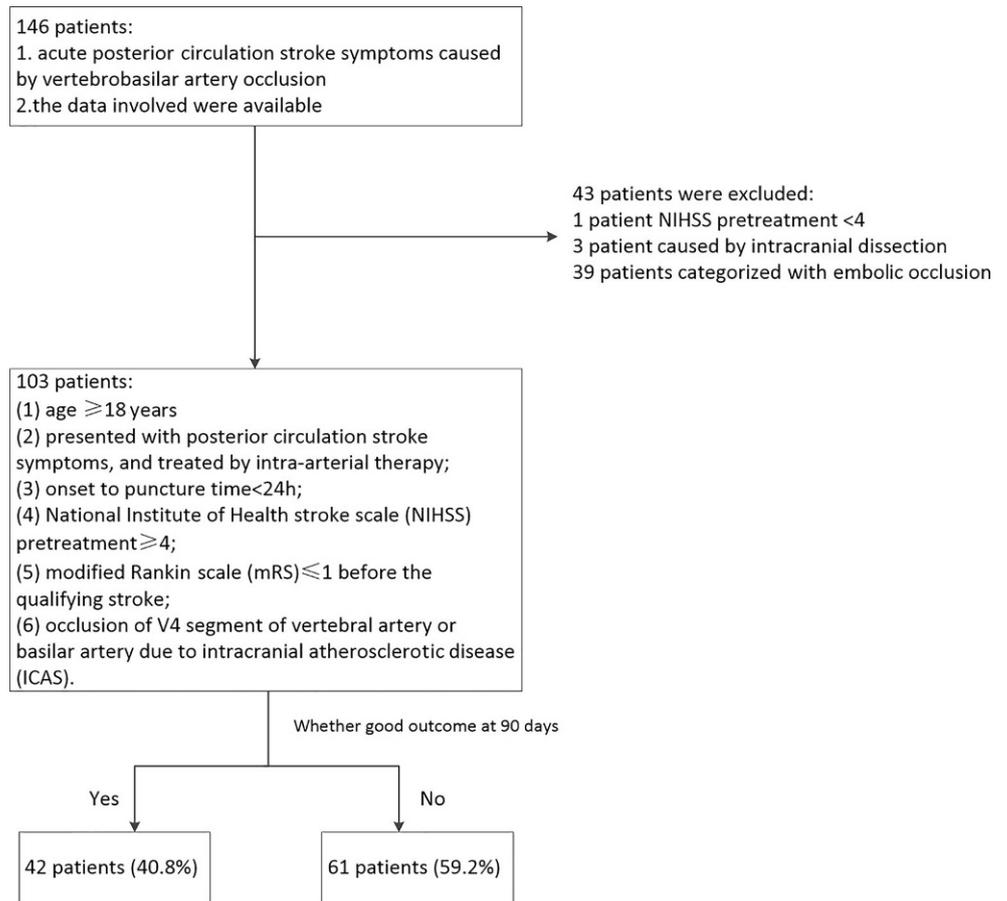


Fig. 2 Receiver operating characteristic curve for 90-day outcome by initial National Institutes of Health Stroke Scale (NIHSS), posterior circulation Acute Stroke Prognosis Early CT Score (pc-ASPECTS), Basilar Artery on Computed Tomography Angiography (BATMAN) score and onset-to-reperfusion time

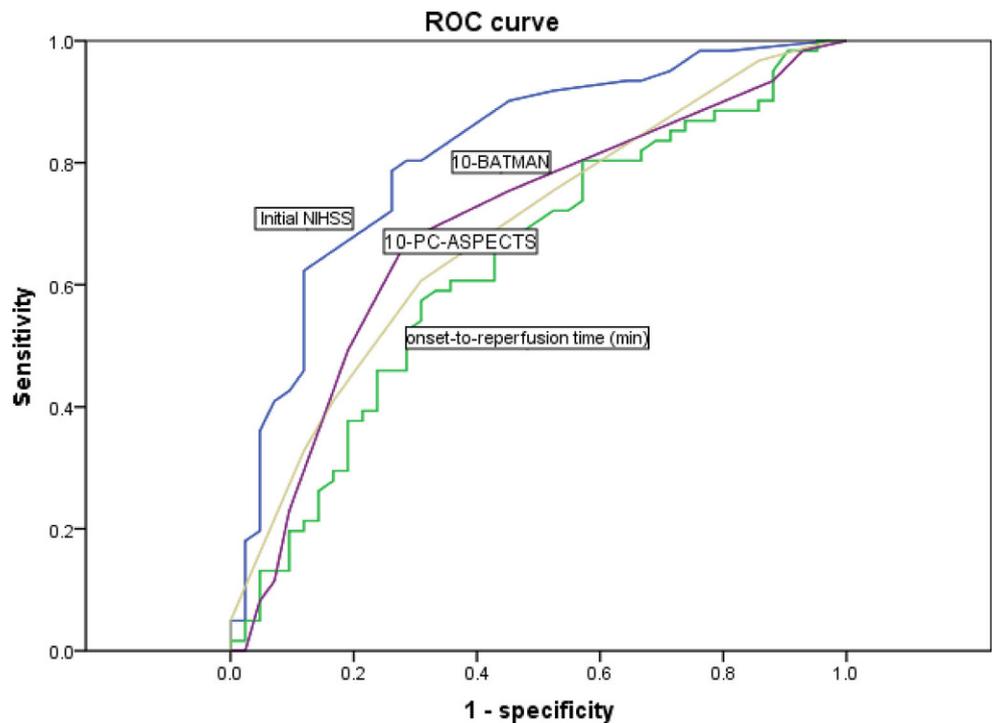


Table 1 Comparison of characteristics between the independence group and the dependence group

Characteristics	Total (n = 103)	Functional independence (n = 42)	Functional dependence (n = 61)	P-value
Age, years, mean ± standard deviation	58.56 ± 9.08	57.90 ± 7.59	59.02 ± 10.01	0.544
Male, n (%)	89 (86.4)	36 (85.7)	53 (86.9)	0.865
<i>Risk factors</i>				
Hypertension, n (%)	80 (77.7)	34 (81.0)	46 (75.4)	0.507
Diabetes, n (%)	33 (32.0)	15 (35.7)	18 (29.5)	0.507
Dyslipidemia, n (%)	28 (27.2)	13 (31.0)	15 (24.6)	0.506
Atrial fibrillation, n (%)	3 (2.9)	1 (2.4)	2 (3.3)	>0.999
Stroke/TIA, n (%)	32 (31.1)	15 (35.7)	17 (27.9)	0.398
Smoker, n (%)	74 (71.8)	31 (73.8)	43 (70.5)	0.713
<i>Laboratory findings</i>				
Glucose, mmol/l (IQR)	7.84 (6.48–9.31)	8.12 (6.44–9.30)	7.80 (6.48–9.47)	0.899
WBC, *10 ⁻⁹ /l, mean ± standard deviation	10.93 ± 3.67	10.83 ± 3.90	11.00 ± 3.52	0.814
RBC, *10 ⁻¹² /l (IQR)	4.87 (4.41–5.27)	4.87 (4.82–5.01)	4.88 (4.44–5.69)	0.412
PLT, *10 ⁻⁹ /l (IQR)	220.0 (181.0–256.0)	221.0 (172.0–281.5)	220.0 (183.0–250.0)	0.541
INR (IQR)	1.00 (0.94–1.04)	1.00 (0.94–1.04)	1.00 (0.94–1.04)	0.729
PT, s (IQR)	11.40 (10.80–12.00)	11.4 (10.8–11.9)	11.4 (10.8–12.0)	0.957
APTT, s (IQR)	25.1 (23.2–28.4)	26.5 (23.4–29.4)	24.6 (23.2–28.3)	0.095
FBG, g/l, mean ± standard deviation	2.84 ± 0.69	2.94 ± 0.80	2.77 ± 0.60	0.244
Prior antiplatelet therapy, n (%)	40 (38.8)	21 (50.0)	19 (31.1)	0.054
Prior anticoagulant therapy, n (%)	1 (1.0)	1 (2.4)	0	0.408
pc-ASPECTS (IQR)	7.0 (5.0–8.0)	7.0 (6.0–8.0)	6.0 (4.0–7.5)	0.001
BATMAN (IQR)	5.0 (4.0–7.0)	7.0 (5.0–7.0)	5.0 (4.0–6.5)	0.001
NIHSS pretreatment, mean ± standard deviation	20.26 ± 10.15	13.79 ± 8.61	24.72 ± 8.65	<0.001
SBP pretreatment, mmHg (IQR)	160.0 (140.0–180.0)	159.0 (143.5–172.3)	160.0 (140.0–180.0)	0.611
DBP pretreatment, mmHg (IQR)	90.0 (80.0–98.0)	88.5 (80.0–95.0)	90.0 (80.0–100.0)	0.491
IVT, n (%)	22 (21.4)	13 (31.0)	9 (14.8)	0.049
General anesthesia, n (%)	87 (84.5)	31 (73.8)	56 (91.8)	0.013
GPI, n (%)	70 (68.0)	27 (64.3)	43 (70.5)	0.507
Angioplasty (balloon and/or stenting), n (%)	65 (63.1)	25 (59.5)	40 (65.6)	0.532
Onset-to-recanalization time, min (IQR)	535.0 (407.0–737.0)	494.0 (374.3–635.3)	584.0 (467.5–803.5)	0.021
mTICI 2b/3, n (%)	86 (83.5)	36 (85.7)	50 (82.0)	0.615
sICH, n (%)	4 (3.9)	0	4 (6.6)	0.249

IQR interquartile range, TIA transient ischemic attack, WBC white blood cell, RBC red blood cell, PLT platelet, INR international normalized ratio, PT prothrombin time, APTT activated partial thromboplastin time, pc-ASPECTS postcirculation Alberta Stroke Program Early CT Score, BATMAN Basilar Artery on Computed Tomography Angiography, NIHSS National Institute of Health stroke scale, SBP systolic blood pressure, DBP diastolic blood pressure, IVT intravenous thrombolysis, mTICI modified Thrombolysis in Cerebral Infarction, GPI Glycoprotein IIb/IIIa inhibitor, FBG fibrinogen, sICH symptomatic intracerebral hemorrhage

Outcome Measurement

The mRS score on follow-up at 90 days was assessed by certified neurologists who were also blinded to baseline characteristics, assessed via telephone or face-to-face interviews. A good outcome or functional independence was regarded as mRS ≤ 2 at 90 days.

Statistical Analysis

Statistical analysis was performed with SPSS statistics version 21.0 (IBM Corp., Armonk, NY, USA). The data were described by means (standard deviations) or medians (25th and 75th percentiles) for continuous variables; frequencies or proportions were presented for categorical variables. First, relationship between characteristics and the 90-day clinical outcome was detected using χ^2 -test, Fisher's exact

Table 2 Logistic regression model for predictors of good outcome

	OR	95% CI	P-value
IVT	7.343	1.621–33.263	0.010
Prior antiplatelet	7.301	1.761–30.265	0.006
pc-ASPECTS, per 1-point increase	1.705	1.127–2.580	0.012
BATMAN	1.395	1.005–1.937	0.047
General anesthesia	0.081	0.010–0.633	0.017
Onset-to-recanalization time (≤ 542 min vs. >542 min)	0.194	0.057–0.661	0.009
NIHSS pretreatment, per 1-point increase	0.882	0.820–0.949	0.001

OR odds ratio, CI confidence interval, IVT intravenous thrombolysis, pc-ASPECTS post-circulation Alberta Stroke Program Early CT Score, BATMAN basilar artery on computed tomography angiography, NIHSS National Institute of Health stroke scale

test, Student's t-test, and Mann-Whitney U-test as appropriate. A logistic regression and receiver operating characteristic (ROC) curve analysis were used to identify predictors for 90-day independence. A *p*-value of <0.05 was considered significant.

Results

A total of 103 patients diagnosed with occlusion due to ICAS after a thorough etiological diagnosis were enrolled in the study (Fig. 1) and 40.8% (42 patients) achieved good outcome at 90 days. The baseline characteristics and outcomes are demonstrated in Table 1. The mean age of the participants was 58.56 years (± 9.08 years) and 86.4% were male. The baseline NIHSS before treatment was 20.26 (± 10.15). Successful reperfusion was achieved in 86 patients (83.5%) and 4 patients (3.9%) had symptomatic intracranial hemorrhage.

Comparison of Characteristics of Patients with 90-day Independence and Dependence

A good outcome or functional independence was regarded as mRS ≤ 2 at 90 days. As shown in Table 1, the risk factors were comparable between the two groups. There was also no significant difference in laboratory findings. Both the pretreatment pc-ASPECT (7.0 [IQR], 6.0–8.0 vs. 6.0 [IQR], 4.5–7.0; $P=0.001$) and BATMAN (7.0 [IQR], 5.0–7.0 vs. 5.0 [IQR], 4.0–6.5; $P=0.001$) were significantly higher in independent patients than in dependent patients. The baseline NIHSS of patients with good outcome was found to be lower (13.79 ± 8.61 vs. 24.72 ± 8.65 , $p < 0.001$).

Before the EVT performed, more patients with 90-day independence received intravenous recombinant tissue plasminogen activator thrombolysis (IVT) (31.0% vs.

14.8%, $p=0.049$). In the procedure, more dependent patients underwent EVT under general anesthesia (73.8% vs. 91.8%, $p=0.013$). Rate of successful reperfusion was comparable between the two groups (85.7% vs. 82.0%, $p=0.615$); however, the time from symptom onset to recanalization was significantly shorter in patients with functional independence than those with functional dependence (494.0 min [IQR], 374.3–635.3 min vs. 584.0 min [IQR], 467.5–803.5 min; $P=0.021$). Of the dependent patients 4 (6.6%) had sICH (defined as intracranial hemorrhage with neurologic worsening more than 4 points on the NIHSS) but none of the independent patients did.

Factors Associated with Good Clinical Outcome

Regression analysis showed that prior antiplatelet therapy (odds ratio [OR] 7.301; 95% confidence interval [CI] 1.761–30.265; $P=0.006$), EVT with pretreatment IVT (EVT+IVT) (OR, 7.343; 95% CI, 1.621–33.263; $P=0.010$), the pc-ASPECT on DWI before EVT (OR, 1.705; 95% CI, 1.127–2.580; $P=0.012$), BATMAN (OR, 1.395; 95% CI, 1.005–1.937; $P=0.047$), general anesthesia (OR, 0.081; 95% CI, 0.010–0.633; $P=0.017$), the onset-to-recanalization time (≤ 542 min vs. >542 min) (OR, 0.194; 95% CI, 0.057–0.661; $P=0.009$) and the initial NIHSS (OR, 0.882; 95% CI, 0.820–0.949; $P=0.001$) were significantly associated with good outcome at 90 days.

As the ROC curve analysis showed (Figure 2), initial NIHSS score (area under the curve, AUC, 0.816; 95% CI, 0.730–0.901; $P < 0.001$) was a significant predictor of good clinical outcome, and the optimal cut-off score was 19.5 (sensitivity 78.7%; specificity 72.5%); however, the BATMAN score (AUC, 0.694; 95% CI, 0.589–0.800; $P=0.001$), pc-ASPECTS on DWI before thrombectomy (AUC, 0.686; 95% CI, 0.583–0.789; $P=0.001$) and onset-to-recanalization time (AUC, 0.634; 95% CI, 0.525–0.744; $P=0.021$) were statistically significant with mild predictive value. The optimal cut-off scores were 5.5 for BATMAN score (sensitivity 67.2%, specificity 71.4%), 6.5 for pc-ASPECTS on DWI before thrombectomy (sensitivity 60.7%; specificity 69.0%) and 542 min for the onset-to-recanalization time (sensitivity 57.4%, specificity 69.0%) (Table 2).

Discussion

This study was based on Chinese population, which was reported with a high incidence of ICAS in VBAO patients [2, 9]. The primary findings of this study were: EVT + IVT, prior antiplatelet therapy, local anesthesia, short onset-to-recanalization time, low initial NIHSS, high pc-ASPECT and BATMAN score might be predictors of a good outcome at 90 days after EVT for patients with VBAO due to

ICAS. Whether pretreatment IVT provides any additional benefits to the patients undergoing EVT remains unclear. A meta-analysis [15] including 13 studies demonstrated that patients undergoing mechanical thrombectomy with IVT had better functional outcomes compared with those without IVT. The present study showed the same benefits of EVT+IVT over EVT without IVT. The use of IVT might facilitate EVT and serve as an adjunct in achieving a higher rate of successful reperfusion and shorter time in procedure, especially for patients with ICAS. For instance, the addition of systemic thrombolysis may also be beneficial in multifocal ischemia or harder to reach clots [15]. As it stands IVT should not be omitted before more evidence was obtained for patients with VBAO due to ICAS.

Antiplatelet therapy pretreatment was considered to be safe and may independently improve the odds of successful reperfusion in patients with emergent large artery occlusion treated with mechanical thrombectomy according to the results of Pandhi et al. [16]. A post hoc analysis of the MR CLEAN study also showed that in patients achieving reperfusion, antiplatelet agents may improve functional outcome [17]. Similar to the previous studies, the results of this study suggest that prior antiplatelet treatment could improve functional outcome after EVT for acute VBAO. Main reasons accounting for the results might be smoother endothelial surface and decreased tissue factor expression, which contribute to easier clot removal and reduced subsequent thrombosis [18]. In addition, distal (small vessel) recanalization might be improved because of less distal microvascular obstruction by antiplatelet use [17]. Developed reperfusion leads to a better outcome on condition that no intracranial hemorrhage happen. The common situation of regular antiplatelet therapy in patients with ICAS would not add the worries of hemorrhagic complications after EVT. In the course of treatment, neurologists might not restrict the use of antiplatelet drugs for possible EVT.

This study showed that the initial NIHSS score, BATMAN and pc-ASPECTS based on pretreatment DWI were independent predictors of good functional outcome in patients with acute VBAO who received EVT, which was in agreement with several previous studies [14, 19–21]. In contrast, there was no significant relationship between pc-ASPECTS and clinical outcome in the studies of Möhlenbruch et al. [22] and Karameshev et al. [23]. The possible reasons for these different results may lie in different inclusion criteria and pathomechanisms of stroke among these studies. Patients with initial NIHSS more than 20 should be cautiously selected only when fulfilling other criteria showing significant benefits.

This study also found an association between the onset-to-recanalization time and the clinical outcome in patients with VBAO, in accordance with the results of a subgroup analysis of BASICS [24]. Nevertheless, some previous stud-

ies concluded that there was no association between time to recanalization and outcome [25, 26]. Main reason for the discrepancy might be the different definition of onset time. Instead of the commonly used time of onset of any symptom, the time of onset of symptoms consistent with a clinical diagnosis of VBAO was used [24], because VBAO due to ICAS is often preceded by prodromal symptoms, such as atypical dizziness.

The appropriate anesthesia technique during the EVT procedure remains an issue of debate. Contrary to numerous studies that have reported better outcomes with general anesthesia in patients with anterior circulation large artery occlusion [27, 28], the results of this study indicated that general anesthesia was negatively associated with good outcome of patients with VBAO. Similarly, Bekelis et al. identified an association of general anesthesia with increased case fatality and length of stay in hospital [29]. In addition, the NASA registry demonstrated that clinical outcomes and survival are significantly better in patients treated with local anesthesia, without increased sICH risk [30]. Local anesthesia showed superiority over general anesthesia because general anesthesia will likely delay procedure initiation due to intubation. Furthermore, general anesthesia is often associated with a drop in blood pressure, with the potential for worsening cerebral ischemia.

This study has several limitations, the major one was the bias being inherent to the retrospective descriptive study design. In addition, the small and unevenly distributed case numbers limited multivariate analyses.

Conclusion

For patients with VBAO due to ICAS, EVT+IVT, prior antiplatelet therapy, local anesthesia, short onset-to-recanalization time, low initial NIHSS, high pc-ASPECT and BATMAN score can be helpful to predict a good outcome at 90 days after EVT.

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Conflict of interest X. Zhang, G. Luo, D. Mo, N. Ma, F. Gao, J Zhang and Z. Miao declare that they have no competing interests.

References

- Schonewille WJ, Wijman CA, Michel P, Rueckert CM, Weimar C, Mattle HP, Engelter ST, Tanne D, Muir KW, Molina CA, Thijs V, Audebert H, Pfefferkorn T, Szabo K, Lindsberg PJ, de Freitas G, Kappelle LJ, Algra A; BASICS study group. Treatment and outcomes of acute basilar artery occlusion in the Basilar Artery Inter-

- national Cooperation Study (BASICS): a prospective registry study. *Lancet Neurol.* 2009;8:724–30.
2. Huo X, Gao F, Sun X, Ma N, Song L, Mo D, Liu L, Wang B, Zhang X, Miao Z. Endovascular mechanical thrombectomy with the solitaire device for the treatment of acute basilar artery occlusion. *World Neurosurg.* 2016;89:301–8.
 3. Mordasini P, Brekenfeld C, Byrne JV, Fischer U, Arnold M, Helder MR, Lüdi R, Mattle HP, Schroth G, Gralla J. Technical feasibility and application of mechanical thrombectomy with the Solitaire FR Revascularization Device in acute basilar artery occlusion. *AJNR Am J Neuroradiol.* 2013;34:159–63.
 4. van Houwelingen RC, Luijckx GJ, Mazuri A, Bokkers RP, Eshghi OS, Uyttenboogaart M. Safety and outcome of intra-arterial treatment for basilar artery occlusion. *JAMA Neurol.* 2016;73:1225–30.
 5. Fahed R, Di Maria F, Rosso C, Sourour N, Degos V, Deltour S, Baronnet-Chauvet F, Léger A, Crozier S, Gabrieli J, Samson Y, Chiras J, Clarençon F. A leap forward in the endovascular management of acute basilar artery occlusion since the appearance of stent retrievers: a single-center comparative study. *J Neurosurg.* 2017;126:1578–84.
 6. Saver JL, Goyal M, van der Lugt A, Menon BK, Majoie CB, Dippel DW, Campbell BC, Nogueira RG, Demchuk AM, Tomasello A, Cardona P, Devlin TG, Frei DF, du Mesnil de Rochemont R, Berkhemer OA, Jovin TG, Siddiqui AH, van Zwam WH, Davis SM, Castañó C, Sapkota BL, Fransén PS, Molina C, van Oostenbrugge RJ, Chamorro Á, Lingsma H, Silver FL, Donnan GA, Shuaib A, Brown S, Stouch B, Mitchell PJ, Davalos A, Roos YB, Hill MD; HERMES Collaborators. Time to treatment with endovascular thrombectomy and outcomes from Ischemic stroke: a meta-analysis. *JAMA.* 2016;316:1279–88.
 7. Lee YY, Yoon W, Kim SK, Baek BH, Kim GS, Kim JT, Park MS. Acute basilar artery occlusion: differences in characteristics and outcomes after endovascular therapy between patients with and without underlying severe atherosclerotic stenosis. *AJNR Am J Neuroradiol.* 2017;38:1600–4.
 8. Kim YW, Hong JM, Park DG, Choi JW, Kang DH, Kim YS, Zaidat OO, Demchuk AM, Hwang YH, Lee JS. Effect of intracranial atherosclerotic disease on endovascular treatment for patients with acute vertebrobasilar occlusion. *AJNR Am J Neuroradiol.* 2016;37:2072–8.
 9. Gao F, Lo WT, Sun X, Mo DP, Ma N, Miao ZR. Combined use of mechanical thrombectomy with angioplasty and stenting for acute basilar occlusions with underlying severe intracranial vertebrobasilar stenosis: preliminary experience from a single Chinese center. *AJNR Am J Neuroradiol.* 2015;36:1947–52.
 10. Lee JS, Hong JM, Lee KS, Suh HI, Demchuk AM, Hwang YH, Kim BM, Kim JS. Endovascular therapy of cerebral arterial occlusions: intracranial atherosclerosis versus embolism. *J Stroke Cerebrovasc Dis.* 2015;24:2074–80.
 11. Tomsick T, Broderick J, Carrozella J, Khatri P, Hill M, Palesch Y, Houry J; Interventional Management of Stroke II Investigators. Revascularization results in the Interventional management of stroke II trial. *AJNR Am J Neuroradiol.* 2008;29:582–7.
 12. Saver JL, Jahan R, Levy EI, Jovin TG, Baxter B, Nogueira RG, Clark W, Budzik R, Zaidat OO; SWIFT Trialists. Solitaire flow restoration device versus the Merci Retriever in patients with acute ischaemic stroke (SWIFT): a randomised, parallel-group, non-inferiority trial. *Lancet.* 2012;380(9849):1241–9.
 13. Puetz V, Sylaja PN, Coutts SB, Hill MD, Dzialowski I, Mueller P, Becker U, Urban G, O'Reilly C, Barber PA, Sharma P, Goyal M, Gahn G, von Kummer R, Demchuk AM. Extent of hypoattenuation on CT angiography source images predicts functional outcome in patients with basilar artery occlusion. *Stroke.* 2008;39:2485–90.
 14. Alemseged F, Shah DG, Diomedes M, Sallustio F, Bivard A, Sharma G, Mitchell PJ, Dowling RJ, Bush S, Yan B, Caltagirone C, Floris R, Parsons MW, Levi CR, Davis SM, Campbell BC. The basilar artery on computed tomography angiography prognostic score for basilar artery occlusion. *Stroke.* 2017;48:631–7.
 15. Mistry EA, Mistry AM, Nakawah MO, Chitale RV, James RF, Volpi JJ, Fusco MR. Mechanical thrombectomy outcomes with and without intravenous thrombolysis in stroke patients. *Stroke.* 2017;48:2450–6.
 16. Pandhi A, Tsvigoulis G, Krishnan R, Ishaq MF, Singh S, Hoit D, Arthur AS, Nিকে C, Alexandrov A, Eljovich L, Goyal N. Antiplatelet pretreatment and outcomes following mechanical thrombectomy for emergent large vessel occlusion strokes. *J Neurointerv Surg.* 2018;10:828–33.
 17. Mulder MJ, Berkhemer OA, Fransén PS, van den Berg LA, Lingsma HF, den Hertog HM, Staals J, Jenniskens SF, van Oostenbrugge RJ, van Zwam WH, Majoie CB, van der Lugt A, Dippel DW; MR CLEAN investigators. Does prior antiplatelet treatment improve functional outcome after intra-arterial treatment for acute ischemic stroke? *Int J Stroke.* 2017;12:368–76.
 18. Amin AR, Vyas P, Attur M, Leszczynska-Piziak J, Patel IR, Weissmann G, Abramson SB. The mode of action of aspirin-like drugs: effect on inducible nitric oxide synthase. *Proc Natl Acad Sci USA.* 1995;92:7926–30.
 19. Yoon W, Kim SK, Heo TW, Baek BH, Lee YY, Kang HK. Predictors of good outcome after stent-retriever thrombectomy in acute basilar artery occlusion. *Stroke.* 2015;46:2972–5.
 20. Singer OC, Berkefeld J, Nolte CH, Bohner G, Haring HP, Trenkler J, Gröschel K, Müller-Forell W, Niederkorn K, Deutschmann H, Neumann-Haefelin T, Hohmann C, Bussmeyer M, Mpotsaris A, Stoll A, Bormann A, Brenck J, Schlamann MU, Jander S, Turowski B, Petzold GC, Urbach H, Liebeskind DS; ENDOSTROKE Study Group. Mechanical recanalization in basilar artery occlusion: the ENDOSTROKE study. *Ann Neurol.* 2015;77:415–24.
 21. Luo G, Mo D, Tong X, Liebeskind DS, Song L, Ma N, Gao F, Sun X, Zhang X, Wang B, Jia B, Fernandez-Escobar A, Miao Z. Factors associated with 90-day outcomes of patients with acute posterior circulation stroke treated by mechanical thrombectomy. *World Neurosurg.* 2018;109:e318–28.
 22. Möhlenbruch M, Stampfl S, Behrens L, Herweh C, Rohde S, Bendzus M, Hametner C, Nagel S, Ringleb PA, Pham M. Mechanical thrombectomy with stent retrievers in acute basilar artery occlusion. *AJNR Am J Neuroradiol.* 2014;35:959–64.
 23. Karameshev A, Arnold M, Schroth G, Kappeler L, Stein P, Gralla J, Brekenfeld C, Findling O, Mono ML, De Marchis GM, Fischer U, Mattle HP, Nedeltchev K, El-Koussy M. Diffusion-weighted MRI helps predict outcome in basilar artery occlusion patients treated with intra-arterial thrombolysis. *Cerebrovasc Dis.* 2011;32:393–400.
 24. Vergouwen MD, Algra A, Pfefferkorn T, Weimar C, Rueckert CM, Thijs V, Kappelle LJ, Schonewille WJ; Basilar Artery International Cooperation Study (BASICS) Study Group. Time is brain(stem) in basilar artery occlusion. *Stroke.* 2012;43:3003–6.
 25. Sairanen T, Strbian D, Soine L, Silvennoinen H, Salonen O, Artto V, Koskela I, Häppölä O, Kaste M, Lindsberg PJ; Helsinki Stroke Thrombolysis Registry (HSTR) Group. Intravenous thrombolysis of basilar artery occlusion: predictors of recanalization and outcome. *Stroke.* 2011;42:2175–9.
 26. Jung S, Mono ML, Fischer U, Galimani A, Findling O, De Marchis GM, Weck A, Nedeltchev K, Colucci G, Mordasini P, Brekenfeld C, El-Koussy M, Gralla J, Schroth G, Mattle HP, Arnold M. Three-month and long-term outcomes and their predictors in acute basilar artery occlusion treated with intra-arterial thrombolysis. *Stroke.* 2011;42:1946–51.
 27. Simonsen CZ, Yoo AJ, Sørensen LH, Juul N, Johnsen SP, Andersen G, Rasmussen M. Effect of general anesthesia and conscious sedation during endovascular therapy on infarct growth and clinical outcomes in acute ischemic stroke: a randomized clinical trial. *JAMA Neurol.* 2018;75:470–7.

28. Löwhagen Hendén P, Rentzos A, Karlsson JE, Rosengren L, Leiram B, Sundeman H, Dunker D, Schnabel K, Wikholm G, Hellström M, Ricksten SE. General anesthesia versus conscious sedation for endovascular treatment of acute ischemic stroke: the anstroke trial (anesthesia during stroke). *Stroke*. 2017;48:1601–7.
29. Bekelis K, Missios S, MacKenzie TA, Tjoumakaris S, Jabbour P. Anesthesia technique and outcomes of mechanical thrombectomy in patients with acute ischemic stroke. *Stroke*. 2017;48:361–6.
30. Abou-Chebl A, Zaidat OO, Castonguay AC, Gupta R, Sun CH, Martin CO, Holloway WE, Mueller-Kronast N, English JD, Linfante I, Dabus G, Malisch TW, Marden FA, Bozorgchami H, Xavier A, Rai AT, Froehler MT, Badruddin A, Nguyen TN, Taqi M, Abraham MG, Janardhan V, Shaltoni H, Novakovic R, Yoo AJ, Chen PR, Britz GW, Kaushal R, Nanda A, Issa MA, Nogueira RG. North American SOLITAIRE Stent-retriever acute stroke registry: choice of anesthesia and outcomes. *Stroke*. 2014;45:1396–401.