Risk factors and prognosis of early neurological deterioration in patients with posterior circulation cerebral infarction

Hui Li
Chengde Central Hospital
Yi Zheng
Chengde Central Hospital
Ding-Ding Zhang
Peking Union Medical College Hospital
Xiu-Ying Cui
Chengde Central Hospital
Xin Zhao
Chengde Central Hospital
Guan-Wen Zhang
Chengde Central Hospital
Fei Yang
Chengde Central Hospital
Fu Yu
Chengde Central Hospital
Xiao-Tian Fan
Chengde Central Hospital
Hao Jiang
Chengde Central Hospital
Jian-Ming Shi
Chengde Central Hospital
Bo Wang
Bijie People's Hospital
Jiang-Tao Zhang
Chengde Central Hospital
Ran Zhang (zhangrancd@163.com)
Chengde Central Hospital

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Abstract

Background: The incidence, risk factors, and pathogenesis of early neurological deterioration (END) in posterior circulation stroke are still unclear. In this study, we aimed to determine the risk factors and prognosis of END in patients with acute posterior circulation cerebral infarction.

Methods: Acute posterior circulation ischemic stroke patients who had completed neuroimaging within 72 hours of onset were selected from a prospective registry study.

Demographic characteristics, physiological data, medical history, laboratory data, in-hospital evaluation, neurological severity and TOAST classification, treatment, and the modified Rankin Scale (mRS) score of patients were assessed. Early neurological deterioration was defined as an increase of ≥2 points in the National Institutes of Health Stroke Scale score between the baseline and 72-hour evaluation. Favorable and poor outcomes were defined as mRSs of 0–2 and ≥3, respectively, at 3 months. The incidence and risk factors were evaluated by univariate and multivariate regression analysis (step-back method).

Results: The analysis included 455 subjects with an acute posterior circulation non-cardiac ischemic stroke, 330 (72.53%) of them male, with an average age of 63.12 (±10.14) years and with 47 (10.33%) having END. The results of univariate and multivariate logistic regression analysis showed that BATMAN scores ≥5 (OR: 0.1, 95% CI: 0.02–0.53, $P < 0.01$), large artery atherosclerosis (OR: 11.55, 95% CI: 4.18–31.93, $P < 0.01$), vascular stenosis >50% (OR: 2.44, 95% CI: 1.1–5.42, $P = 0.029$), reperfusion therapy (OR: 4.21, 95% CI: 1.66–10.64, $P < 0.01$), and the distribution of pontine lesions (OR: 5.66, 95% CI: 2.39–13.44, $P < 0.01$) were significantly associated with END. Patients with END had a lower rate of favorable outcomes at discharge and long-term follow-up ($P < 0.001$), regardless of whether they received reperfusion therapy.

Conclusion: The lesion distribution of the pons, the progression of temporo-occipital lobe lesions, and large arterial atherosclerosis are independent risk factors of END that might predict a poor short- and long-term prognosis.

Introduction

Patients with acute posterior circulation ischemic stroke may experience early neurological deterioration (END), resulting in a significant increase in disability and mortality[1, 2]. It has been confirmed that END is significantly associated with ischemic progression[3, 4]; symptomatic intracranial hemorrhage and malignant edema may also be key factors[5].

Previous studies have found that END in posterior circulation ischemic stroke (PCIS) is related to the baseline National Institutes of Health Stroke Scale (NIHSS) score, hypertension, stroke history, atrial fibrillation, pontine lesions, and the size and number of lesions[6]. However, a transcranial Doppler ultrasonography study found that, in patients with suspected vertebrobasilar insufficiency, an increased risk of END was associated with altered hemodynamics, in which poor carrier arterial condition[7] and

atherosclerosis played an important role in promoting END[8]. However, the incidence, potential pathogenesis, risk factors, and clinical outcome of END in the posterior circulation ischemic stroke population have not yet been fully elucidated.

In this study, we evaluated incidence and potential risk factors in a cohort of non-cardiac PCIS patients and followed up on their functional outcomes[9, 10]. We also aimed to identify clinical and neuroimaging predictors associated with END, as well as potential strategies for preventing and treating END.

Methods

This study was a prospective acute PCIS registry study that consecutively enrolled PCIS patients (n = 520) admitted to Chengde Central Hospital from January 1, 2020, to December 31, 2021. PCIS was diagnosed by a stroke specialist through medical records and imaging lesions, and END was defined as an increase of ≥ 2-points on the NIHSS score between the baseline and 72-hour evaluation. Inclusion criteria were as follows: 1. age ≥ 18 years; 2. time from onset to emergency department < 48 hours, and the baseline NIHSS score was clear; 3. PCIS confirmed by head MRI; 4. comprehensive follow-up. Exclusion criteria were as follows: 1. hemorrhagic stroke and anterior circulation ischemic stroke; 2. patients with cardioembolic disease (such as atrial fibrillation, valve disease, and heart valve replacement) or with another determined or undetermined etiology; 3. failure to undergo neuroimaging (refusal to undergo MRI or contraindications to MRI); 4. prehospital disability (modified Rankin Scale score > 2). Finally, 455 patients with PCIS were included. The flowchart of the study is shown in Fig. 1.

The Institutional Review Board of Chengde Central Hospital approved the study, and informed consent was obtained from participants.

All patients were fully evaluated according to a standardized protocol, and the following clinical and imaging variables were collected: demographic characteristics, physiological data, medical history, laboratory data, in-hospital evaluation, neurological severity and TOAST classification, treatment, and clinical outcome, as well as magnetic resonance imaging, echocardiography, electrocardiogram, cervical vascular ultrasound, and transcranial Doppler data. Neurological severity was assessed using the NIHSS score at onset, 72 hours, and at discharge. According to the treatment of patients with END, participants fell into non-reperfusion and reperfusion therapy subgroups, and subgroup analysis was performed. Reperfusion therapy included intravenous thrombolysis and endovascular therapy (EVT; all EVT patients were primarily treated with stent thrombectomy or direct thrombus aspiration); patients who received non-reperfusion therapy with medical management (MM) received standard antithrombotic therapy.

All researchers performed head computed tomography and magnetic resonance imaging (MRI) (Discovery MR750 3.0 T; 2019; GE, Boston, Massachusetts, USA) according to published protocols. The MR imaging protocol included diffusion-weighted imaging (TR: 8500 ms; TE: 110 ms; slice thickness: 6 mm; FOV: 240 mm), T1-weighted imaging (TR: 2000 ms; TE: 32 ms; FOV: 240 mm; slice thickness: 6 mm), T2-weighted imaging (TR: 6000 ms; TE: 125 ms; FOV: 240 mm; slice thickness: 6 mm), fluid-attenuated inversion recovery (TR: 8500 ms; TE: 110 ms; FOV: 240 mm; slice thickness: 6 mm), and

intracranial time-of-flight magnetic resonance angiography (TR: 23 ms; TE: 3.4 ms; FOV: 240 mm; slice thickness: 1.4 mm). The obtained images were read by two experienced radiologists and recorded; if there was any disagreement, the expert panel voted and finally reached a consensus. The infarct lesion was assessed using the Posterior Circulation Acute Stroke Prognostic Early CT Score (PC-ASPECTS) based on the images. PC-ASPECTS has a total of 10 points, with 1 point being subtracted for any lesions on either side of the cerebellum, occipital lobe, or thalamus, and 2 points being subtracted for acute lesions in the midbrain or pons. Ischemic progression was defined as the progression of the ischemic penumbra to infarct or a decrease of < 2 points in PC-ASPECTS[3, 11]. Infarct enlargement was defined as a decrease of ≥ 2 points in the PC-ASPECTS score[11]. Baseline collateral status and thrombus burden can be assessed by CTA or MRA using the BATMAN score, both proximal and distal to vessel occlusion[12]. Figure 2 is an example of PC-ASPECTS and BATMAN scores. The etiological classification of patients with PCIS in this study included large artery atherosclerosis and small artery occlusion[13].

The modified Rankin Score (mRS) was used to assess the clinical outcome; favorable and poor outcomes were defined as mRSs of 0–2 and ≥ 3, respectively, at 3 months. Clinical outcomes were obtained from Apr. 2022 through face-to-face visits or telephone follow-ups, assessed by certified neurologists.

All statistical analyses were performed with SPSS (version 26, 2019, NC). Continuous variables were expressed as interquartile ranges (IQRs) or mean, and categorical variables were expressed as frequencies. For comparison of baseline group characteristics, we used the independent sample *t*-test for normally distributed data, the Wilcoxon rank sum or Kruskal–Wallis test for non-normally distributed continuous variables, and the chi-squared test for categorical variables. Logistic regression was used for multivariate analysis. Two-way $P < 0.05$ was considered statistically significant.

Results

Among 509 patients with acute non-cardiogenic PCIS, 455 (89.4%) participants were included in our analysis. Their mean age was 63.12 (± 10.14) years, 330 (72.53%) were male, and 47 (10.33%) developed END. The baseline characteristics are shown in Table 1.

Table 1
Characteristics of patients

	Total (n = 455)	no-END (n = 408)	END (n = 47)	P value
Clinical parameters				
Age, median (IQR)	63.12 (± 10.14)	63.13 (± 10.12)	63.11 (± 10.51)	0.753
Male sex, n (%)	330 (72.53)	296 (72.55)	34 (72.34)	0.976
Current drinker, n (%)	201 (44.18)	180 (44.12)	21 (44.68)	0.941
Current smoker, n (%)	200 (43.96)	179 (43.87)	21 (44.68)	0.916
BMI (kg/m^2), median (IQR)	25.4 (23.2–26.9)	25.4 (23.21–26.9)	25.45 (23–26.57)	0.698
Diabetes mellitus, n (%)	157 (34.51)	142 (34.8)	15 (31.91)	0.693
Hypertension, n (%)	346 (76.04)	310 (75.98)	36 (76.6)	0.925
SBP (mmHg), median (IQR)	160 (146–174)	159.5 (145.25–175)	163 (149–172)	0.717
Hyperlipidemia, n (%)	102 (22.42)	89 (21.81)	13 (27.66)	0.363
Previous stroke, n (%)	129 (28.35)	117 (28.68)	12 (25.53)	0.651
Coronary heart disease, n (%)	47 (10.33)	43 (10.54)	4 (8.51)	0.665
Onset–to–door time (h), (< 24 h), n (%)	270 (59.34)	231 (56.62)	39 (82.98)	< 0.001*
Length of hospital stay	13 (11–15)	13 (10–14)	14 (11–15)	0.097
Laboratory tests				
Total cholesterol (mmol/L)	4.2 (3.6–5)	4.2 (3.6–5)	4.3 (3.7–5.3)	0.342
TG (mmol/L)	1.44 (1.08–1.96)	1.43 (1.09–1.96)	1.44 (1.03–2.1)	0.527
HDL (mmol/L)	1.14 (1.01–1.29)	1.14 (1–1.29)	1.19 (1.03–1.32)	0.291
LDL (mmol/L)	2.28 (1.85–2.86)	2.28 (1.83–2.83)	2.36 (2.01–3.04)	0.267
Cystatin C	1.04 (0.91–1.2)	1.05 (0.91–1.3)	1 (0.88–1.12)	0.223
Creatinine	62 (53–71)	61 (53–71)	65 (54–70)	0.442
Homocysteine	15 (12–22)	15 (12–22)	16 (12–23)	0.576

	Total (n = 455)	no-END (n = 408)	END (n = 47)	P value
Glomerular filtration rate	116.49 (95.3–137.16)	116.65 (95.46–137.57)	116.48 (95.08–130.35)	0.854
Carotid ultrasound[†]				
Angiostenosis > 50%	65 (14.38)	53 (13.03)	12 (26.67)	0.013*
Plaque	407 (90.04)	365 (89.68)	42 (93.33)	0.437
TOAST classification				
LAA, n (%)	209 (45.93)	167 (40.93)	42 (89.36)	< 0.001*
SAO, n (%)	245 (53.85)	240 (58.82)	5 (10.64)	< 0.001*
Imaging parameters				
PC-ASPECTS at arrival, median (IQR)				
Total	8 (8–9)	8 (8–9)	8 (8–9)	< 0.001*
Thalamic involvement				
Unilateral, n (%)	83 (18.24)	77 (18.87)	6 (12.77)	0.305
Bilateral, n (%)	7 (1.54)	5 (1.23)	2 (4.26)	0.110
Cerebellar involvement, n (%)	83 (18.24)	75 (18.38)	8 (17.02)	0.819
Occipital–temporal lobe involvement, n (%)	45 (9.89)	36 (8.82)	9 (19.15)	0.025*
Midbrain involvement, n (%)	17 (3.74)	14 (3.43)	3 (6.38)	0.312
Pontine involvement, n (%)	229 (50.33)	195 (47.79)	34 (72.34)	< 0.01*
Final PC-ASPECTS	8 (8–9)	8 (8–9)	8 (8–8)	< 0.001*
BATMAN collateral score[‡]	6 (6–8)	6 (6–8)	6 (6–8)	< 0.001*
BATMAN collateral score (≥ 5)	8 (1.93)	4 (1.08)	4 (9.3)	< 0.001*
PCA subscore	2 (1–2)	2 (1–2)	2 (1–2)	< 0.001

	Total (n = 455)	no-END (n = 408)	END (n = 47)	P value
BA subscore	3 (3–3)	3 (3–3)	3 (3–3)	< 0.001*
VA subscore	1 (1–1)	1 (1–1)	1 (1–1)	< 0.001*
P-com subscore	0 (0–0)	0 (0–0)	0 (0–0)	< 0.001*
Presence of fetal type PCA				
None, n (%)	84 (20.24)	74 (19.89)	10 (23.26)	0.603
Unilateral, n (%)	64 (15.42)	57 (15.32)	7 (16.28)	0.869
Bilateral, n (%)	20 (4.82)	17 (4.57)	3 (6.98)	0.485
Occlusion location	53 (12.77)	42 (11.29)	11 (25.58)	< 0.01*
PCA, n (%)	36 (8.67)	27 (7.26)	9 (20.93)	< 0.01*
BA, n (%)	11 (2.65)	7 (1.88)	4 (9.3)	< 0.01*
VA, n (%)	21 (5.06)	16 (4.3)	5 (11.63)	0.038*
GCS score	15 (15–15)	15 (15–15)	15 (15–15)	0.328
Initial NIHSS score, median (IQR)	2 (1–4)	2 (1–4)	3 (2–5)	< 0.001*
NIHSS ≥ 5, n (%)	74 (16.26)	59 (14.46)	15 (31.91)	< 0.01*
Mental status ≥ 1, n (%)	12 (2.64)	10 (2.45)	2 (4.26)	0.465
Motor ≥ 2, n (%)	106 (23.3)	86 (21.08)	20 (42.55)	< 0.01*
Cranial and cerebellar ≥ 2, n (%)	106 (23.3)	88 (21.57)	18 (38.3)	0.01*
Reperfusion (EVT ± IV thrombolysis), n (%)	52 (11.43)	38 (9.31)	14 (29.79)	< 0.001*
Functional outcomes				

	Total (n = 455)	no-END (n = 408)	END (n = 47)	P value
Discharge mRS, n (%)	403 (88.57)	388 (95.1)	15 (31.91)	< 0.001*
mRS 0–2 (people–year), n (%)	422 (92.75)	398 (97.55)	24 (51.06)	< 0.001*

END: early neurological deterioration; N: number; IQR: interquartile range; BMI: body mass index; SBP: systolic blood pressure; TG: triglycerides; HDL: high-density lipoprotein; LDL: low-density lipoprotein; TOAST: Trial of Org 10172 in Acute Stroke Treatment; LAA: large artery atherosclerosis; SAO: small artery occlusion; PC-ASPECTS: Posterior Circulation-Alberta Stroke Program Early Computed Tomography Score; PCA: posterior cerebral artery; BA: basilar artery; VA: vertebral artery; P-com: posterior communicating artery; BATMAN: Basilar Artery on Computed Tomography Angiography; GCS: Glasgow Coma Scale; NIHSS: National Institutes of Health Stroke Scale; IV ± EVT: intravenous thrombolysis with or without endovascular treatment; mRS: modified Rankin scale. *P < 0.05 was considered significant.

†No carotid ultrasound (n = 3): No-END (n = 1); END (n = 2)

‡ No magnetic resonance angiography (n = 40): No-END (n = 36); END (n = 4)

The median NIHSS score was 2 (IQR 1–4) at baseline, 3 (IQR 2–6) at 72 hours, and 2 (IQR 1–5) at discharge (Fig. 3). The median length of hospital stay was 13 (IQR 11–15) days.

The END and non-END patients showed similar demographic characteristics, and the data between groups were comparable. The median baseline NIHSS was higher in the END group (3 vs. 2, $P < 0.001$). END-related variables were as follows: time from stroke to emergency department < 24 hours, vessel stenosis > 50%, occipitotemporal and pontine lesions, lower ASPECTS score, BATMAN < 5, any vessel occlusion, minor stroke, reperfusion treatment (Table 1). In the multivariate logistic regression model, the following variables remained independent predictors of END: pontine lesions (OR = 5.66, 95% CI 2.39–13.44, $P < 0.001$), occipitotemporal lesions (OR = 3.39, 95% CI 1.15–9.96, $P = 0.026$), large atherosclerotic type (OR = 11.55, 95% CI 4.18–31.93, $P < 0.001$), reperfusion therapy (OR = 4.21, 95% CI 1.66–10.64, $P = 0.002$), time from stroke to emergency department < 24 hours (OR = 0.1, 95% CI 0.02–0.53, $P = 0.007$), BATMAN ≥ 5 (OR = 0.1, 95% CI 0.02–0.53, $P = 0.007$), vascular stenosis > 50% (OR = 2.44, 95% CI 1.1–5.42, $P = 0.029$). Low BATMAN collateral scores were more common in the END group (9.3% vs. 1.08%, $P < 0.001$). The etiological classification of infarction included 209 cases (45%) of large atherosclerotic type and 53.85% of small artery occlusive type. In the END group, the intracranial large atherosclerotic type was more prevalent (89%, $P < 0.001$). After adjusting for confounders, only large-arterial atherosclerosis was an independent predictor of END (Table 2).

Table 2
Results of multivariable regression analysis for predictors of END

	Model 1[a]		Model 2[b]	
	OR (95% CI)	P value	OR (95% CI)	P value
Age, median (IQR)	0.98 (0.95–1.02)	0.392	0.99 (0.95–1.03)	0.506
Male sex, n (%)	0.93 (0.44–1.99)	0.853	0.96 (0.38–2.4)	0.926
Diabetes mellitus, n (%)			0.67 (0.3–1.48)	0.318
Hypertension, n (%)			0.98 (0.38–2.47)	0.957
Pontine involvement	3.72 (1.77–7.84)	< 0.01*	5.66 (2.39–13.44)	< 0.001*
Occipital–temporal lobe involvement	–	–	3.39 (1.15–9.96)	0.026*
LAA, n (%)	14.25 (5.32–38.71)	< 0.001*	11.55 (4.18–31.93)	< 0.001*
Reperfusion, n (%)	5.37 (2.33–12.42)	< 0.001*	4.21 (1.66–10.64)	< 0.01*
Onset-to-door time (h), (< 24 h), n (%)	–	–	0.36 (0.15–0.88)	0.025*
BATMAN collateral score (≥ 5)	0.15 (0.03–0.64)	0.011*	0.1 (0.02–0.53)	< 0.01*
Angiostenosis > 50%	2.22 (1.02–4.87)	0.046*	2.44 (1.1–5.42)	0.029*

OR: odds ratio; CI: confidence interval; LAA: large artery atherosclerosis; BATMAN: Basilar Artery on Computed Tomography Angiography. *P < 0.05 was considered significant.

[a]Adjusted for male sex and age

[b]Adjusted for male sex, age, current smoker, diabetes mellitus, hypertension, hyperlipidemia, previous stroke, coronary heart disease, and SBP

Of the END cases, 37 (78.7%) were caused by ischemic progression, 6 (12.8%) by enlarged infarcts, and 2 (4.3%) by intracranial hemorrhage. Thirty-eight patients with END (82.98% vs. 56.62%, $P < 0.001$) arrived at the emergency department within 24 hours, and 14 (29.79%) received reperfusion therapy (Table 3). Subjects who received reperfusion had higher blood lipids ($P < 0.05$), and the proportion of good prognosis was lower than that in the MM group (12.8% vs. 38.3%, $P = 0.464$), but the difference was not significant.

Table 3
Comparison of reperfusion and MM in patients of END

	Reperfusion (n = 14)	MM (n = 33)	P value
Age, median (IQR)	61.5 (± 11.06)	63.79 (± 10.37)	0.501
Male sex, n (%)	10 (71.4%)	24 (72.7%)	0.927
Current smoker, n (%)	5 (35.7%)	16 (48.5%)	0.421
Diabetes mellitus, n (%)	6 (42.9%)	9 (27.3%)	0.295
Hypertension, n (%)	10 (71.4%)	26 (78.8%)	0.586
SBP (mmHg), median (IQR)	160.07 (24.72)	161.97 (18.8)	0.775
Total cholesterol (mmol/L)	5.17 (0.92)	4.15 (1.16)	< 0.01*
TG (mmol/L)	1.42 (1.06–1.8)	1.53 (1.01–2.23)	0.553
HDL (mmol/L)	1.29 (0.13)	1.11 (0.25)	0.014*
LDL (mmol/L)	2.99 (0.76)	2.28 (0.81)	< 0.01*
Angiostenosis > 50%†	4 (28.6%)	8 (24.2%)	0.846
LAA, n (%)	13 (92.9%)	29 (87.9%)	0.613
PC-ASPECTS at arrival, median (IQR)	8 (5.75–8.25)	8 (8–8)	0.955
BATMAN collateral score‡	6 (4–6.5)	6 (6–8)	0.154
BATMAN collateral score (≥ 5) ‡	11 (78.6%)	28 (84.8%)	0.057
Occlusion ‡	5 (35.7%)	6 (18.2%)	0.29
NIHSS ≥ 5	5 (35.7%)	10 (30.3)	0.716
Discharge mRS, n (%)	3 (21.4%)	12 (36.4%)	0.315
mRS 0–2 (people–year)	6 (42.9%)	18 (54.5%)	0.464

*P < 0.05 was considered significant.

†No carotid ultrasound: MM (n = 2).

‡No magnetic resonance angiography: MM (n = 4).

Compared with the subjects without END, the END group had a lower proportion of good prognosis at discharge (31.91% vs. 95.1%, $P < 0.001$). After 553 person-years of follow-up (12 patients lost to follow-

up), the proportion of patients with a favorable mRS in the END group was lower (51.06% vs. 97.55%, $P < 0.001$).

In subgroup analysis, END was divided into the oral drug group and reperfusion therapy (including IVT and EVT). Fourteen patients (29.79%) received reperfusion therapy, including 2 patients who received EVT. The END reperfusion group and MM group were compared between groups (Table 3). Blood lipids were higher in the reperfusion group ($P < 0.05$). There was no significant correlation between NIHSS score and vascular assessment between groups. The proportion of good prognosis in the reperfusion group (12.8% vs. 38.3%, $P = 0.464$) was lower than that in the MM group, but the difference was not significant.

Discussion

The incidence of END in patients with noncardiogenic PCIS in this study was 10.3%. END was associated with a worse baseline NIHSS score, pons location, poorer vascular status, as well as a lower rate of favorable outcomes at discharge and long-term follow-up.

The incidence of END in PCIS ranged from 5.1–28.57% in previous studies [2, 6, 14, 15], in which the risk of END increased in patients with single small infarcts and vertebrobasilar occlusion[2, 14]. Compared with non-END patients, this study found that a higher baseline NIHSS score was associated with the occurrence of END, which was consistent with the results of previous studies[6, 14, 15]. In our study, the lower incidence of 10.3% may be due to the inclusion of more minor stroke patients.

This study found that the anatomical distribution of lesions is related to END. Lesions in the pons have been reported to be related to the occurrence of END, which may be related to basilar artery perforator lesions[6], such as atherosclerotic lesions at the opening of larger diameter perforating arteries, leading to decreased perfusion, thrombus extension, and involvement of adjacent branch arteries[16]. The concentrated distribution of fiber bundles in the pontine region can rapidly increase the NIHSS score when stroke progresses[17]. Previous studies have not found temporo-occipital lobe lesions to be associated with END. In the present study, 38.8% of patients with temporo-occipital lobe lesions had posterior cerebral artery occlusion, which was speculated to be related to poor collateral circulation[18]. Furthermore, lower collateral circulation and severe vascular stenosis were associated with END. Previous studies on patients with acute ischemic stroke have found that basilar artery stenosis or posterior cerebral artery stenosis is independently associated with END[8], which supports our finding.

We found that the cause of ischemic progression accounted for 78.7% of the causes of END, while infarct enlargement and intracranial hemorrhage accounted for about 17%. Fu et al.[3] examined computed tomography perfusion, perfusion weighted imaging, and diffusion weighted imaging in patients with acute ischemic stroke who received reperfusion therapy and found that END was independently associated with the progression of the ischemic penumbra to infarcts or new infarcts. In patients with acute subcortical small infarction (SSI) in the vertebrobasilar artery perforator territory, proximal SSI was significantly associated with END, which was explained by focal thrombus, hemodynamic instability-related progressive shedding of unstable plaque covering the vessel, poor collateral circulation, or acute

inflammation or secondary edema[14]. Large artery atherosclerosis (LAA) was not associated with END in a study on patients with vertebrobasilar occlusion[2]. However, LAA was found to be associated with END in the acute ischemic stroke population[8], and a multicenter study identified intracranial atherosclerosis as a risk factor for PCIS[19]. The relationship between the etiology of stroke and END in the PCIS population is currently unclear. In this study, both LAA and small artery occlusion were associated with END, while, after the confounding model was adjusted, the significance of small vessel occlusion was weakened, supporting the relationship between LAA and END.

Interestingly, our findings showed that reperfusion therapy was related to END, which may be related to a more serious patient condition as well as the timely visit to the emergency department. However, the sample size of this group of cases was small, and more data are needed. We found a worse prognosis in the END participants but did not observe that reperfusion therapy resulted in a better clinical functional outcome[20]. A study based on intravenous thrombolysis in patients with ischemic stroke also found that END was associated with poor prognosis[21], which is consistent with the findings of our study. Intravenous thrombolytic therapy has a limited effect on improving the long-term prognosis of ischemic stroke caused by atherosclerotic plaque[22], which may be related to the finding that reperfusion therapy was not associated with better clinical functional prognosis in our study.

The strengths of this study are that all patients with non-cardiac PCIS were included if possible and the use of multimodal MRI, ensuring precise assessment. Patients with a history of atrial fibrillation were excluded from this study, allowing us to focus on the relationship between vascular status in END. As the NIHSS score is dominated by symptoms of anterior circulation and lacks good sensitivity to posterior circulation symptoms[20, 23], we made efforts to increase the precision of the data by comparing the total NIHSS score and its subsets[11]. In addition, despite being retrospective, these data are reliable and robust due to the prospective collection of the data and standardized work in acute ischemic stroke treatment.

Nevertheless, this study had several limitations. First, the research on END focused on the factors related to the malignant adverse disease course of mild stroke. Although the sample size of this pilot study was small, the results of this study described the occurrence of END in patients with acute posterior circulation cerebral infarction, making future studies possible. Second, in this single-center retrospective study, selection bias and recall bias should be considered. Third, we routinely used MRA or ultrasonography for evaluation, so the location and distribution of the actual perforating arteries could not be determined, and the possibility of overestimation when measuring vascular lesions should be considered. Finally, in order to evaluate the operability, this study defined vascular occlusion as the occlusion of any part of the posterior circulation, which was different from previous studies. The results did not show a significant correlation between vascular occlusion and END, which may be related to the existence of early ischemic preconditioning, calling for more rigorous definitions, imaging assessments, and expanded sample sizes to confirm these findings.

Conclusion

This study found that, in patients with acute non-cardiogenic PCIS, the distribution and progression of pontine and temporo-occipital lobe lesions and atherosclerosis of large arteries were associated with END, and that poor collateral circulation could further lead to disease deterioration due to the difficulty of rapid compensation. In patients receiving reperfusion therapy, the risk of END was higher, which may be related to the early stage of the unstable disease course, and further observation in large samples is needed. The short- and long-term prognosis of patients with END was worse.

Abbreviations

END: early neurological deterioration; PCIS: posterior circulation ischemic stroke; NIHSS: National Institutes of Health Stroke Scale; EVT: endovascular therapy; IV: intravenous thrombolysis; MM: medical management; MRI: magnetic resonance imaging; PC-ASPECTS: Posterior Circulation Acute Stroke Prognostic Early Computed Tomography Score; mRS: the modified Rankin Score; TOAST: Trial of Org 10172 in Acute Stroke Treatment; LAA: large artery atherosclerosis; SAO: small artery occlusion; PCA: posterior cerebral artery; BA: basilar artery; VA: vertebral artery; P-com: posterior communicating artery; BATMAN: Basilar Artery on Computed Tomography Angiography; and GCS: Glasgow Coma Scale.

Declarations

Ethics approval and consent to participate

The Ethics Committee of Chengde Central Hospital approved this study. All study subjects have their informed consent. All methods were performed following the relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

LH, ZJT, and ZR contributed to the conception of the study; LH, YF, SJM, and ZR contributed significantly to the analysis and manuscript preparation; and LH and ZJT drafted the manuscript. LH, ZY, ZJT, and CXY contributed significantly to imaging reading and collection of clinical data; LH, ZDD, ZR, and ZX performed the data analyses and wrote the manuscript; and LH, ZJT, CXY, WB, and ZGW helped perform the analysis with constructive discussions. FY and FXT helped with supervision. All authors read and approved the final version of the manuscript.

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Authors' information

[1] Chengde Medical University, China.[2] Department of Neurology, Chengde Central Hospital, China.[3] Image center, Chengde Central Hospital, China.[4] Central laboratory, Peking Union Medical College Hospital, China.[5] Clinical blood laboratory, Chengde Central Hospital, China.[6] Information center, Chengde Central Hospital, China.[7] Department of Neurology, Bijie People's Hospital, China.

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Figures

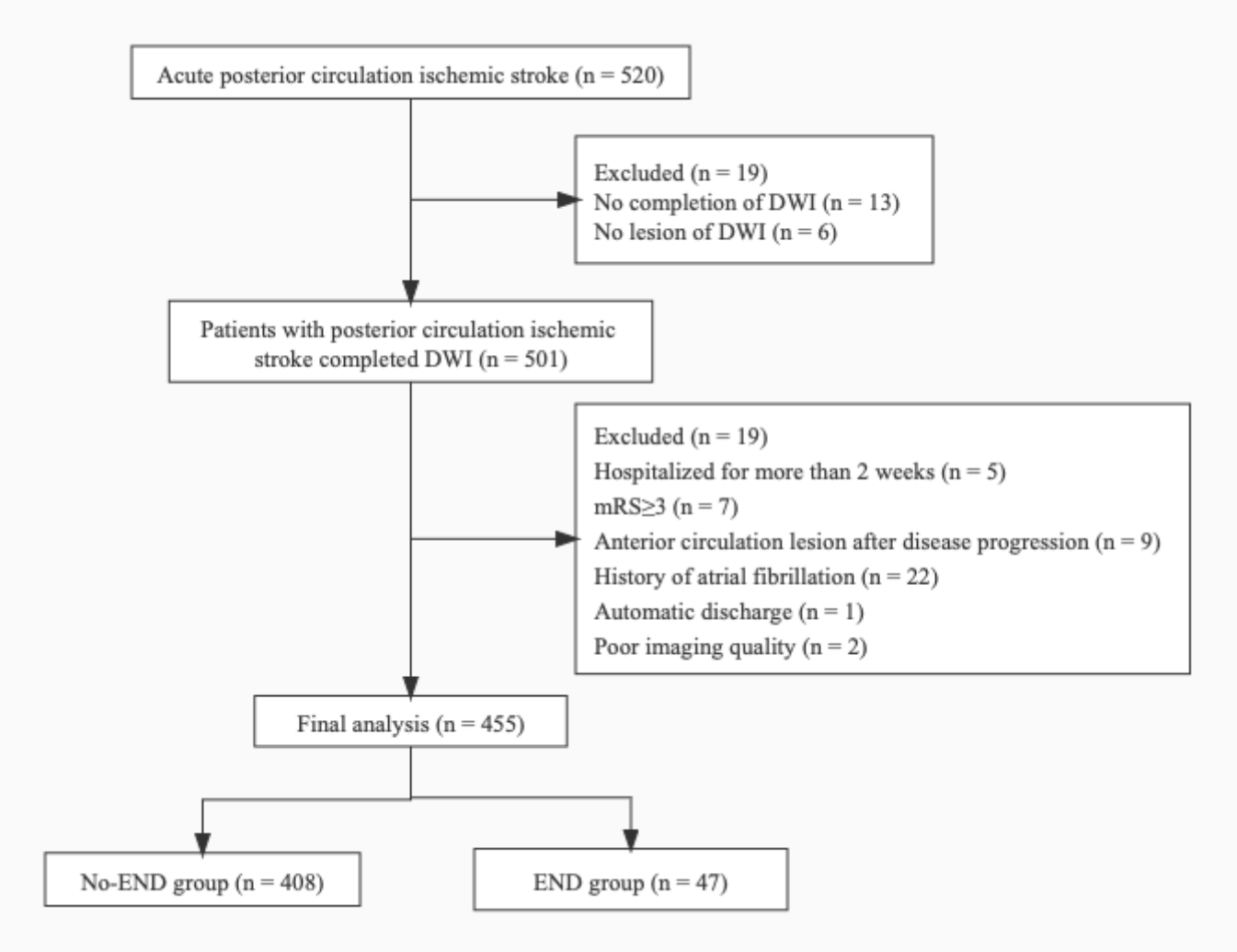

Figure 1

Flowchart of participants included in analyses

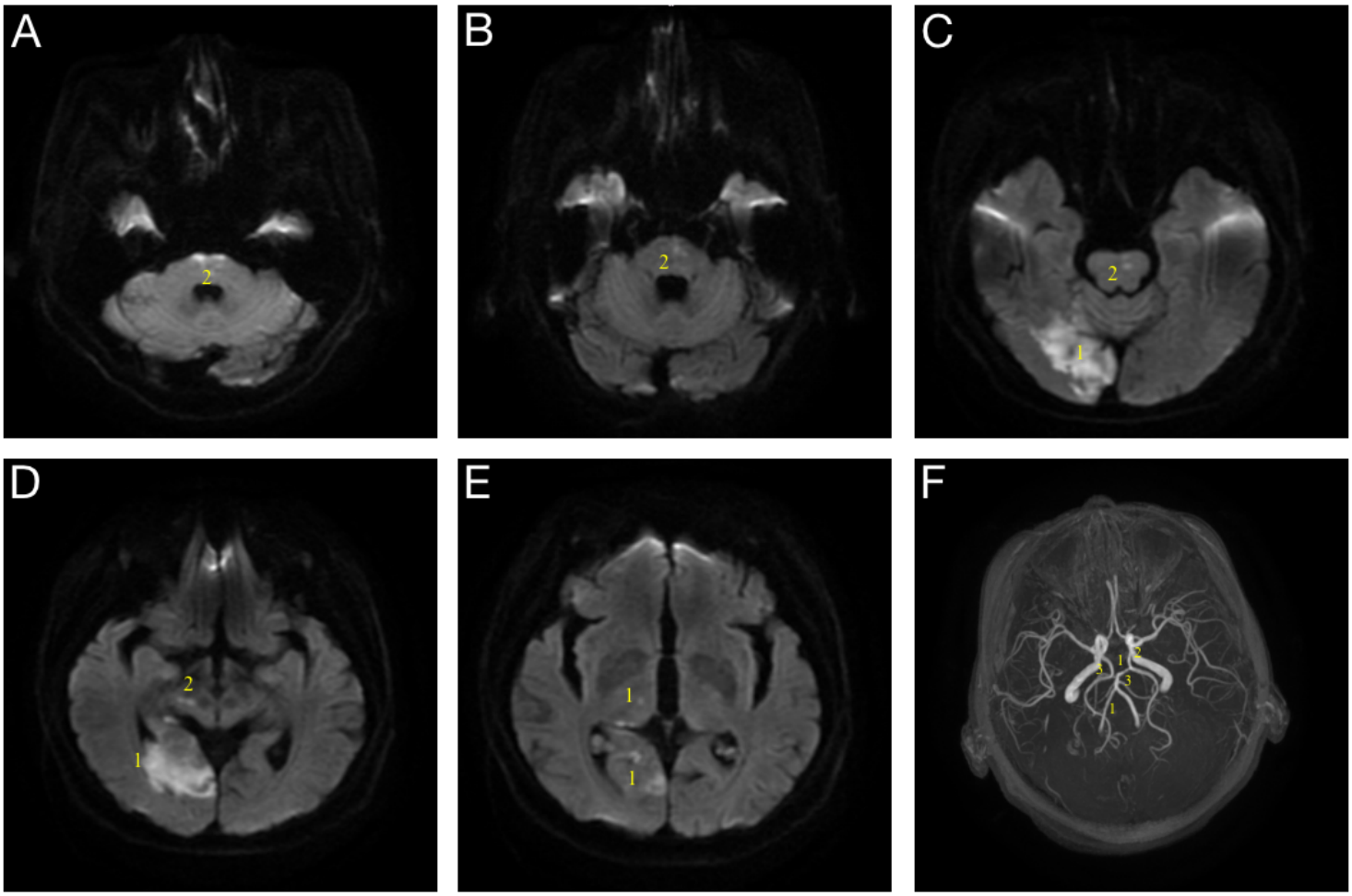

Figure 2

An example of PC-ACPECT score calculation from the cohort. (A, B) Diffusion restriction was seen at the pontine level. Two points were subtracted at this level. No acute infarction was observed in the bilateral cerebellum. (C) Acute infarction was observed at the pontine level and right PCA territories. Three points were subtracted at this level. (D) Acute infarction was observed at the midbrain level and right PCA territories. Three points were subtracted at this level. (E) Acute infarction was observed in the right thalami. One point was subtracted at this level, constituting a total score of 4. An example of BATMAN score calculation from the cohort. (F) For the BATMAN score, three points were given for right fPCA, two points were given for left P-com, one point was given for left PCA, threepoints were given for basilar artery, and one point was given for vertebral artery. The total BATMAN score was 10. PC-ASPECTS, Posterior Circulation-Alberta Stroke Program Early Computed Tomography Score; BATMAN, Basilar Artery on Computed Tomography Angiography; BA, basilar artery; PCA, posterior cerebral artery; VA, vertebral artery; fPCA, fetal posterior cerebral artery; P-com: posterior communicating artery.

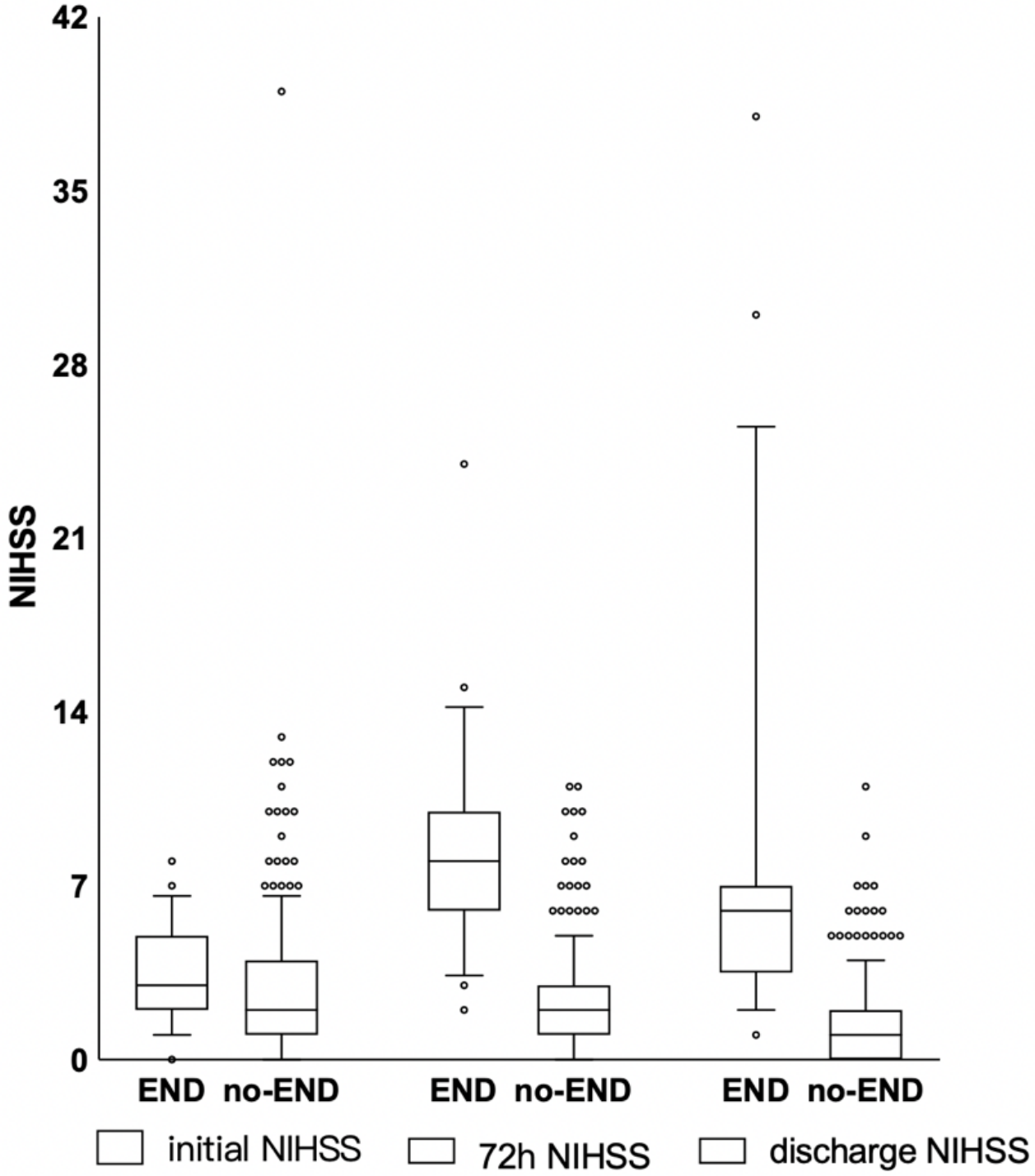

Figure 3

Evolution of total NIHSS score in the END and no-END patients during hospitalization