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FLAIR vascular hyperintensity-DWI mismatch most likely to benefit from recanalization and good outcome after stroke

Yong Wang, MD, Zhijun Zhou, MD, Shaohua Ding, MD*

Abstract

We assessed the value of fluid-attenuated inversion recovery vascular hyperintensity (FVH)-diffusion-weighted imaging (DWI) mismatch in predicting revascularization and functional outcome in stroke patients with large vessel occlusion (LVO) after endovascular thrombectomy (EVT).

Seventy-two acute stroke patients within 6 hour of stroke onset who received EVT were enrolled. FVH-DWI mismatch, revascularization (mTICI score), functional outcome (mRS at 3 months) and other clinical data were collected. Statistical analysis was performed to predict revascularization and functional outcome after stroke.

Twenty-nine patients (60.42%) had FVH-DWI mismatch in patients with complete revascularization and 8 patients (33.33%) had FVH-DWI mismatch in patients with no/partial revascularization, and there was significant difference in 2 groups ($t=4.698$; $P=.045$). The good functional outcome group (37/72; 51.39%) had higher FVH score (4.38 ± 1.53 vs 3.49 ± 1.52; $t=2.478$; $P=.016$), higher FVH-DWI mismatch ratio (81.25% vs 48.15%; $t=10.862$; $P=.002$), higher complete revascularization ratio (83.78% vs 48.57%; $t=10.036$; $P=.002$) than the poor functional outcome group (35/72; 48.61%). Spearman's rank correlation analysis revealed that FVH-DWI mismatch was positively correlated with complete revascularization ($r=0.255$; $P=.030$) and good functional outcome ($r=0.417$; $P=.000$). Multivariable logistic regression analysis demonstrated that FVH-DWI mismatch was independently associated with complete revascularization (OR, 0.328; 95% CI, 0.117–0.915; $P=.033$) and good functional outcome (OR, 0.169; 95% CI, 0.061–0.468; $P=.001$).

Assessments of FVH-DWI mismatch before thrombectomy therapy might be useful for predicting revascularization and functional outcome in stroke patients with LVO.

Abbreviations: AIS = acute ischemic stroke, ASPECTS = Alberta Stroke Program Early CT Score, CI = confidence interval, DSA = digital subtraction angiography, DWI = diffusion weighted imaging, EVT = endovascular thrombectomy, FLAIR = fluid-attenuated inversion recovery, FVH = fluid-attenuated inversion recovery vascular hyperintensity, ICA = internal carotid artery, LVO = large vessel occlusion, MCA = middle cerebral artery, MRA = magnetic resonance angiography, MRI = magnetic resonance imaging, mRS = Modified Rankin Scale, mTICI = Modified Thrombolysis in Cerebral Ischemia, NIHSS = National Institutes of Health Stroke Scale.

Keywords: collateral circulation, diffusion-weighted imaging, magnetic resonance imaging, prognosis, stroke

1. Introduction

Acute ischemic stroke (AIS) is a cerebrovascular disease seriously harmful to human life, which has high mortality and disability rates. Recanalization is the most important modifiable prognostic factor for improved functional outcome and reduced mortality in ischemic stroke treatment. Intravenous thrombolysis with tissue plasminogen activator within 4 or 5 hours after symptom onset is an efficient treatment, but in cases of thromboembolic occlusion of major cerebral arteries, its effectiveness decreases with less than 50% of recanalization rates.[1]

Endovascular thrombectomy (EVT) is emerging as the first-line treatment for AIS patients with large vessel occlusion (LVO) of the middle cerebral artery (MCA) or internal carotid artery (ICA).[2–4] Currently, the basic tool for EVT is a stent retriever. EVT, as a mechanical intervention, is associated with cell damage, which can cause an increase in the inflammatory response in the form of a higher number of neutrophils.[5] Although tent retrievers have revolutionized endovascular treatment of AIS, EVT may cause endothelial injury and intimal layer edema.[6,7] Even though, it has recently been demonstrated that EVT can resolve LVO, providing an alternative and synergistic method for restoring blood flow in cerebral vessels.[3,8] The successful revascularization in EVT of stroke is defined as the achievement of grades 2b (≥50% of filling of the arterial territory distal to obstruction) or 3 (complete revascularization) according to the modified Thrombolysis In Cerebral Infarction (mTICI) scale).[9–11] Achieving complete or near

complete reperfusion has been associated with improved clinical outcomes.[2] Despite the high ratio of successful recanalization, the clinical outcomes of EVT vary among studies.

Identification of salvageable brain tissue using core-penumbral surrogate markers could identify patients most likely to benefit from revascularization therapies. Therefore, it is important for clinical outcomes to detect impaired yet viable tissue reliably and quickly. Advanced imaging method was an essential component in support of EVT for AIS with LVO.[12–14] Fluid-attenuated inversion recovery vascular hyperintensities (FVH) characterizes the relative absence of normal flow void in the subarachnoid spaces. FVH presence is a slow blood flow through the leptomeningeal collaterals.[15] On MRI, the abnormal infarct lesions on DWI are earlier than fluid-attenuated inversion recovery vascular (FLAIR), while FVH precedes DWI and can be seen beyond the boundaries of DWI lesions. FVH was commonly seen after stroke patients with LVO, and was considered to maintain some perfusion distal to the occlusion site while awaiting revascularization.[16–18] When FVHs extended beyond the boundaries of the cortical DWI lesion, it is considered to be FVH-DWI mismatch. FVH-diffusion weighted imaging (DWI) mismatch, focusing on FVH beyond the boundaries of DWI lesion (irretrievable tissue), is an alternative to assess tissue at risk of infarct expansion and to select patients likeliest to benefit from thrombectomy.[19] Currently available studies mainly reported that FVH-DWI mismatch could predict Perfusion weighted imaging (PWI) -DWI mismatch[20] or ischemic penumbra.[19] The value of FVH-DWI mismatch in predicting successful revascularization and clinical outcome with acute stroke after EVT has not been reported.

Therefore, in our study, we hypothesized that FVH-DWI mismatch is associated with successful revascularization in acute stroke patients, and also associated with favorable outcome with acute stroke after EVT. We sought to assess the value of FVH-DWI mismatch in predicting successful revascularization and clinical outcome with acute stroke after EVT.

2. Materials and methods

2.1. Subjects and clinical data

The prospective registry of acute stroke patients was evaluated with data from the Taizhou People's Hospital between January 2017 to March 2019. Acute stroke was defined as acute clinical vascular syndrome with evidence of cerebral infarction on DWI. According to the criteria for intravenous thrombolytic therapy, patients received intravenous thrombolysis (IVT) (Alteplase; rt-PA) within 4.5 hours of stroke onset after CT scanning, then MRI examination was performed immediately. If patients within 6 hours of stroke onset had LVO on magnetic resonance angiography (MRA), the thrombectomy was performed immediately. The patients included in the current study presented the following:

(1) a first-ever acute anterior circulation stroke or a previous mild cerebral infarction that did not affect the neurological score;
(2) acute stroke patients ≤6 hours of stroke onset;
(3) pretreatment MRI with DWI, FLAIR and MRA;
(4) receiving thrombectomy therapy; and
(5) a clinical follow-up of the modified Rankin scale (mRS) at 3 months.

The exclusion criteria were as follows:

(1) cerebral hemorrhage, tumor or trauma detected by the CT scanner;

(2) any contraindication for MRI;
(3) any missing mRS at 3 months after stroke;
(4) refusal of thrombectomy; and
(5) any MRI or digital subtraction angiography (DSA) that could not be evaluated due to a motion artifact.

Age; sex; homocysteine (blood test level >15 μmol/L); the National Institutes of Health Stroke Scale (NIHSS) score at admission; history of hypertension (>140/90 mmHg), diabetes mellitus (fasting plasma glucose ≥126 mg/dL (7.00 mmol/L) or 2-h plasma glucose after a 75-g oral glucose tolerance test ≥200 mg/dL (11.1 mmol/L)), hyperlipidemia (blood serum total cholesterol >150 mg/dL (1.70 mmol/L)/ triglyceride >220 mg/dL (5.72 mmol/L)/ low density lipoprotein-cholesterol >140 mg/dL (3.64 mmol/L)), and atrial fibrillation were collected. The functional outcome was evaluated by mRS at 3 months after stroke onset. Favorable functional outcome was defined as an mRS score ≤2 at 3 months.[21] All patients in this study provided written informed consent before examination. The study was approved by the local ethics committee of the Taizhou People's Hospital.

2.2. MRI protocol

MRI examinations were performed with a 3.0 Tesla MRI scanner (Skyra, Siemens, Enlargen, Germany) with an 8-channel receiver array head coil. The MRI protocol included FLAIR axis sequencing, DWI axial scanning and MRA. The detailed imaging parameters were as follows: FLAIR (inverse recovery (IR) sequence, TR 7000 ms, TE 120 ms, acquisition matrix, 356×151; field of view (FOV), 230 mm × 230 mm; flip angle (FA), 90°; slices, 18; section thickness, 6 mm; and intersection gap, 1.3 mm) and DWI (spin echo (SE) sequence, TR, 2501 ms; TE, 98 ms; acquisition matrix, 152×122; 3 directions; FOV, 230 mm × 230 mm; FA, 90°; slices, 18; section thickness, 6 mm; and intersection gap, 1.3 mm. DWI was obtained with b values of 0 and 1000 s/mm²). 3D-MRA scans (the fast field echo (FFE) sequence, TR, 4.9 ms; TE, 1.82 ms; acquisition matrix, 528×531; FOV, 330 mm × 330 mm; section thickness, 1.2 mm).

2.3. Image analysis

Two experienced neuroradiologists (YW and ZZ), blinded to the clinical data, independently evaluated these images, in case of a discrepant assessment results between the 2 readers, images were reviewed, and a consensus was established. According to their spatial distribution in the Alberta Stroke Program Early CT Score (ASPECTS) cortical areas (insula, M1-M6),[19] the FVH scores was assessed from 0 (no FVH) to 7 (FVHs abutting all ASPECTS cortical areas). FVH-DWI mismatch was assessed in axial FLAIR and DWI images, FVH-DWI mismatch was considered present when FVHs extended beyond the boundaries of the cortical DWI lesion (ie, when ≥1FVH was facing the isointense cortex on DWI). No FVH-DWI mismatch was defined as no FVH or all FVHs were facing the hyperintense cortex on DWI. Two experienced interventional neuroradiologists (YW and ZZ) who were blinded to the clinical information assessed the baseline angiography data of the EVT patients. The extent of cerebral tissue reperfusion was assessed with the mTICI scale (0 = complete occlusion to 3 = complete revascularization), complete revascularization was the state of 2b or 3 grades, no/partial revascularization was the state of 2a or 1 or 0.[22]

2.4. Statistical analysis

Descriptive statistics were used to assess the association between mTICI state and baseline variables, mRS score and baseline variables. Continuous data were described as the mean ± SD and compared using independent-samples t test or Mann–Whitney U test; whereas categorical variables was presented as number (percentage) and compared using chi-squared test or Fisher exact test. $P < .05$ was considered to indicate statistically significance. Kappa-values were used to determine inter-rater agreement. Logistic regression analysis of significantly associated variables was used to identify factors predictive of successful revascularization and favorable outcome. Univariate and multivariate logistic regression analysis was performed using mRS at 3 months as the outcome variable, and the odds ratios (OR) and 95% confidence interval (CI) were obtained. All statistical analyses were conducted using commercially available software (SPSS for Windows, version 19.0; SPSS).

3. Results

3.1. Comparison of complete and no/partial revascularization in acute stroke

Among 130 randomized patients in the study, 72 patients (41 men and 31 women; mean age [years ± SD] 69.69 ± 10.91; range, 40–82) fulfilled the inclusion criteria. Fifty-eight patients were excluded (18 patients without pretreatment MRI; 12 patients with severely artifacted FLAIR or DWI sequences; 23 patients who did not undergo angiography; 5 patients without mRS at 3 months). In 72 patients, 33 patients (45.83%) received thrombectomy therapy and 39 patients (54.17%) received both intravenous thrombolysis and thrombectomy therapy. 37/72

patients had FVH-DWI mismatch and 35/72 patients had no FVH-DWI mismatch, the interobserver agreement for FVH-DWI mismatch was $k = 0.96$ (95% CI, 0.92–0.99). As shown in Table 1, The patients did not differ with regard to sex ($t = 3.427$; $P = .080$), age ($t = -1.036$; $P = .304$), NIHSS at admission ($t = -1.302$; $P = .197$), median time to onset ($t = -1.745$; $P = .085$), median time to MRI scan ($t = 0.874$; $P = .385$) or median time to thrombectomy ($t = 1.504$; $P = .137$) between complete revascularization and no/partial revascularization. The FVH score was significantly higher in patients with complete revascularization than in patients with no/partial revascularization ($4.23 ± 1.67$ vs $3.08 ± 1.56$; $t = 2.809$; $P = .006$). Twenty-nine patients (60.42%) had FVH-DWI mismatch in patients with complete revascularization and 8 patients (33.33%) had FVH-DWI mismatch in patients with no/partial revascularization, and there was significant difference in 2 groups ($t = 4.698$; $P = .045$) (Figs. 1–3A). The clinical outcome in complete revascularization was better than that in no/partial revascularization ($t = -4.612$; $P = .000$). There was no significant difference in smoking, alcohol drinking, diabetes mellitus, hypertension, atrial fibrillation, hyperlipidemia and homocysteine between the 2 groups ($P = .096$) (Table 1).

3.2. Comparison of good and poor functional outcome in acute stroke

The analysis of 72 patients with LVO revealed that 37 of 72 patients (51.39%) had a good functional outcome (mRS at 3 months 0–2) and 35 (48.61%) had a poor functional outcome (mRS at 3 months 3–6). The good functional outcome group was younger than the poor functional outcome group ($66.24 ± 12.66$ vs $72.29 ± 9.97$; $t = -2.241$; $P = .028$). Besides, the good func-

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Table 1

Comparison of complete revascularization and no/partial revascularization with acute stroke patients.

	Complete revascularization(n = 48)	No/partial revascularization(n = 24)	T/χ^2	P
Sex (male), n (%)	31 (64.58%)	10 (41.67%)	3.427	.080
Age (y), mean ± SD	68.17 ± 12.91	71.21 ± 8.91	−1.036	.304
Median time to onset (h), mean ± SD	2.79 ± 1.48	3.38 ± 0.98	−1.745	.085
Median time to MRI scan(h), mean ± SD	3.70 ± 1.88	3.32 ± 1.49	0.874	.385
Median time to thrombectomy(h), mean ± SD	4.83 ± 1.97	4.11 ± 1.80	1.504	.137
NIHSS at admission, mean ± SD	13.33 ± 4.86	15.43 ± 9.36	−1.302	.197
Smoking, n (%)	5 (10.42%)	1 (4.17%)	0.205	.656
Alcohol drinking, n (%)	5 (10.42%)	1 (4.17%)	0.205	.656
Diabetes mellitus, n (%)	16 (33.33%)	4 (16.67%)	2.215	.170
Hypertension, n (%)	45 (93.75%)	24 (100%)	0.391	.546
Atrial fibrillation, n (%)	22 (45.83%)	16 (66.67%)	2.786	.134
Hyperlipidemia, n (%)	3 (6.25%)	3 (12.50%)	0.205	.393
Homocysteine, n (%)	3 (6.25%)	1 (4.17%)	0.000	1.000
FVH score, mean ± SD	4.23 ± 1.67	3.08 ± 1.56	2.809	.006*
DWI volume (mL), mean ± SD	28.96 ± 38.11	47.80 ± 30.79	−2.101	.039*
FVH/DWI mismatch, n (%)	29 (60.42%)	8 (33.33%)	4.698	.045*
mTICI, n (%)			91.658	.000*
0	–	0 (0.00%)		
1	–	5 (20.83%)		
2a	–	19 (79.17%)		
2b	23 (47.92%)	–		
3	25 (52.08%)	–		
mRS at 3 months, mean ± SD	2.56 ± 1.62	4.33 ± 1.34	−4.612	.000*

DWI = diffusion-weighted imaging, FVH = fluid-attenuated inversion recovery vascular hyperintensity, mRS = modified Rankin Scale, mTICI = the Modified Thrombolysis in Cerebral Ischemia, NIHSS = National Institutes of Health Stroke Scale.
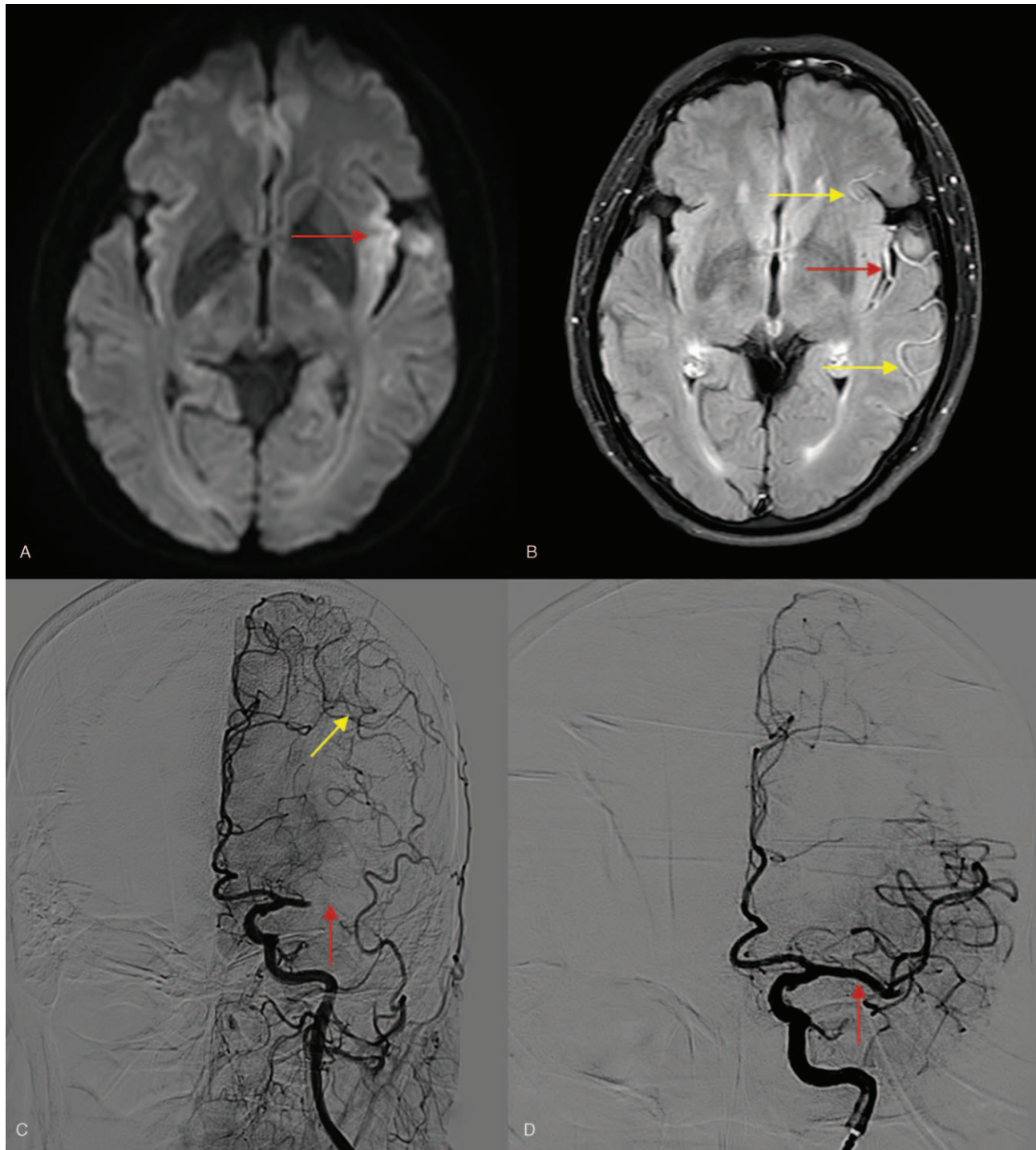* $P < .05$.

Figure 1. Illustrative case of FVH-DWI mismatch. Hyperintense lesions in the left temporal lobe (red arrow) on admission DWI (A) with FVH on fluid-attenuated inversion recovery (B), some facing the DWI lesion (red arrow) whereas others are seen well beyond the boundaries of DWI signal changes (yellow arrow), indicating a FVH-DWI mismatch. DSA image before therapy (C) showed occlusion from the horizontal segment of the left middle cerebral artery to the lateral fissure trunk (red arrow). Abundant collateralization was formed by left anterior cortical arteries (yellow arrow). After thrombectomy, DSA image (D) showed the left middle cerebral artery was complete revascularization (red arrow), Modified Thrombolysis in Cerebral Ischemia scale grade was 3. DSA = digital subtraction angiography, DWI = diffusion weighted imaging, FVH = fluid-attenuated inversion recovery vascular hyperintensity

tional outcome group had higher FVH score (4.38 ± 1.53 vs 3.49 ± 1.52; $t = 2.478$; $P = .016$), higher FVH-DWI mismatch ratio (81.25% vs 48.15%; $t = 10.862$; $P = .002$), higher complete revascularization ratio (83.78% vs 48.57%; $t = 10.036$; $P = .002$)

than the poor functional outcome group (Fig. 3B). There were no statistically significant differences in sex, hypertension, diabetes mellitus, hyperlipidemia, atrial fibrillation or homocysteine levels between the 2 groups ($P > .05$) (Table 2).
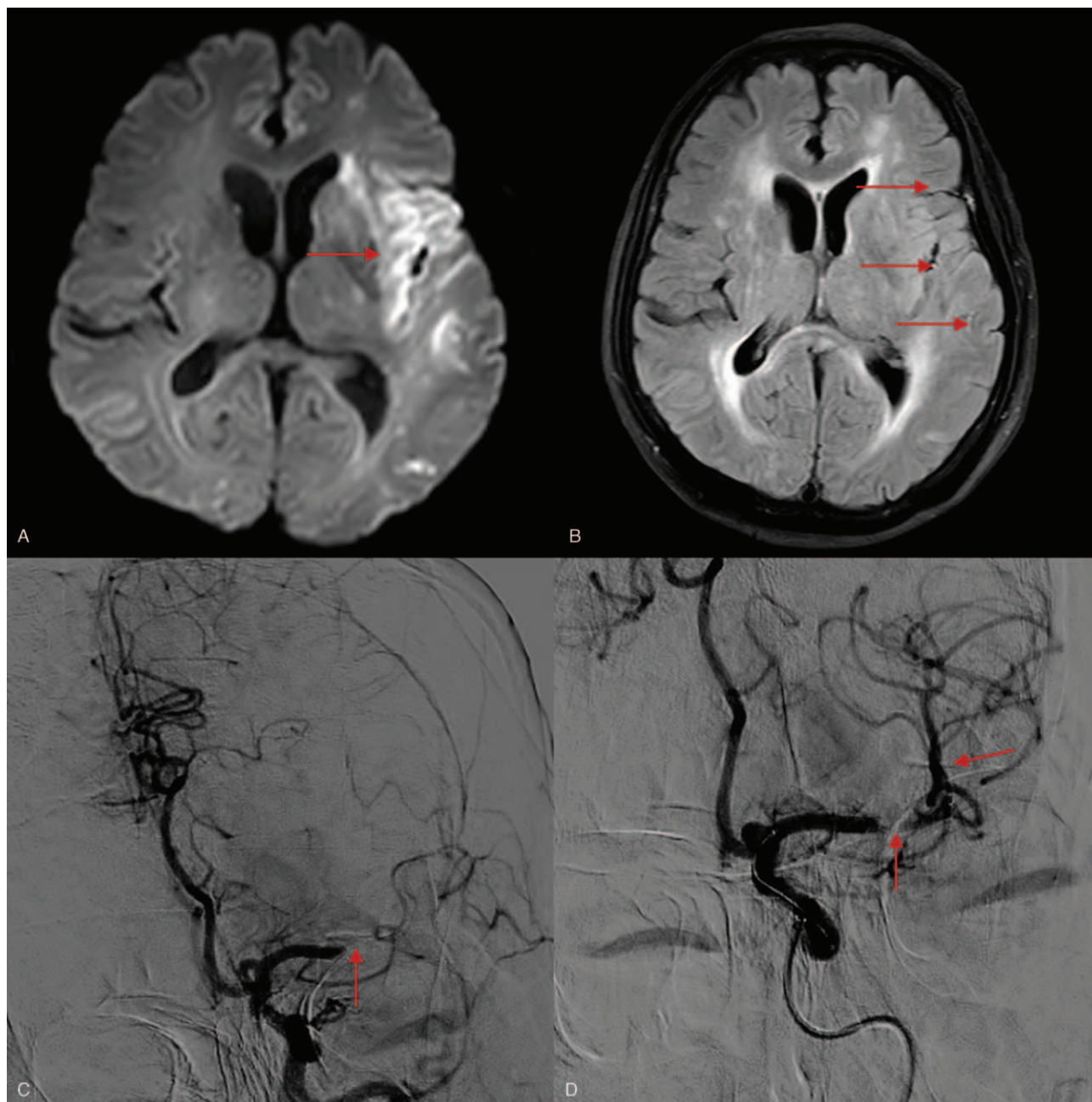
Figure 2. Illustrative case of no FVH-DWI mismatch. Hyperintense lesions in the left temporal lobe and left occipital lobe (red arrow) on admission DWI (A), FVH on fluid-attenuated inversion recovery (B) are seen in the DWI lesion (red arrow) whereas not beyond the boundaries of DWI signal changes, indicating no FVH-DWI mismatch. DSA image before therapy (C) showed occlusion of the left middle cerebral artery M1 segment (red arrow). After thrombectomy, DSA image (D) showed the left middle cerebral artery was partial revascularization (red arrow), Modified Thrombolysis in Cerebral Ischemia scale grade was 2a. DSA = digital subtraction angiography, DWI = diffusion weighted imaging, FVH = fluid-attenuated inversion recovery vascular hyperintensity.

3.3. The value of FVH-DWI mismatch in predicting revascularization and functional outcome in acute stroke

Spearman's rank correlation analysis revealed that FVH-DWI mismatch was positively correlated with complete revascularization ($r = 0.255$; $P = .030$); FVH-DWI mismatch also was positively correlated with good functional outcome ($r = 0.417$; $P = .000$). All variables were incorporated into multivariable logistic regression analysis and the entry mode was selected. Multivariable logistic regression analysis demonstrated that FVH-DWI mismatch was independently associated with complete revascularization (OR, 0.328; 95% CI, 0.117–0.915; $P = .033$). Age, FVH-DWI mismatch and complete revascularization were independently associated with good functional outcome (OR, 1.062; 95% CI, 1.006–1.122; $P = .030$; OR, 0.169; 95% CI, 0.061–0.468; $P = .001$; OR, 5.471; 95% CI, 1.826–16.386; $P = .002$) (Table 3).
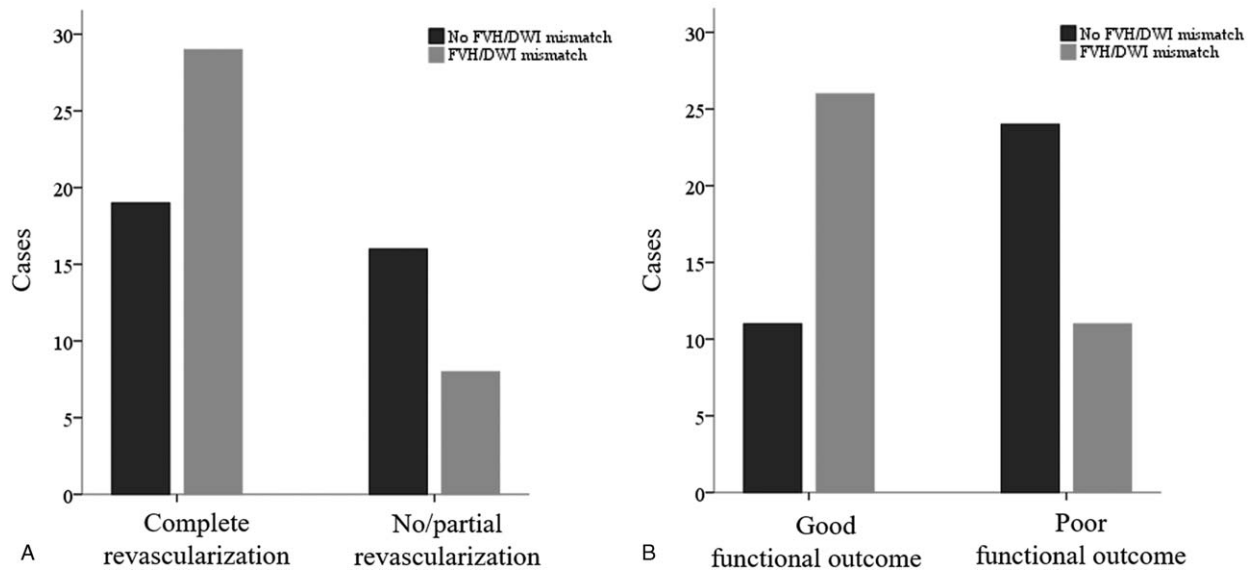
Figure 3. (A) Average and standard deviation bar chart representing fluid-attenuated inversion recovery vascular hyperintensity-diffusion weighted imaging mismatch difference between complete revascularization and no/ partial revascularization, (B) good functional outcome and poor functional outcome.

4. Discussion

IVT is often ineffective for patients with a proximal occlusion. The rate of recanalization after IVT has been reported to be 30% in patients with a proximal occlusion of MCA.[23] Recent randomized trials have demonstrated the efficacy of EVT in association with IVT, in acute stroke related to the occlusion of the proximal MCA with 6 hours of symptom onset.[24] In our study, all patients were a first-ever acute anterior circulation stroke within 6 hours of symptom onset. EVT should be performed as soon as possible after symptom onset.[24] All patients in our study were performed EVT immediately after LVO was found on MRA. It is crucial for functional outcome

to detect impaired yet viable tissue reliably and quickly before EVT. FVH-DWI mismatch can be used to evaluate ischemic penumbra, which has the advantages of simple, convenient and no post-processing. FVH-DWI mismatch was evaluated independently by 2 experienced neuroradiologists blinded to the clinical data, and the interobserver agreement for FVH-DWI mismatch was high ($k=0.96$). For patients with inconsistent assessment, 2 experienced neuroradiologists and another senior experienced neuroradiologist jointly reassess and reach an agreement. This makes it possible to evaluate revascularization and functional outcome by using FVH-DWI mismatch.

Table 2

Comparison of good functional outcome and poor functional outcome with acute stroke patients.

	Good functional outcome (mRS (0–2); n = 37)	Poor functional outcome (mRS (3–6); n = 35)	T/χ^2	P
Sex (male), n (%)	25 (67.57%)	16 (45.71%)	3.503	.095
Age (y), mean ± SD	66.24 ± 12.66	72.29 ± 9.97	−2.241	.028*
Median time to onset (h), mean ± SD	2.78 ± 1.46	3.20 ± 1.23	−1.310	.195
Median time to MRI scan(h), mean ± SD	3.76 ± 1.75	3.38 ± 1.78	0.906	.368
Median time to thrombectomy(h), mean ± SD	4.53 ± 1.77	5.50 ± 2.02	1.543	.127
NIHSS at admission, mean ± SD	12.41 ± 4.83	13.69 ± 3.59	−1.271	.208
Smoking, n (%)	4 (10.81%)	2 (5.71%)	0.126	.675
Alcohol drinking, n (%)	5 (13.51%)	1 (2.86%)	1.461	.200
Diabetes mellitus, n (%)	12 (32.43%)	8 (22.86%)	0.822	.435
Hypertension, n (%)	35 (94.59%)	34 (97.14%)	0.000	1.000
Atrial fibrillation, n (%)	17 (45.95%)	21 (60.00%)	1.425	.249
Hyperlipidemia, n (%)	3 (8.11%)	3 (8.57%)	0.000	1.000
Homocysteine, n (%)	3 (8.11%)	1 (2.86%)	0.945	.615
FVH score, mean ± SD	4.38 ± 1.53	3.49 ± 1.52	2.478	.016*
DWI volume(mL), mean ± SD	24.31 ± 32.46	46.79 ± 37.85	−2.710	.008*
FVH/DWI mismatch, n (%)	26 (81.25%)	11 (48.15%)	10.862	.002*
mTICI (2b-3), n (%)	31 (83.78%)	17 (48.57%)	10.036	.002*

DWI = diffusion-weighted imaging; FVH = fluid-attenuated inversion recovery vascular hyperintensity; mRS = modified Rankin Scale; mTICI = the Modified Thrombolysis in Cerebral Ischemia; NIHSS = National Institutes of Health Stroke Scale.
* $P < .05$.

Table 3

Multivariable logistic regression analysis of variables independently associated with successful revascularization and favorable outcome.

Independent variable	Revascularization (OR (95%CI))	P	Functional outcome (OR (95%CI))	P
Sex	0.067 (0.143–1.069)	.067	0.512 (0.199–1.318)	.165
Age	1.024 (0.979–1.071)	.302	1.062 (1.006–1.122)	.030*
Median time to onset	1.386 (0.948–2.027)	.092	1.736 (0.942–3.197)	.077
Median time to MRI scan	0.876 (0.651–1.178)	.381	1.055 (0.487–2.286)	.892
Median time to thrombectomy	0.806 (0.606–1.074)	.140	0.669 (0.345–1.297)	.234
NIHSS at admission	1.048 (0.947–1.160)	.364	1.099 (0.986–1.225)	.088
Smoking	0.374 (0.041–3.395)	.382	1.339 (0.117–15.263)	.814
Alcohol drinking	0.374 (0.041–3.395)	.382	1.339 (0.117–15.263)	.814
Diabetes mellitus	0.400 (0.117–1.368)	.144	0.431 (0.097–1.917)	.269
Hypertension	1.533 (0.151–15.576)	.718	3.223 (0.192–54.212)	.416
Atrial fibrillation	2.364 (0.851–6.562)	.099	1.988 (0.577–6.848)	.276
Hyperlipidemia	2.143 (0.399–11.521)	.375	6.000 (0.664–54.206)	.111
Homocysteine	0.652 (0.064–6.625)	.718	3.375 (0.334–34.094)	.303
FVH score	0.729 (0.513–1.036)	.078	0.809 (0.552–1.186)	.278
DWI volume	1.004 (0.988–1.012)	.600	1.006 (0.988–1.023)	.542
FVH/DWI mismatch	0.328 (0.117–0.915)	.033*	0.169 (0.061–0.468)	.001*
mTICI (2b-3)	–	–	5.471 (1.826–16.386)	.002*

DWI = diffusion-weighted imaging, FVH = Fluid-attenuated inversion recovery vascular hyperintensity, mTICI = the Modified Thrombolysis in Cerebral Ischemia, NIHSS = National Institutes of Health Stroke Scale.
* P < .05.

Although direct comparisons between FVH extent and DSA are limited,[25,26] irrespective of the quotation method, there is accumulating evidence that FVH distal to arterial occlusion represent good collaterals. There are several advantages of using FVH-DWI mismatch evaluating revascularization[27]: it is a reproducible method; it does not require gadolinium contrast; it is easily assessable by the naked eye directly without need for post-processing. In our study, 51.39% stroke patients with LVO occlusion had FVH-DWI mismatch. 60.42% had FVH-DWI mismatch in patients with complete revascularization and 33.33% had FVH-DWI mismatch in patients with no/partial revascularization. Patients with complete revascularization had higher FVH-DWI mismatch ratio than no/partial revascularization. This finding is consistent with Legrand et al.[20] Their results demonstrated that combination of DWI and FLAIR findings can identify patients with M1 occlusion who are likely to benefit from recanalization. We found that FVH-DWI mismatch was positively correlated with complete revascularization, and was independently associated with complete revascularization. FVH represent good collaterals protecting the penumbra from rapidly decaying while awaiting reperfusion. Good collaterals allow retrograde recombinant tissue plasminogen activator (rtPA) access to the distal end of the thrombus during thrombolysis and facilitate clot retrieval during EVT, thus enhancing the rate of successful recanalization.[28–31]

The mTICI scale has been accepted as the standard scale due to simple and intuitive.[32] mTICI 2b and mTICI 3 grades was considered as successful revascularization.[22] In our study, of 72 patients with LVO, 48 patients (66.67%) were complete revascularization after thrombectomy therapy and 24 patients (33.33%) were no/partial revascularization. Revascularization rate was chosen as the primary outcome because it is a major early indicator of treatment success and has been reported to be a predictor of clinical outcome.[33–35] We found that the good functional outcome group had higher FVH score, higher FVH-DWI mismatch ratio and higher complete revascularization ratio than the poor functional outcome group. A recent meta-analysis showed that good collaterals may enhance the rate of revascularization in patients with stroke receiving EVT.[29] Our

study showed that FVH-DWI mismatch was positively correlated with good functional outcome, and was independently associated with good functional outcome. FVH located beyond the DWI cortical lesion boundaries, as FVH-DWI mismatch, reacts the impaired yet viable tissue. This tissue restores its function after achieving recanalization. Maybe this is the reason why patients with FVH-DWI mismatch are more likely to have favorable clinical outcome. In addition, in our study, we found that there was no significant difference in age between complete revascularization and no/partial revascularization, while the age in good functional outcome group was significant older than that in poor functional outcome group. Goyal et al[2] reported that although age does not modify the treatment effect, it remains a strong independent predictor of final outcome.

However, this study has some limitations. Our study is based on selected patients with LVO from a single center. A small sample size limits the comparisons FVH-DWI mismatch and no FVH-DWI mismatch in complete revascularization and/or no/partial revascularization. We, however, compared the FVH-DWI mismatch difference between complete revascularization and no/partial revascularization. Despite the small number of cases, we still found FVH-DWI mismatch was associated with complete revascularization and good functional outcome. Besides, the small sample size of the current study also limits the comparisons between the subgroups (thrombolysis + trombectomy vs trombectomy). Therefore, we will compare the subgroups by expanding the sample size in our future study.

5. Conclusions

The good functional outcome had higher FVH-DWI mismatch ratio and higher complete revascularization ratio than the poor functional outcome. FVH-DWI mismatch was independently associated with complete revascularization and good functional outcome. Assessments of FVH-DWI mismatch before thrombectomy therapy might be useful for predicting revascularization and functional outcome in stroke patients with LVO.

Author contributions

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