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Benefit from revascularization after thrombectomy according to FLAIR vascular hyperintensities–DWI mismatch

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Abstract

Objectives We tested whether FLAIR vascular hyperintensities (FVH)–DWI mismatch could identify candidates for thrombectomy most likely to benefit from revascularization.

Methods We retrospectively reviewed 100 patients with proximal MCA occlusion from 18 stroke centers randomized in the IV-thrombolysis plus mechanical thrombectomy arm of the THRACE trial (2010–2015). We tested the associations between successful revascularization on digital subtraction angiography (modified Thrombolysis in Cerebral Infarction 2b/3) and 3-month favorable outcome (modified Rankin Scale score ≤ 2), stratified on FVH–DWI mismatch status, with secondary analyses adjusted on National Institutes of Health Stroke Scale (NIHSS) and DWI lesion volume.

Results FVH–DWI mismatch was present in 79% of patients, with a similar prevalence at 1.5 T (80%) and 3 T (78%). Successful revascularization (74%) was more frequent in patients with FVH–DWI mismatch (63/79, 80%) than in patients without (11/21, 52%), $p = 0.01$. The OR of favorable outcome for revascularization were 15.05 (95% CI 3.12–72.61, $p < 0.001$) in patients with FVH–DWI mismatch and 0.83 (95% CI 0.15–4.64, $p = 0.84$) in patients without FVH–DWI mismatch ($p = 0.011$ for interaction). Similar results were observed after adjustment for NIHSS (OR = 12.73 [95% CI 2.69–60.41, $p = 0.001$] and 0.96 [95% CI 0.15–6.30, $p = 0.96$]) or for DWI volume (OR = 12.37 [95% CI 2.76–55.44, $p = 0.001$] and 0.91 [95% CI 0.16–5.33, $p = 0.92$]) in patients with and without FVH–DWI mismatch, respectively.

Conclusions The FVH–DWI mismatch identifies patients likeliest to benefit from revascularization, irrespective of initial DWI lesion volume and clinical stroke severity, and could serve as a useful surrogate marker for penumbral evaluation.

Key Points

- *The FVH–DWI mismatch, defined by FLAIR vascular hyperintensities (FVH) located beyond the boundaries of the DWI lesion, is associated with large penumbra.*
- *Among stroke patients with proximal middle cerebral artery occlusion referred for thrombectomy, those with FVH–DWI mismatch are most likely to benefit from revascularization.*
- *FVH–DWI mismatch provides an alternative to PWI–DWI mismatch in order to select patients who are candidates for thrombectomy.*

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Keywords Stroke · Magnetic resonance imaging · Collateral circulation · Thrombectomy · Prognosis

Abbreviations

DSA	Digital subtraction angiography
FLAIR	Fluid-attenuated inversion recovery
FVH	FLAIR vascular hyperintensities
MCA	Middle cerebral artery
mRS	Modified Rankin Scale
NIHSS	National Institutes of Health Stroke Scale
OR	Odds ratio
PWI	Perfusion-weighted imaging
THRACE	THRombectomie des Artères CErébrales (mechanical thrombectomy after intravenous alteplase versus alteplase alone after stroke)
TICI	Thrombolysis in Cerebral Infarction

Introduction

The efficacy of mechanical thrombectomy (MT) in patients with acute ischemic stroke due to anterior large cerebral vessel occlusion [1] has dramatically changed the landscape of stroke care [2], and more so with the recent demonstration of a strong benefit of MT in late presenters, when properly selected using clinical-imaging biomarkers of salvageable tissue [3, 4]. Recent trials have, indeed, confirmed that the identification of salvageable brain tissue using core-penumbral surrogate markers could identify patients most likely to benefit from revascularization therapies, even in late therapeutic windows, with a compelling reduction in disability [3, 4]. Thus, imaging biomarkers that quickly and reliably detect impaired yet viable tissue are of great interest in patient care.

On MRI, in normal conditions, intracranial arteries appear dark on fluid-attenuated inversion recovery (FLAIR) sequence due to the flow–void phenomenon caused by a loss of signal intensity produced by the movement of blood. After an arterial occlusion, FLAIR vascular hyperintensities (FVH) are commonly seen and represent slow retrograde flow through leptomeningeal collaterals [5], which maintain some perfusion distal to the occlusion site while awaiting revascularization [6]. Focusing on FVH beyond the boundaries of the DWI lesion, we recently showed that FVH–DWI mismatch is an alternative to perfusion-weighted imaging (PWI)–DWI mismatch to assess tissue at risk of infarct expansion [7] and to select patients likeliest to benefit from intravenous thrombolysis [8]. However, these findings were based on (1) data extracted from a single center, with standardized 2D FLAIR sequence, which raises questions about the generalizability of the results; (2) 24-h MR angiography, likely to include late, futile revascularization; (3) patients treated with intravenous thrombolysis only, which is no longer the standard of care for patients with large vessel occlusion.

Focusing on MRI-selected patients randomized in the thrombolysis plus mechanical thrombectomy group of the multicenter THRombectomie des Artères CErébrales (THRACE) trial [9], we tested whether FVH–DWI mismatch could identify patients most likely to benefit from revascularization, with the hypothesis that the association between revascularization and favorable outcome would be stronger in patients with FVH–DWI mismatch than in patients without.

Materials and methods

In order to determine whether MT in addition to intravenous thrombolysis improves clinical outcome in patients with acute ischemic stroke, THRACE [9], a multicenter randomized controlled trial in France, included patients 18–80 years old with acute ischemic stroke (National Institutes of Health Stroke Scale [NIHSS] score ≥ 10 and ≤ 25) due to proximal occlusion randomly assigned to receive either intravenous thrombolysis or thrombolysis plus MT, between 2010 and 2015. Each enrolling center was free to use its routine CT or MRI stroke protocol for patient selection. Of note, according to the French recommendations [10], MRI is implemented as first-line imaging in candidates for reperfusion therapy, whenever feasible. Patients were eligible for inclusion if intravenous thrombolysis could be administered within 4 h of symptom onset and if MT could be initiated within 5 h of symptom onset. The THRACE study was approved by the CPP (Comité de Protection des Personnes) III Nord Est Ethics Committee and the research boards of the participating centers. All patients or their legal representatives provided written informed consent [9]. We retrospectively reviewed prospectively acquired data from the THRACE trial, including MR-selected patients allocated to the intravenous thrombolysis plus MT group who had an occlusion of the M1 portion of the middle cerebral artery (MCA), to minimize heterogeneity of the potential collateral supply, and who underwent digital subtraction angiography (DSA). MR images from 18 stroke centers in France were reviewed. FLAIR sequences were those routinely used in each center and were not standardized. Supplementary Table lists the main parameters of the 2D FLAIR sequences. FVH were defined as focal, tubular, or serpentine hyperintensities in the subarachnoid space relative to cerebrospinal fluid [11] and corresponding to a typical arterial course. Blinded to angiographic and clinical data, FLAIR and DWI sequences were reviewed together to assess the FVH–DWI mismatch (i.e., FVH extending beyond the boundaries of the cortical DWI lesion, Fig. 1) by a single radiologist (LL, 6 years of experience in neuroradiology) given the previously reported high interobserver agreement [7].

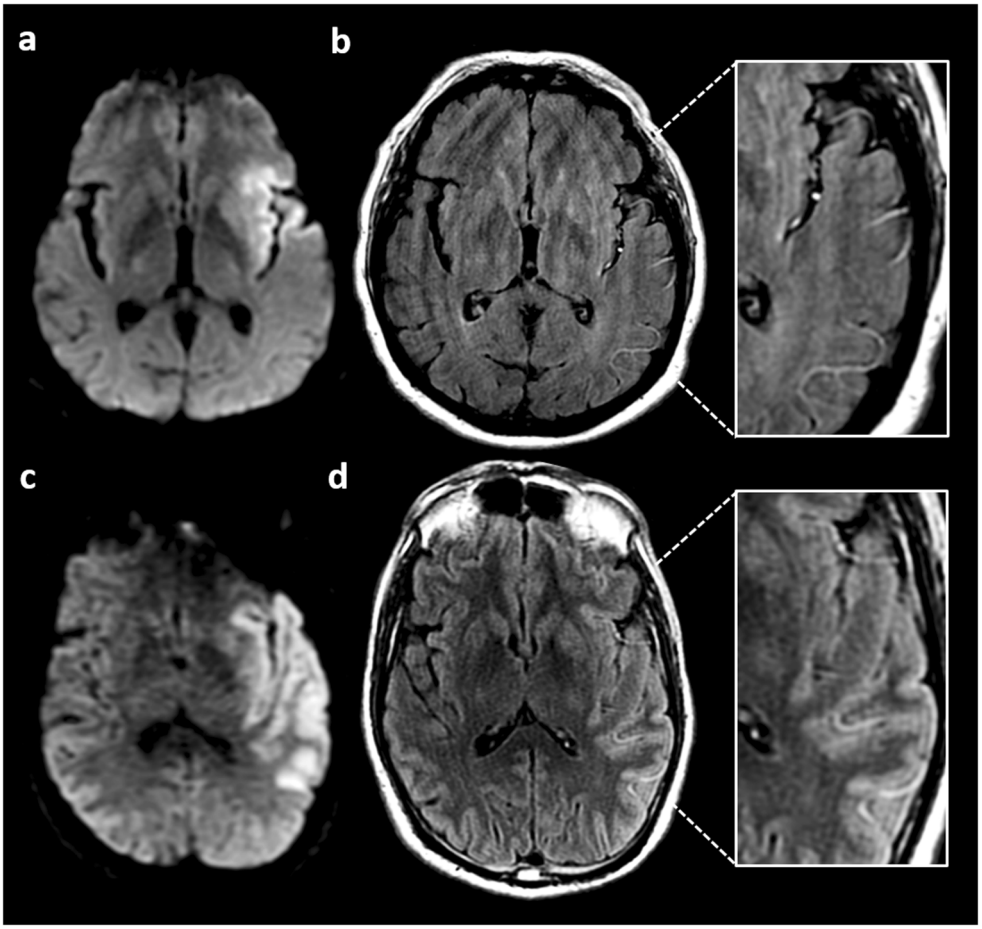

Fig. 1 Illustrative cases of fluid-attenuated inversion recovery (FLAIR) vascular hyperintensities (FVH)–diffusion-weighted imaging (DWI) mismatch and no FVH–DWI mismatch. FVH–DWI mismatch (**a**, **b**). MRI of woman in her 70's obtained 148 min after stroke onset. Hyperintense lesion in the left middle cerebral artery territory on admission DWI (**a**) with posterior FVH on FLAIR (**b**) facing normal cortex. No FVH–DWI mismatch (**c**, **d**). MRI of a man in his 50's obtained 110 min after stroke onset. Large hyperintense lesion in the left middle cerebral artery territory on admission DWI (**c**) with FVH on FLAIR (**d**) facing cortex with DWI signal changes

The FVH–DWI mismatch was rated as either present or absent. Baseline DWI lesion volume was determined semi-automatically on Olea Sphere™ (V3.0, OLEA MEDICAL) [12]. After motion correction and cerebrospinal fluid masking, a threshold of apparent diffusion coefficient $< 0.6 \times 10^{-3}$ mm^2/s [12] was applied to the apparent diffusion coefficient map, with manual adjustment of lesion boundaries. Pretreatment occlusion was assessed on MR angiography. Successful early revascularization was assessed on DSA, and defined as modified Thrombolysis in Cerebral Infarction (TICI) 2b or 3 [1, 13] (Fig. 2). We excluded patients whose DSA had not been transmitted to the imaging core laboratory.

Descriptive statistics were used to assess the association between FVH–DWI mismatch presence and baseline variables. Categorical variables were described as number (percentage) and compared using $\chi 2$ or Fisher's exact test, as appropriate. Continuous variables were described as mean ± SD or median (interquartile range) and compared using Student's t test or Mann–Whitney U test. The primary prespecified hypothesis was that the association between revascularization and 3-month favorable outcome (modified Rankin Scale (mRS) score ≤ 2) would be stronger in patients with FVH–DWI mismatch than in patients without. We tested this hypothesis with logistic regression analyses stratified on FVH–DWI mismatch status to study its potential role in the association (odds ratios [OR] with 95% confidence interval [CI]) between successful revascularization (explanatory variable) and 3-month favorable outcome (dependent variable). Secondary analyses, by design also stratified on FVH–DWI mismatch status, considered any better functional outcome at 3 months (shift analysis over the whole range of the mRS) and early neurological improvement, defined as ΔNIHSS (24-h NIHSS − initial NIHSS) ≥ 8 [14]. Binary logistic regression models were used, except for the shift analysis of the mRS, where an ordinal logistic regression was performed after ensuring that the assumption of proportional odds ratios was met. These analyses were secondarily adjusted on predefined potential confounders (NIHSS; baseline DWI volume) using Firth's correction [15]. Only one confounder was introduced in each model to avoid potential overfitting, given the small number of patients without FVH–DWI mismatch but with favorable outcome [16]. The interaction between FVH–DWI mismatch and revascularization to predict outcomes of interest was assessed using the Breslow-Day test. A 2-tailed p value < 0.05 was considered significant (statistical analyses by GT and LL, using SAS 9.4 and SPSS 19.0).

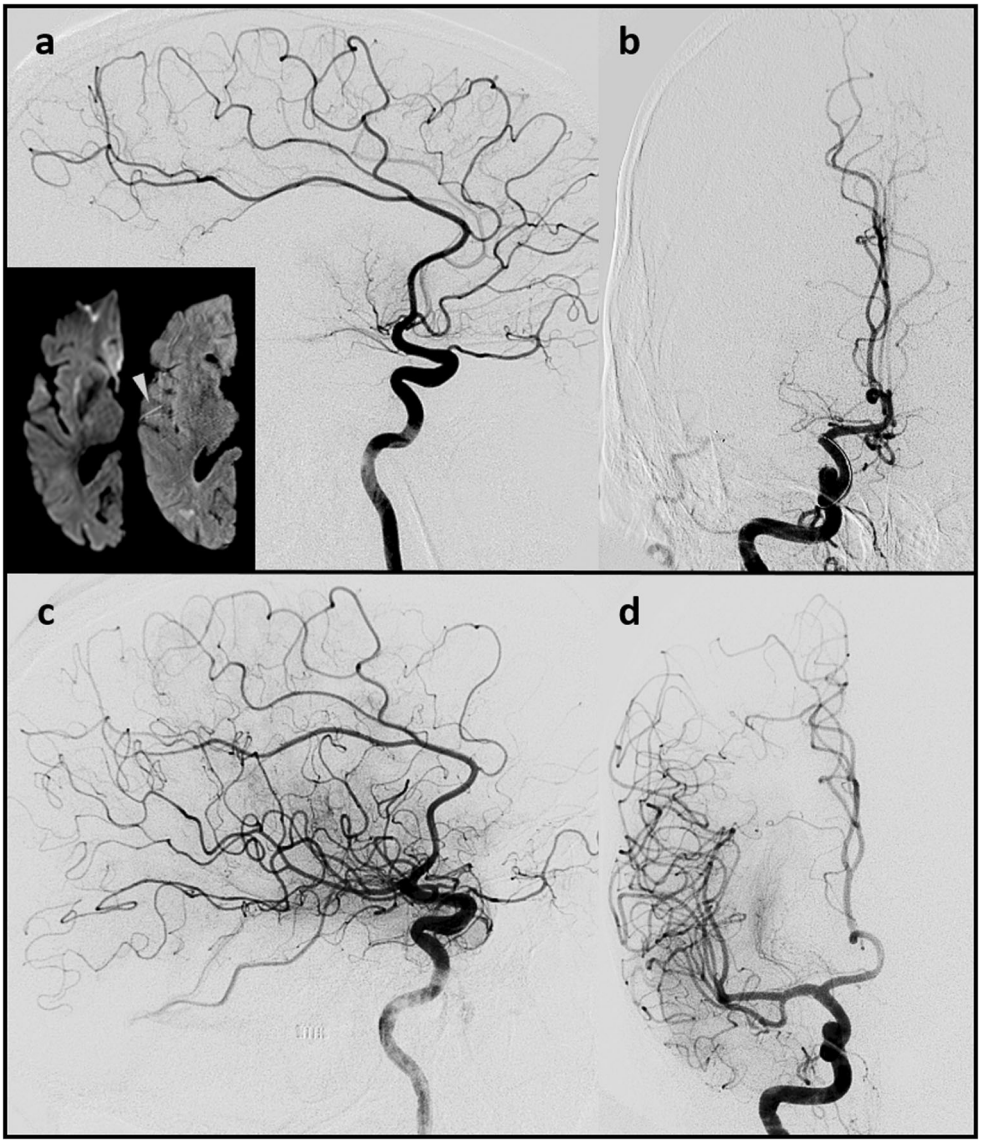

Fig. 2 Illustrative case of successful revascularization. Proximal occlusion of the right middle cerebral artery on pretreatment digital subtraction angiography (DSA) (**a**, **b**). Fluid-attenuated inversion recovery (FLAIR) vascular hyperintensities (FVH) (arrowhead) facing normal cortex on DWI obtained 78 min after stroke onset (**a**, inset, DWI left image, FLAIR right image). Complete revascularization on DSA after thrombectomy (**c**, **d**), Thrombolysis in Cerebral Infarction (TICI) = 3

Results

Amongst 414 randomized patients in the THRACE trial [9], 100 patients (54 men and 46 women; mean age [years ± SD] 63.2 ± 13.1; range, 32–79) fulfilled the inclusion criteria (see Fig. 3 for the flow chart). Of note, as stated in the THRACE princeps study, initial radiological assessments were done with MRI in 148 (73%) of 204 patients in the thrombolysis plus MT group. 79/100 patients had FVH–DWI mismatch and 21/100 patients had no FVH–DWI mismatch. As shown in Table 1, there was no significant difference between the two groups for admission NIHSS score, time from onset to initial MRI, time from onset to intravenous thrombolysis, or time from onset to catheterization room. DWI lesion volume was smaller in patients with FVH–DWI mismatch than in patients without (median [interquartile range] of 16 mL [9–34] vs 75 mL [38–122], $p < 0.001$). All 22 patients with DWI lesion restricted to the deep MCA territory (caudate/lentiform nuclei and/or internal capsule) had FVH–DWI mismatch. There was no difference in the prevalence of FVH–DWI mismatch between patients imaged at 1.5 T or 3 T (48/60 [80%] vs 31/40 [78%], respectively, $p = 0.76$) or across manufacturers (General Electric: 36/43 [84%]; Philips: 26/38 [68%]; Siemens: 17/19 [89%]; $p = 0.11$). Of the six patients imaged with 3D FLAIR (Philips' MR unit), only two had an FVH–DWI mismatch.

Successful revascularization occurred in 74/100 patients and was more frequent ($p = 0.01$) in patients with FVH–DWI mismatch (63/79, 80%) than in patients without (11/21, 52%). After stratification for FVH–DWI mismatch status (Table 2), the association between revascularization and favorable outcome was significant in patients with FVH–DWI mismatch (OR 15.05, 95% CI 3.12–72.61, $p < 0.001$), but not in patients without FVH–DWI mismatch (OR 0.83, 95% CI

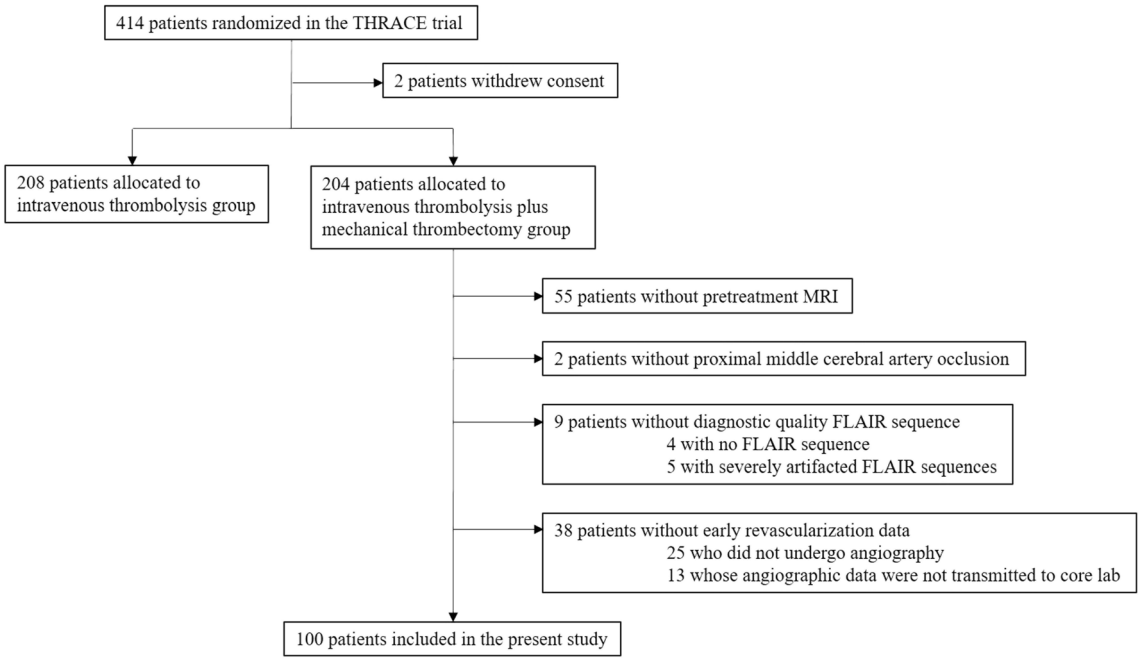

Fig. 3 Flow chart of inclusion

0.15–4.64, $p = 0.84$), $p = 0.011$ for interaction. In an exploratory analysis adjusted for the admission NIHSS score, the OR of favorable outcome for revascularization was 12.73 (95% CI 2.69–60.41, $p = 0.001$) in patients with FVH–DWI mismatch and 0.96 (95% CI 0.15–6.30, $p = 0.96$) in patients without FVH–DWI mismatch. Similarly, after adjustment for baseline DWI volume, the OR of favorable outcome for revascularization was 12.37 (95% CI 2.76–55.44, $p = 0.001$) in patients with FVH–DWI mismatch and 0.91 (95% CI 0.16–5.33, $p = 0.92$) in patients without FVH–DWI mismatch.

In ordinal logistic regression (shift analysis over the whole range of the mRS, Fig. 4), the association between revascularization and better outcome was significant in patients with FVH–DWI mismatch (OR 9.99, 95% CI 3.34–29.84, $p < 0.0001$), but not in patients without FVH–DWI mismatch (OR 0.77, 95% CI 0.16–3.60, $p = 0.74$), $p = 0.009$ for interaction. Similar results were observed after adjustment for admission NIHSS score or DWI lesion volume (data not shown).

Successful revascularization was significantly associated with early neurological improvement in patients with FVH–DWI mismatch (OR 24.82, 95% CI 3.05–201.66, $p < 0.0001$) but not in patients without (OR 1.50, 95% CI 0.26–8.82, $p = 0.65$), $p = 0.03$ for interaction (Table 2).

Discussion

In a post hoc analysis of patients included in the THRACE multicenter trial, we showed that among acute ischemic stroke patients with proximal MCA occlusion, FVH–DWI mismatch conspicuously identifies candidates who are most likely to benefit from MT, irrespective of initial DWI lesion volume or clinical stroke severity. Indeed, the effect size for favorable outcome after revascularization was much stronger (OR 15.05) in patients with FVH–DWI mismatch than in those without (OR 0.83), with a significant interaction between these variables ($p = 0.011$).

There is accumulating evidence that FVH distal to an arterial occlusion represent good collaterals in the early time window. Although direct comparisons between FVH extent and DSA are limited [5, 17–19], most studies reported FVH to be associated with good collaterals. Irrespective of the quotation method, extensive FVH were also reported to be associated with smaller baseline DWI lesions [7, 17, 20, 21], larger PWI–DWI mismatch [7, 20, 22], milder hypoperfusion [22], smaller infarct growth [20, 22–24], and better clinical outcome [7, 8, 17, 19, 21–23]. Accordingly, here, in patients with proximal MCA occlusion, FVH–DWI mismatch was associated with smaller baseline DWI lesion volumes and was always present in isolated striatocapsular infarcts, typically seen in patients with good collaterals [25–27]. Altogether, these results strengthen the notion that FVH, especially those located beyond the DWI lesion [8, 21], represent good collaterals protecting the penumbra from rapidly decaying while awaiting reperfusion. Good collaterals may enhance the rate of successful reperfusion and recanalization by allowing retrograde recombinant tissue plasminogen activator (rtPA) access to the distal end of the thrombus during thrombolysis [28] and/or decreasing impaction force on the thrombus (pressure gradient across the thrombus) [29], thus facilitating clot retrieval during MT [6, 30–32]. In line with this, in the intravenous thrombolysis plus MT group of the THRACE study,

Table 1 Univariate comparisons between patients according to FVH–DWI mismatch

	FVH–DWI mismatch ($n = 79$)	No FVH–DWI mismatch ($n = 21$)	p value
Demographics/risk factors			
Age, years	65 ± 13	56 ± 13	0.008
Male	38 (48%)	16 (76%)	0.02
Hypertension*	36 (47%)	7 (33%)	0.27
Diabetes mellitus†	3 (4%)	1 (5%)	0.62
Hyperlipidemia‡	30 (43%)	8 (42%)	0.91
Current smoking‡	16 (23%)	10 (56%)	0.007
Characteristics at admission			
Systolic BP, mmHg	139 ± 21	141 ± 18	0.72
Diastolic BP, mmHg	80 ± 15	85 ± 13	0.20
Serum glucose, g/L*	1.2 ± 0.2	1.4 ± 1.0	0.48
NIHSS score	18 (14–20)	19 (17–21)	0.09
Initial MRI			
Time from onset to initial MRI, min†	113 (86–140)	117 (98–137)	0.63
DWI volume, mL	16 (9–34)	75 (38–122)	<0.001
Time from onset to intravenous thrombolysis	155 (125–179)	140 (117–168)	0.65
Time from onset to catheterization room§	199 (169–250)	207 (185–237)	0.48
Mechanical thrombectomy duration, min‖	45 (21–81)	44 (30–85)	0.76
Successful revascularization	63 (80%)	11 (52%)	0.01
24-h follow-up			
NIHSS score#	8 (4–16)	14 (6–24)	0.03
Early neurological improvement#	40 (53%)	9 (45%)	0.54
3-month follow-up			
mRS score	2 (1–4)	4 (1–4)	0.27
mRS ≤ 2**	45 (57%)	10 (48%)	0.44

Numbers are mean ± SD or median (interquartile range). *FVH* FLAIR vascular hyperintensities, *DWI* diffusion-weighted imaging, *BP* blood pressure, *NIHSS* National Institutes of Health Stroke Scale, *mRS* modified Rankin Scale

*Hypertension and serum glucose: missing data ($n = 2$)

† Diabetes mellitus and time from onset to initial MRI: missing data ($n = 1$)

‡ Hyperlipidemia and current smoking: missing data ($n = 12$)

§ Time from onset to catheterization room: missing data ($n = 6$)

‖ Available in 89 patients (69 in the FVH–DWI mismatch group and 20 in the no FVH–DWI mismatch group)

24-h NIHSS score and early neurological improvement: missing data ($n = 4$)

**mRS score extrapolated as favorable outcome (mRS ≤ 2) for 1 patient with 24-h and 7-day NIHSS score = 0

successful revascularization was more frequent in patients with FVH–DWI mismatch than in others. Further, the current analysis matches the results obtained with a distinct cohort of patients treated with intravenous thrombolysis alone, in which patients with FVH–DWI mismatch showed better outcomes when recanalized, with effect sizes of comparable magnitude [7, 8], suggesting the key role of FVH–DWI mismatch in identifying tissue at risk and collateralization. Our results reinforce the findings from a recent study in which the authors showed that a higher load of FVH outside the DWI lesion was associated with favorable clinical outcome [21]. However, in this monocentric cohort of patients treated between 2004 and 2014, the rate of recanalization was relatively low, likely because of the use of first-generation devices for MT, the indications for MT were not standardized with an important risk of bias by indication, and, more importantly, the benefit of revascularization stratified on FVH pattern was not assessed, limiting applicability in the modern MT era. In contrast, in the current study using data from patients treated with latest-generation MT devices, we showed that the benefit of revascularization depended on the visibility of FVH outside the DWI lesion, without the need to estimate their load or number. An alternative mean of selecting candidates for recanalization with a limited infarct core and a large amount of potentially salvageable tissue is based on a clinical deficit that is disproportionately severe relative to the infarct volume [3], known

Table 2 Patients' characteristics according to FVH–DWI mismatch and revascularization

	FVH–DWI mismatch ($n = 79$)			No FVH–DWI mismatch ($n = 21$)		
	Complete revascularization ($n = 63$)	No/partial revascularization ($n = 16$)	p value	Complete revascularization ($n = 11$)	No/partial revascularization ($n = 10$)	p value
Initial NIHSS	18 (14–20)	20 (14–22)	0.26	19 (17–22)	19 (17–21)	0.81
Time from onset to MRI, min*	112 (82–147)	120 (94–135)	0.99	117 (97–139)	116 (96–135)	0.53
Baseline DWI volume, mL	16 (8–34)	16 (10–41)	0.33	81 (39–130)	48 (35–120)	0.70
Early neurological improvement†	39 (64%)	1 (7%)	< 0.001	5 (50%)	4 (40%)	0.50
3-month mRS ≤ 2‡	43 (68%)	2 (13%)	< 0.001	5 (45%)	5 (50%)	0.84

FVH FLAIR vascular hyperintensities, *DWI* diffusion-weighted imaging, *NIHSS* National Institutes of Health Stroke Scale, *mRS* modified Rankin Scale
Median (interquartile range)

*Time from onset to MRI: missing data ($n = 1$)

† Early neurological improvement: missing data ($n = 4$)

‡ Extrapolated as favorable outcome (mRS ≤2) for 1 patient with 24-h and 7-day NIHSS score = 0

as the "clinical-DWI mismatch" [33]. This approach involves a volumetric analysis of the infarct core on DWI or on computed tomography (CT) perfusion maps, which requires dedicated automated software or manual segmentation. In

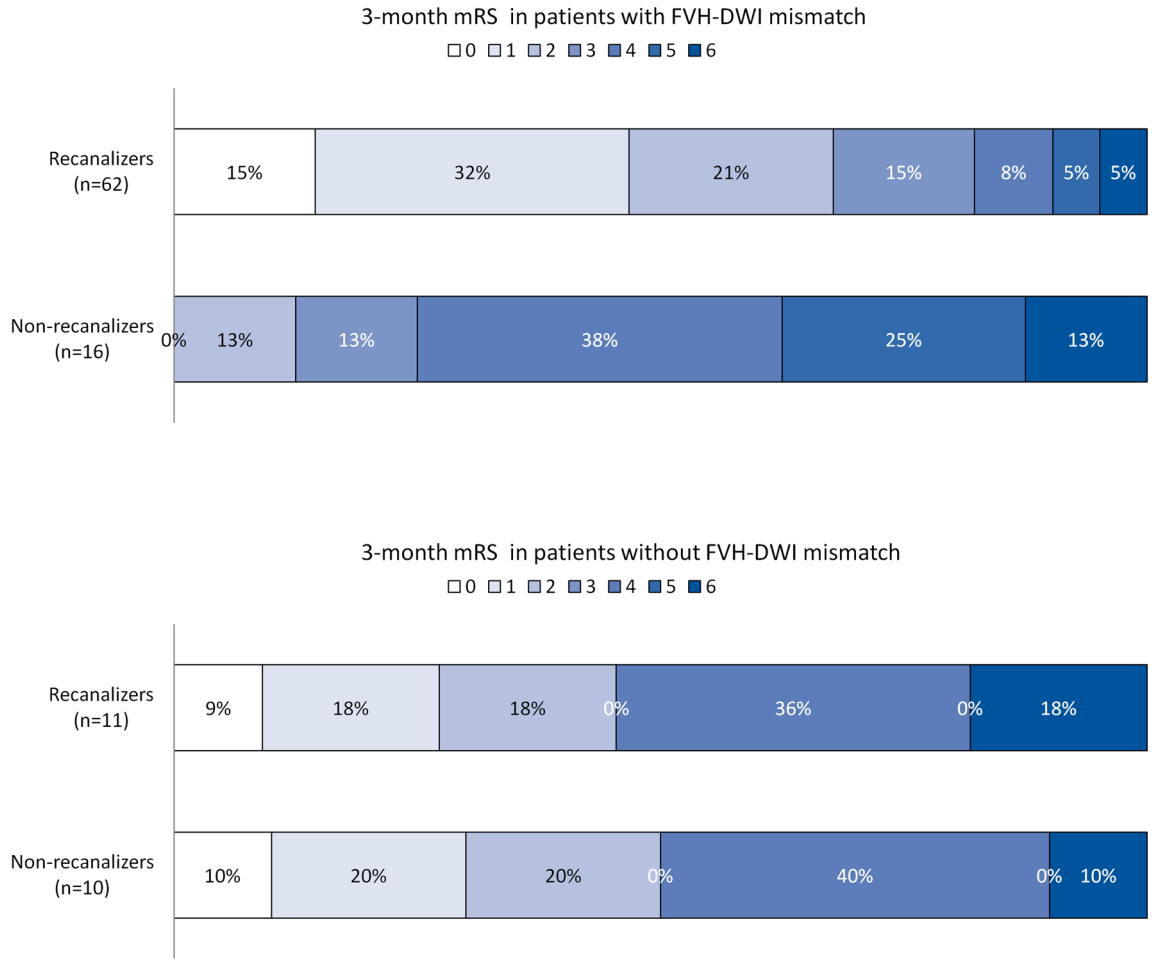

Fig. 4 3-month mRS in patients with and without recanalization according to FVH–DWI mismatch status. mRS: modified Rankin Scale, FVH: fluid-attenuated inversion recovery (FLAIR) vascular hyperintensities, DWI: diffusion-weighted imaging. One missing data in the group "FVH–DWI mismatch/recanalizers"

contrast, FVH–DWI mismatch is a reproducible method [7] assessable by the naked eye directly on the PACS (picture archiving and communication system) or any DICOM (digital imaging and communications in medicine) viewer without the need for post-processing. Compared to the PWI–DWI mismatch [4], it does not require gadolinium injection or dedicated software and therefore decreases scan duration. As previously suggested [7], FVH–DWI mismatch could help identify good responders to recanalization whenever PWI is unavailable or patients have difficult venous access or contraindications for gadolinium use.

Our study has several limitations. First, although multicenter and prospective, the THRACE trial was not designed for the purpose of our analysis increasing the risk of type 1 error. Amongst 414 randomized patients in the THRACE trial, only 100 were included in our study, with potential selection bias. The small size of the "no FVH–DWI mismatch" group precluded subgroup analyses. Second, our prespecified hypothesis that the association between revascularization and favorable outcome would be stronger in patients with FVH–DWI mismatch than in patients without precluded the use of the full range of THRACE patients, since revascularization was not assessed in the IV-tPA group. In addition, in the absence of a control group without revascularization therapy, no definite conclusions about the potential futility of treatment in patients with no or little salvageable tissue can be made. Accordingly, the absence of FVH–DWI mismatch should not be used to withhold patients from revascularization therapy. Third, TICI 3 and TICI 2b patients were considered together, even though TICI 3 reperfusions have been shown to be associated with higher rates of functional independence [34]. Fourth, we deliberately selected a population of patients with proximal MCA occlusion to minimize heterogeneity of the potential collateral supply and our results cannot be generalized to all stroke patients. All MR images were obtained within 4 h from stroke onset and results might differ at later time points. Last, some patients were excluded because of FLAIR artifacts, but the proportion of these severely artifacted FLAIR sequences was relatively low (< 5%). FLAIR and DWI sequences were different among centers, which could have influenced the assessment of the FVH–DWI mismatch. However, the prevalence of the FVH–DWI mismatch was similar across magnetic field strengths and manufacturers (although lower in 3D FLAIR acquisitions), suggesting that it can be used on all MR units.

In conclusion, our multicenter data supply further evidence that FVH–DWI mismatch is usable on all MR units and identifies those patients with proximal MCA occlusion likeliest to benefit from revascularization, irrespective of initial DWI lesion volume and clinical stroke severity. This simple surrogate biomarker provides an alternative to PWI– or clinical–DWI mismatch in order to select candidates for future trials aimed at refining patients' selection for MT.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Catherine Oppenheim.

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry One of the authors (GT) has significant statistical expertise.

Informed consent Written informed consent was obtained from all subjects (patients) or their legal representatives in the THRACE study.

Ethical approval The THRACE study was approved by the CPP (Comité de Protection des Personnes) III Nord Est Ethics Committee and the research boards of the participating centers.

Study subjects or cohorts overlap In addition to the THRACE trial [1], the stroke population studied here has been published previously in the following articles dealing with entirely different scientific questions, respectively cost-effectiveness of thrombectomy in patients with acute ischemic stroke [2], impact of pretreatment lesional volume on clinical outcome and thrombectomy efficacy [3], outcome after reperfusion therapies in patients with large baseline DWI stroke lesions [4], susceptibility vessel sign [5, 6], inter- and intraobserver reliability for angiographic leptomeningeal collateral flow assessment by the American Society of Interventional and Therapeutic Neuroradiology/Society of Interventional Radiology scale [7], imaging features and safety and efficacy of endovascular stroke treatment [8] and Validation of Overestimation Ratio and TL-SVS as imaging biomarker of cardioembolic stroke and time from onset to MRI [9] whereas we focused on FLAIR vascular hyperintensities.

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Methodology

- Retrospective review of prospectively acquired data
- Prognostic study/observational
- Multicenter study

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