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Puncture-to-Reperfusion Time and Functional Outcome Across Degrees of Successful Reperfusion After Mechanical Thrombectomy

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Abstract

Background

The association between intraprocedural delay and functional outcome may differ according to the final degree of reperfusion achieved. We examined the association between puncture-to-reperfusion time and functional outcome across final mTICI 2b and mTICI 2c/3 reperfusion after mechanical thrombectomy.

Methods

This retrospective cohort included 418 patients with acute ischemic stroke who achieved final mTICI 2b or mTICI 2c/3 reperfusion. Puncture-to-reperfusion time was analyzed continuously, centered at 90 minutes, and scaled per 30-minute increase. Multivariable regression models included reperfusion grade, time, and their interaction. The primary outcome was functional independence at 90 days (modified Rankin Scale score 0–2). Pass number (1, 2, or ≥ 3) was examined descriptively as an exploratory measure of procedural burden.

Results

Final reperfusion was mTICI 2b in 133 patients and mTICI 2c/3 in 285. Functional independence occurred in 39.1% and 58.9%, respectively. Each 30-minute increase in puncture-to-reperfusion time was associated with lower adjusted odds of functional independence in the mTICI 2b group (adjusted odds ratio [aOR], 0.77; 95% confidence interval [CI], 0.63–0.95; P = 0.015) and the mTICI 2c/3 group (aOR, 0.83; 95% CI, 0.73–0.95; P = 0.006). There was no evidence that the time-outcome association differed between reperfusion groups (interaction P = 0.538). At 90 minutes, mTICI 2c/3 was associated with higher odds of functional independence than mTICI 2b (aOR, 1.81; 95% CI, 1.07–3.05; P = 0.026). In the exploratory analysis (n = 415), observed functional independence declined across 1, 2, and ≥ 3 passes in both reperfusion groups, with the most pronounced decrease in the mTICI 2b group.

Conclusions

Longer puncture-to-reperfusion time was associated with worse functional outcome across both degrees of successful reperfusion. Near-complete or complete reperfusion retained a favorable association at the reference time, but it did not eliminate the adverse association of procedural delay. The exploratory pass-number pattern was consistent with increasing procedural burden but does not establish an independent pass effect. These findings favor rapid achievement of the highest safely attainable reperfusion grade.

1. Introduction

Mechanical thrombectomy improves outcome in acute ischemic stroke caused by large-vessel occlusion, but its benefit decreases as reperfusion is delayed [1, 2]. This time dependence continues after arterial puncture: longer procedures prolong tissue ischemia and often reflect technical difficulty, repeated device manipulation, or both [6–11]. Puncture-to-reperfusion time is therefore not merely an operational metric; it is a clinically relevant component of reperfusion performance.

Final angiographic reperfusion is conventionally considered successful at modified Thrombolysis in Cerebral Infarction (mTICI) grade 2b or higher. However, successful reperfusion is not a homogeneous endpoint. Patients with near-complete or complete reperfusion (mTICI 2c/3) generally have better outcomes than those with residual mTICI 2b reperfusion [3–5, 12, 14]. A procedural result must therefore be evaluated along two dimensions: how completely flow is restored and how long restoration takes.

These dimensions may compete during thrombectomy. After mTICI 2b has been reached, further attempts may increase the reperfused territory, but they also consume time and may increase the risks of embolization, endothelial injury, perforation, or hemorrhage [9, 15–17]. The relevant question is not whether speed or completeness matters in isolation, but whether the association between procedural delay and outcome differs across degrees of successful reperfusion.

We therefore investigated puncture-to-reperfusion time in relation to clinical outcomes among patients with final mTICI 2b versus mTICI 2c/3 reperfusion. The primary objective was to estimate the association between each 30-minute increase in procedure time and 90-day functional independence within each reperfusion group and to test whether this association was modified by final reperfusion grade. We hypothesized that longer procedure time would be associated with worse outcome in both groups, while higher-quality reperfusion would remain favorable at a common procedural duration.

2. Methods

2.1 Study design and population

We conducted a retrospective observational cohort study of consecutive patients with acute ischemic stroke treated with mechanical thrombectomy at Yangpu Hospital, Tongji University School of Medicine, Shanghai, China, including the North Campus, between January 2020 and December 2025. The present analysis was restricted to patients with final mTICI 2b, 2c, or 3 reperfusion and complete data for procedural timing, prespecified covariates, and 90-day outcome. Patients with final reperfusion below mTICI 2b were excluded because the study question concerned heterogeneity within successful reperfusion. The final cohort comprised 418 patients (Figure S1).

2.2 Variables and definitions

Baseline variables included age, sex, pre-stroke modified Rankin Scale (mRS) score, admission National Institutes of Health Stroke Scale (NIHSS) score, Alberta Stroke Program Early CT Score (ASPECTS), vascular risk factors, bridging intravenous thrombolysis, onset-to-puncture time, target occlusion site,

and stroke etiology according to the Trial of Org 10172 in Acute Stroke Treatment classification. Procedural variables included anesthesia strategy, puncture-to-reperfusion time, and number of thrombectomy passes. Final angiographic reperfusion was graded using the mTICI scale in routine clinical practice.

Puncture-to-reperfusion time was defined as the interval from arterial puncture to achievement of the final reperfusion grade. Reperfusion degree was categorized as mTICI 2b versus mTICI 2c/3. The latter category represented near-complete or complete reperfusion, which has been associated with outcomes closer to mTICI 3 than to conventional mTICI 2b [3–5].

2.3 Outcomes

The primary outcome was functional independence at 90 days, defined as mRS 0–2. Secondary outcomes were excellent functional outcome at 90 days (mRS 0–1), 90-day all-cause mortality, discharge NIHSS score, and intracranial hemorrhagic transformation on post-treatment neuroimaging.

2.4 Statistical analysis

Continuous variables are presented as mean ± standard deviation or median (interquartile range), and categorical variables as counts and percentages. Between-group comparisons used Welch's t test, the Mann-Whitney U test, Pearson's chi-square test, or Fisher's exact test, as appropriate. Puncture-to-reperfusion time was modeled continuously, centered at 90 minutes and scaled per 30-minute increase. The primary logistic regression model included final reperfusion grade (mTICI 2c/3 vs mTICI 2b), procedure time, and their interaction, adjusted for age, sex, admission NIHSS, pre-stroke mRS, bridging intravenous thrombolysis, onset-to-puncture time, anesthesia type, and occlusion site. Binary outcomes were analyzed using logistic regression with robust standard errors, and discharge NIHSS using multivariable linear regression with HC3 robust standard errors. Adjusted marginal probabilities were derived by standardizing model predictions over the observed covariate distribution.

As a secondary analysis, patients were classified into four groups according to reperfusion grade and puncture-to-reperfusion time (≤ 90 vs > 90 minutes). The 90-minute cutoff was used for clinical interpretability rather than as a validated biological threshold.In an exploratory analysis, thrombectomy passes were categorized as 1, 2, or ≥ 3 and cross-classified with final mTICI 2b versus mTICI 2c/3. Three patients with unclear pass-number records were excluded from the exploratory analysis. Observed rates of 90-day functional independence with 95% confidence intervals were reported descriptively.Analyses were performed using SciPy version 1.17.0 and statsmodels version 0.14.6.

3. Results

3.1 Cohort and procedural characteristics

Among 418 patients, 133 (31.8%) achieved final mTICI 2b reperfusion and 285 (68.2%) achieved mTICI 2c/3. The mTICI 2c/3 group included more men (59.3% versus 45.1%; P = 0.007), and target occlusion

sites differed between groups (P = 0.007). Other baseline characteristics were broadly similar (Table 1).

Median puncture-to-reperfusion time was 100 minutes (IQR, 45–145) in the mTICI 2b group and 83 minutes (IQR, 51–135) in the mTICI 2c/3 group (P = 0.305). The mTICI 2b group required more thrombectomy passes (median, 2 [IQR, 1–3] versus 1 [IQR, 1–2]; P < 0.001). No data were missing for variables included in the primary analyses.

Table 1
Baseline and procedural characteristics according to final reperfusion grade

Characteristic	mTICI 2b (n = 133)	mTICI 2c/3 (n = 285)	P value
Age, years	75.3 ± 12.6	74.2 ± 12.3	0.379
Male sex	60 (45.1%)	169 (59.3%)	0.007
Admission NIHSS	16 (9–22)	14 (7–20)	0.099
Pre-stroke mRS	0 (0–1)	0 (0–0)	0.098
ASPECTS	8 (6–8)	7 (6–9)	0.721
Hypertension	98 (73.7%)	217 (76.1%)	0.587
Diabetes mellitus	37 (27.8%)	89 (31.2%)	0.479
Atrial fibrillation	58 (43.6%)	118 (41.4%)	0.671
Coronary heart disease	27 (20.3%)	72 (25.3%)	0.266
Bridging intravenous thrombolysis	55 (41.4%)	128 (44.9%)	0.495
Onset-to-puncture time, min	220 (155–355)	225 (160–382)	0.571
Target occlusion site			0.007
ICA	38 (28.6%)	83 (29.1%)	
M1	44 (33.1%)	131 (46.0%)	
M2	23 (17.3%)	22 (7.7%)	
Other	28 (21.1%)	49 (17.2%)	
General anesthesia	27 (20.3%)	82 (28.8%)	0.066
Puncture-to-reperfusion time, min	100 (45–145)	83 (51–135)	0.305
Thrombectomy passes	2 (1–3)	1 (1–2)	< 0.001
TOAST classification			0.758
Large-artery atherosclerosis	66 (49.6%)	144 (50.5%)	
Cardioembolism	62 (46.6%)	134 (47.0%)	
Other/undetermined	5 (3.8%)	7 (2.5%)	

Data are mean ± SD, median (IQR), or n (%). Other occlusion sites include ACA, posterior-circulation, and other/unspecified sites. NIHSS indicates National Institutes of Health Stroke Scale; ASPECTS, Alberta

Stroke Program Early CT Score; mRS, modified Rankin Scale; TOAST, Trial of Org 10172 in Acute Stroke Treatment.

3.2 Clinical outcomes by reperfusion grade

Functional independence occurred in 52 patients (39.1%) with mTICI 2b and 168 (58.9%) with mTICI 2c/3 (unadjusted OR, 2.24; 95% CI, 1.47–3.41; P < 0.001). Excellent functional outcome was also more frequent, while mortality and discharge NIHSS were lower, in the mTICI 2c/3 group. Intracranial hemorrhagic transformation did not differ significantly (Table 2).

Table 2
Unadjusted clinical outcomes according to final reperfusion grade

Outcome	mTICI 2b (n = 133)	mTICI 2c/3 (n = 285)	Unadjusted OR (95% CI)	P value
90-day mRS 0–1	31 (23.3%)	102 (35.8%)	1.83 (1.15–2.93)	0.011
90-day mRS 0–2	52 (39.1%)	168 (58.9%)	2.24 (1.47–3.41)	< 0.001
90-day mortality	28 (21.1%)	38 (13.3%)	0.58 (0.34–0.99)	0.044
Discharge NIHSS	5.5 (3–10)	4 (2–8)	-	0.011
Intracranial hemorrhagic transformation	12 (9.0%)	27 (9.5%)	1.06 (0.52–2.15)	0.883

ORs compare mTICI 2c/3 with mTICI 2b. Discharge NIHSS was compared nonparametrically and is not expressed as an OR.

3.3 Puncture-to-reperfusion time across reperfusion grades

In the adjusted interaction model, longer puncture-to-reperfusion time was associated with lower odds of 90-day functional independence in both reperfusion groups. Per 30-minute increase, the aOR was 0.77 (95% CI, 0.63–0.95; P = 0.015) in the mTICI 2b group and 0.83 (95% CI, 0.73–0.95; P = 0.006) in the mTICI 2c/3 group. The reperfusion-grade-by-time interaction was not significant (interaction OR, 1.07; 95% CI, 0.85–1.35; P = 0.538), providing no evidence that the time-outcome association differed between groups. At the reference time of 90 minutes, mTICI 2c/3 was associated with higher odds of functional independence than mTICI 2b (aOR, 1.81; 95% CI, 1.07–3.05; P = 0.026) (Table 3 and Fig. 1).

For excellent functional outcome, longer time was associated with lower odds in the mTICI 2b group but not significantly in the mTICI 2c/3 group; however, the interaction was not significant. Each 30-minute increase was associated with a higher discharge NIHSS in both groups. For mortality, longer time was associated with higher odds in the mTICI 2c/3 group, but the interaction again was not significant. No adjusted association was observed for intracranial hemorrhagic transformation (Table 3).

Table 3
Adjusted associations of procedure time and reperfusion grade with clinical outcomes

Outcome	Model estimate	Adjusted OR or β (95% CI)	P value
90-day mRS 0–2	mTICI 2c/3 vs 2b at 90 min	1.81 (1.07–3.05)	0.026
	Per 30-min delay: mTICI 2b	0.77 (0.63–0.95)	0.015
	Per 30-min delay: mTICI 2c/3	0.83 (0.73–0.95)	0.006
	Grade × time interaction	1.07 (0.85–1.35)	0.538
90-day mRS 0–1	mTICI 2c/3 vs 2b at 90 min	1.45 (0.77–2.76)	0.253
	Per 30-min delay: mTICI 2b	0.80 (0.66–0.97)	0.025
	Per 30-min delay: mTICI 2c/3	0.92 (0.80–1.05)	0.225
	Grade × time interaction	1.14 (0.92–1.42)	0.229
90-day mortality	mTICI 2c/3 vs 2b at 90 min	0.69 (0.37–1.30)	0.251
	Per 30-min delay: mTICI 2b	1.11 (0.93–1.32)	0.256
	Per 30-min delay: mTICI 2c/3	1.24 (1.06–1.46)	0.008
	Grade × time interaction	1.12 (0.90–1.40)	0.306
Discharge NIHSS	mTICI 2c/3 vs 2b at 90 min	-0.77 (-2.19 to 0.65)	0.287
	Per 30-min delay: mTICI 2b	0.75 (0.19–1.31)	0.009
	Per 30-min delay: mTICI 2c/3	0.72 (0.26–1.18)	0.002
	Grade × time interaction	-0.03 (-0.74 to 0.69)	0.943
Intracranial hemorrhagic transformation	mTICI 2c/3 vs 2b at 90 min	0.99 (0.45–2.17)	0.977
	Per 30-min delay: mTICI 2b	1.00 (0.86–1.15)	0.949
	Per 30-min delay: mTICI 2c/3	0.95 (0.80–1.13)	0.588
	Grade × time interaction	0.96 (0.78–1.18)	0.685

Binary outcomes are adjusted ORs; discharge NIHSS estimates are adjusted β coefficients, with positive values indicating worse NIHSS. Models were adjusted for age, sex, admission NIHSS, pre-stroke mRS,

bridging intravenous thrombolysis, onset-to-puncture time, anesthesia type, and target occlusion site. Time was centered at 90 minutes.

3.4 Secondary four-group analysis

Using the secondary 90-minute stratification, patients with mTICI 2b and procedure time > 90 minutes had the lowest adjusted standardized probability of functional independence (31.1%). Compared with this reference group, adjusted odds were higher for mTICI 2b with time ≤ 90 minutes (aOR, 4.86; 95% CI, 2.10-11.25), mTICI 2c/3 with time > 90 minutes (aOR, 3.22; 95% CI, 1.58–6.57), and mTICI 2c/3 with time ≤ 90 minutes (aOR, 5.29; 95% CI, 2.71–10.33) (Table 4 and Fig. 2). This analysis illustrates joint patterns but does not establish a threshold effect or equivalence between groups.

Table 4
Secondary joint analysis using a 90-minute puncture-to-reperfusion cutoff

Reperfusion/time group	n	Adjusted OR for mRS 0–2 (95% CI)	P value	Adjusted standardized probability (95% CI)
mTICI 2b + > 90 min	73	Reference	-	31.1% (22.2–40.0%)
mTICI 2b + ≤ 90 min	60	4.86 (2.10-11.25)	< 0.001	59.1% (48.2–70.0%)
mTICI 2c/3 + > 90 min	131	3.22 (1.58–6.57)	0.001	51.7% (42.9–60.5%)
mTICI 2c/3 + ≤ 90 min	154	5.29 (2.71–10.33)	< 0.001	60.6% (54.5–66.8%)

The 90-minute cutoff was used for secondary clinical stratification and should not be interpreted as a validated treatment threshold.

3.5 Exploratory analysis by thrombectomy pass number

Among the 415 patients with at least one recorded thrombectomy pass, observed functional independence declined as pass burden increased within both reperfusion groups (Table 5 and Fig. 3). In the mTICI 2b group, mRS 0–2 occurred in 27 of 53 patients after 1 pass (50.9%; 95% CI, 37.9%-63.9%), 16 of 34 after 2 passes (47.1%; 95% CI, 31.5%-63.3%), and 9 of 46 after ≥ 3 passes (19.6%; 95% CI, 10.7%-33.2%). Corresponding rates in the mTICI 2c/3 group were 104 of 166 (62.7%; 95% CI, 55.1%-69.6%), 38 of 68 (55.9%; 95% CI, 44.1%-67.1%), and 23 of 48 (47.9%; 95% CI, 34.5%-61.7%). mTICI 2c/3 had a numerically higher observed rate than mTICI 2b within every pass category. Because these comparisons were unadjusted and pass number overlaps mechanistically with procedure duration, the findings should be interpreted as descriptive rather than as evidence of an independent or causal pass effect.

Table 5
Exploratory 90-day functional independence by pass number and final reperfusion grade

Final reperfusion grade	Pass category	n	mRS 0–2, n	Observed rate (95% CI)
mTICI 2b	1 pass	53	27	50.9% (37.9%-63.9%)
mTICI 2b	2 passes	34	16	47.1% (31.5%-63.3%)
mTICI 2b	≥ 3 passes	46	9	19.6% (10.7%-33.2%)
mTICI 2c/3	1 pass	166	104	62.7% (55.1%-69.6%)
mTICI 2c/3	2 passes	68	38	55.9% (44.1%-67.1%)
mTICI 2c/3	≥ 3 passes	48	23	47.9% (34.5%-61.7%)

Three patients recorded as having zero passes were excluded. Estimates are unadjusted observed proportions with 95% binomial confidence intervals.

4. Discussion

In this cohort of patients who achieved successful reperfusion, longer puncture-to-reperfusion time was associated with worse functional outcome across both final reperfusion grades. Each 30-minute increase corresponded to 23% lower adjusted odds of functional independence after mTICI 2b and 17% lower odds after mTICI 2c/3. The interaction was not significant, so the numerical difference between these estimates should not be interpreted as evidence that one reperfusion group is more vulnerable to delay. At a common reference time of 90 minutes, mTICI 2c/3 remained associated with higher odds of functional independence. The central finding is therefore additive in clinical meaning: time matters across successful reperfusion grades, and more complete reperfusion remains desirable, but neither dimension should be interpreted without the other.

Procedure time remains relevant after successful reperfusion

The time dependence of thrombectomy is well established [1, 2], but onset-to-treatment metrics do not fully capture intraprocedural delay. After puncture, prolonged attempts continue to expose threatened brain tissue to ischemia and may also mark difficult anatomy, resistant thrombus, distal embolization, underlying intracranial atherosclerosis, or complications. Our findings are consistent with prior work linking longer thrombectomy procedure time to worse outcome [10]. They also complement the first-pass literature, in which early near-complete or complete reperfusion is associated with better outcomes than the same final grade achieved after repeated attempts [6–8, 11, 13].

Because procedure duration partly reflects case complexity, the present estimates should not be read as purely causal time penalties. Nevertheless, the consistency of the association with both functional independence and discharge NIHSS supports puncture-to-reperfusion time as a clinically meaningful performance measure rather than a neutral by-product of technical difficulty.

The favorable association of mTICI 2c/3 at 90 minutes accords with evidence that conventional successful reperfusion includes clinically important heterogeneity [3–5, 12, 14]. Residual hypoperfused tissue after mTICI 2b may continue to infarct, whereas mTICI 2c/3 restores flow to a larger fraction of the affected territory. However, the lack of interaction is equally important: our data do not show that achieving mTICI 2c/3 compensates for a prolonged procedure, nor that the effect of time differs materially by final grade. This is consistent with interpreting reperfusion completeness and procedure time as related but distinct dimensions of procedural success.

Implications for attempts beyond mTICI 2b

The results support rapid attainment of the highest safely achievable reperfusion grade, but they do not justify routine continuation after mTICI 2b. Previous studies have reported that selected patients can be upgraded from mTICI 2b to mTICI 2c/3 [15], whereas other analyses have questioned a uniform functional benefit and raised concern about hemorrhagic risk from additional attempts [16, 17]. Whether another pass is worthwhile depends on the amount and eloquence of residual territory, technical accessibility, expected probability of improvement, elapsed procedure time, and risk of vascular injury.

Our dataset records only final mTICI grade and total puncture-to-reperfusion time. It does not identify when mTICI 2b was first achieved, the additional time or passes used thereafter, or whether final mTICI 2c/3 resulted directly or after secondary improvement. Therefore, this analysis cannot estimate the causal benefit of an additional pass after mTICI 2b. A rapidly achieved mTICI 2c/3 result and a late conversion from mTICI 2b to mTICI 2c/3 are clinically different trajectories despite sharing the same final grade.

Pass number as a complementary marker of procedural burden

The exploratory pass analysis provided a complementary view of the procedural trajectory. Functional independence declined with increasing pass category in both reperfusion groups, and the particularly low observed rate after ≥ 3 passes with final mTICI 2b suggests a high-burden, low-yield procedural phenotype. By contrast, mTICI 2c/3 retained higher observed functional independence across all pass categories, although its rate also declined as passes accumulated. This pattern is compatible with prior evidence linking first-pass or low-pass reperfusion to better outcomes [6–8, 11, 13].

Pass number is a marker of resistant occlusion, anatomy, operator strategy, device choice, complications, and elapsed ischemic time. The dataset does not distinguish passes performed before versus after first achieving mTICI 2b. Accordingly, pass number adds context to the primary time-based findings but does not replace them or define a universal stopping threshold.

Strengths and limitations

The principal strength of this study is its direct evaluation of puncture-to-reperfusion time within distinct degrees of successful reperfusion, using time as a continuous exposure and formally testing effect

modification. Standardized probability curves improve clinical interpretability, and the secondary grouped analysis illustrates the joint distribution without replacing the continuous model.

Several limitations require emphasis. First, the retrospective single-center design is susceptible to residual confounding, selection bias, and confounding by indication. Second, procedure time and final reperfusion grade are post-treatment variables shaped by procedural strategy and technical complexity; adjustment cannot fully separate these mechanisms. Third, the cohort excluded patients with failed reperfusion and missing essential or 90-day data, limiting generalizability and potentially introducing selection bias. Fourth, routine angiographic grading may be subject to interobserver variability. Fifth, we lacked pass-by-pass reperfusion grades, time to first mTICI 2b, time spent pursuing a higher grade, the anatomical and functional importance of residual territory, and detailed complications of additional attempts. The exploratory pass analysis additionally excluded three zero-pass cases and was unadjusted, making it vulnerable to confounding and sparse-cell imprecision. Finally, the sample size may have been insufficient to detect modest interaction effects, and the 90-minute cutoff was not externally validated.

Clinical implications

Procedure time should be interpreted alongside, not beneath, final reperfusion grade. A complete angiographic result achieved only after substantial delay may not carry the same prognosis as early complete reperfusion, while stopping rapidly at mTICI 2b may leave clinically relevant tissue unreperfused. The practical target is rapid, near-complete or complete, and safe reperfusion. Future studies should reconstruct pass-by-pass trajectories and quantify the incremental time, tissue gain, and complication risk associated with attempts after first achieving mTICI 2b.

5. Conclusion

Longer puncture-to-reperfusion time was associated with worse functional outcome after both mTICI 2b and mTICI 2c/3 reperfusion, without evidence that the association differed by final reperfusion grade. Near-complete or complete reperfusion was associated with better functional outcome at a common procedural duration, but it did not negate the adverse association of delay. Exploratory pass-number findings were directionally consistent with increasing procedural burden, especially when ≥ 3 passes ended in mTICI 2b, but were descriptive and do not define an independent effect or stopping threshold. These data support rapid achievement of the highest safely attainable reperfusion grade.

Declarations

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics approval and consent to participate

This retrospective study was conducted using de-identified clinical data. The Institutional Ethics Committee of Yangpu Hospital, Tongji University School of Medicine determined that the study was exempt from formal ethical review and that the requirement for informed consent was waived because of its retrospective nature and the use of anonymized patient information. The study was conducted in accordance with the Declaration of Helsinki and applicable institutional guidelines.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

SG and XX contributed equally to this work. SG and XX conceived and designed the study, collected and analyzed the data, and drafted the original manuscript. DH, DZ and YY participated in data collection, literature retrieval and manuscript revision. LH supervised the entire research project, reviewed and revised the manuscript critically, and finalized the submitted version. All authors read and approved the final manuscript.

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Figures

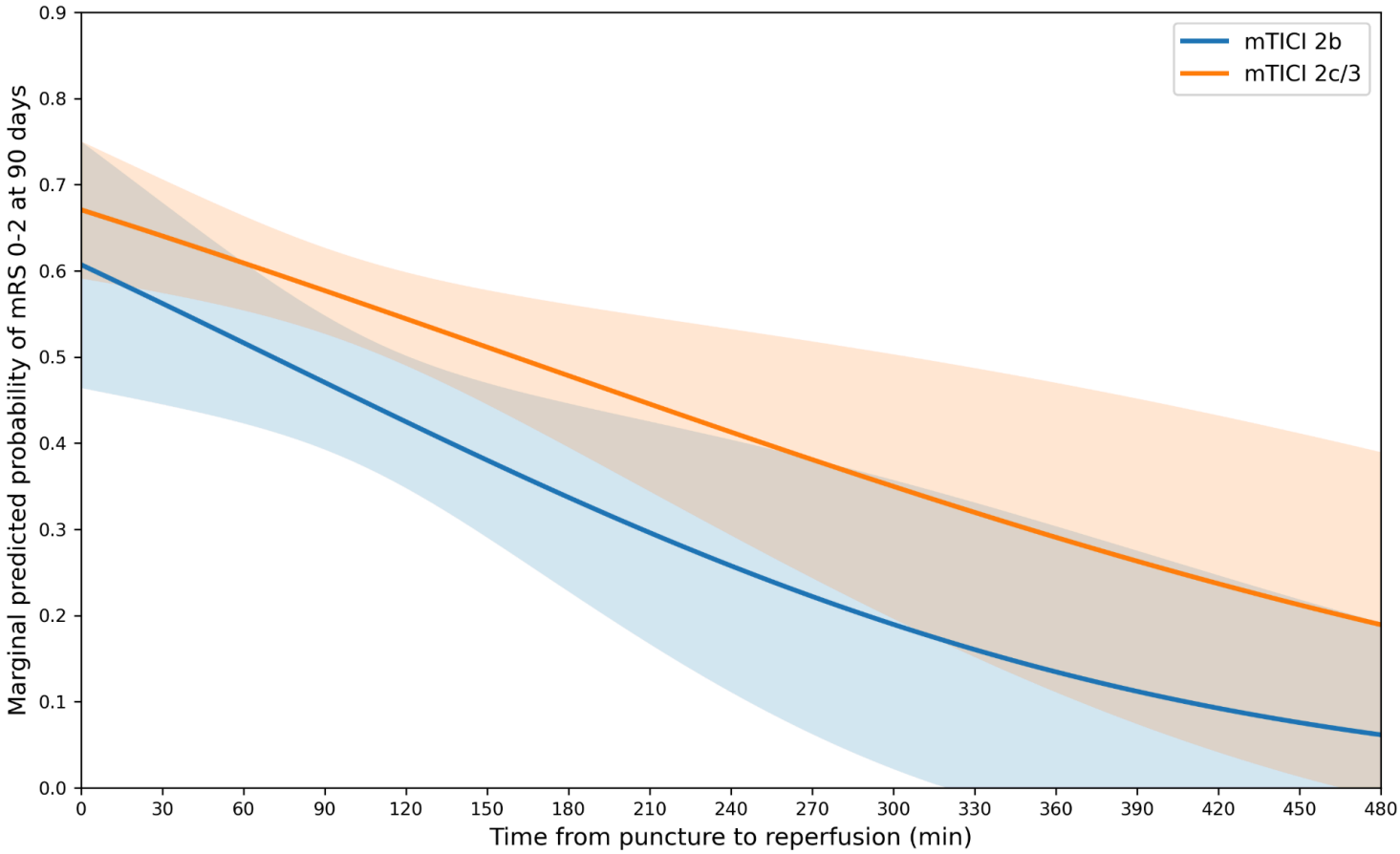

Figure 1

Adjusted marginal predicted probability of 90-day functional independence (mRS 0-2) across puncture-to-reperfusion time by final reperfusion grade. Shaded bands indicate pointwise 95% CIs. Predictions at the extremes of the observed time distribution are imprecise and should be interpreted cautiously.

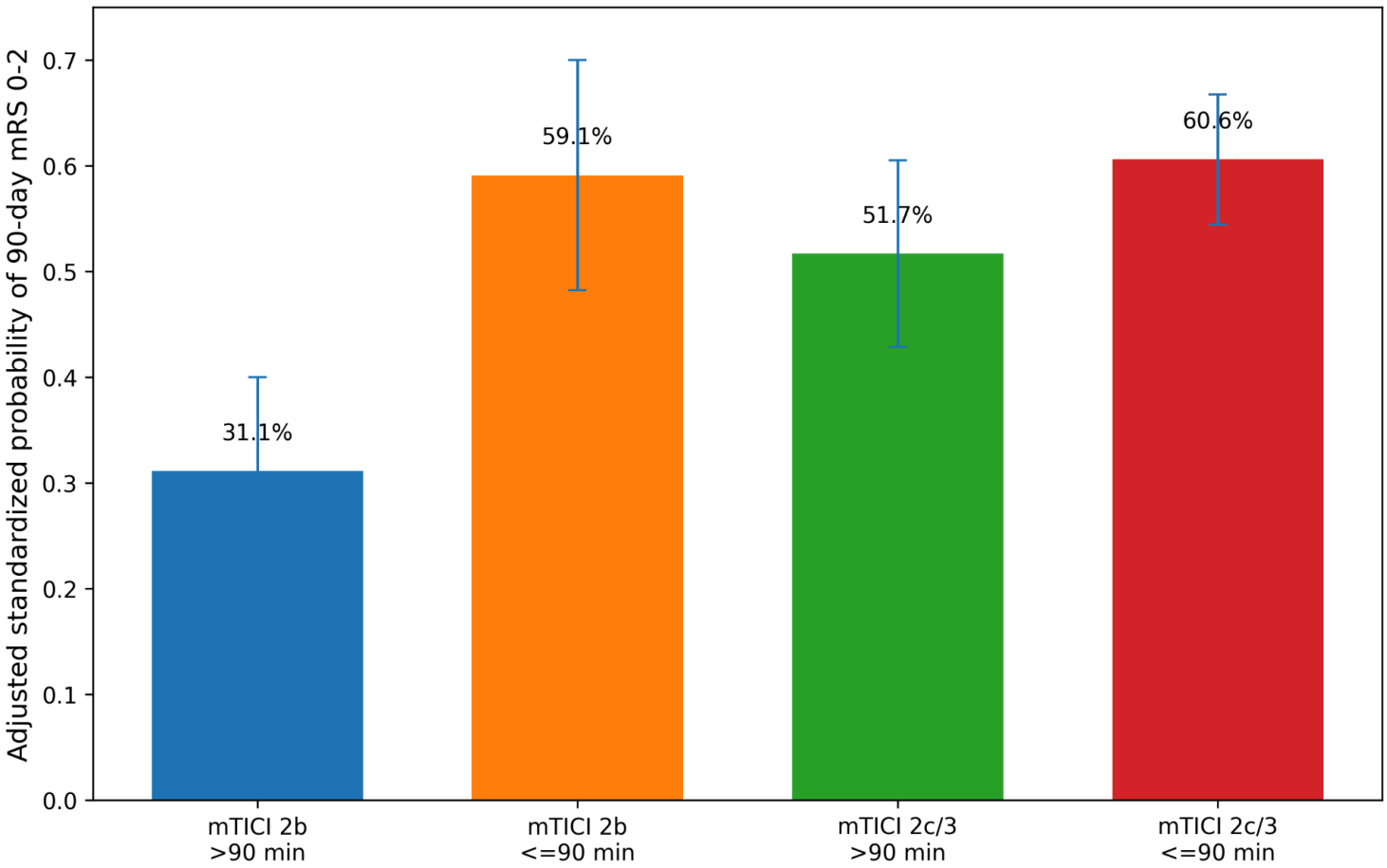

Figure 2

Adjusted standardized probability of 90-day functional independence in the four reperfusion-grade/time groups. Error bars indicate 95% CIs.

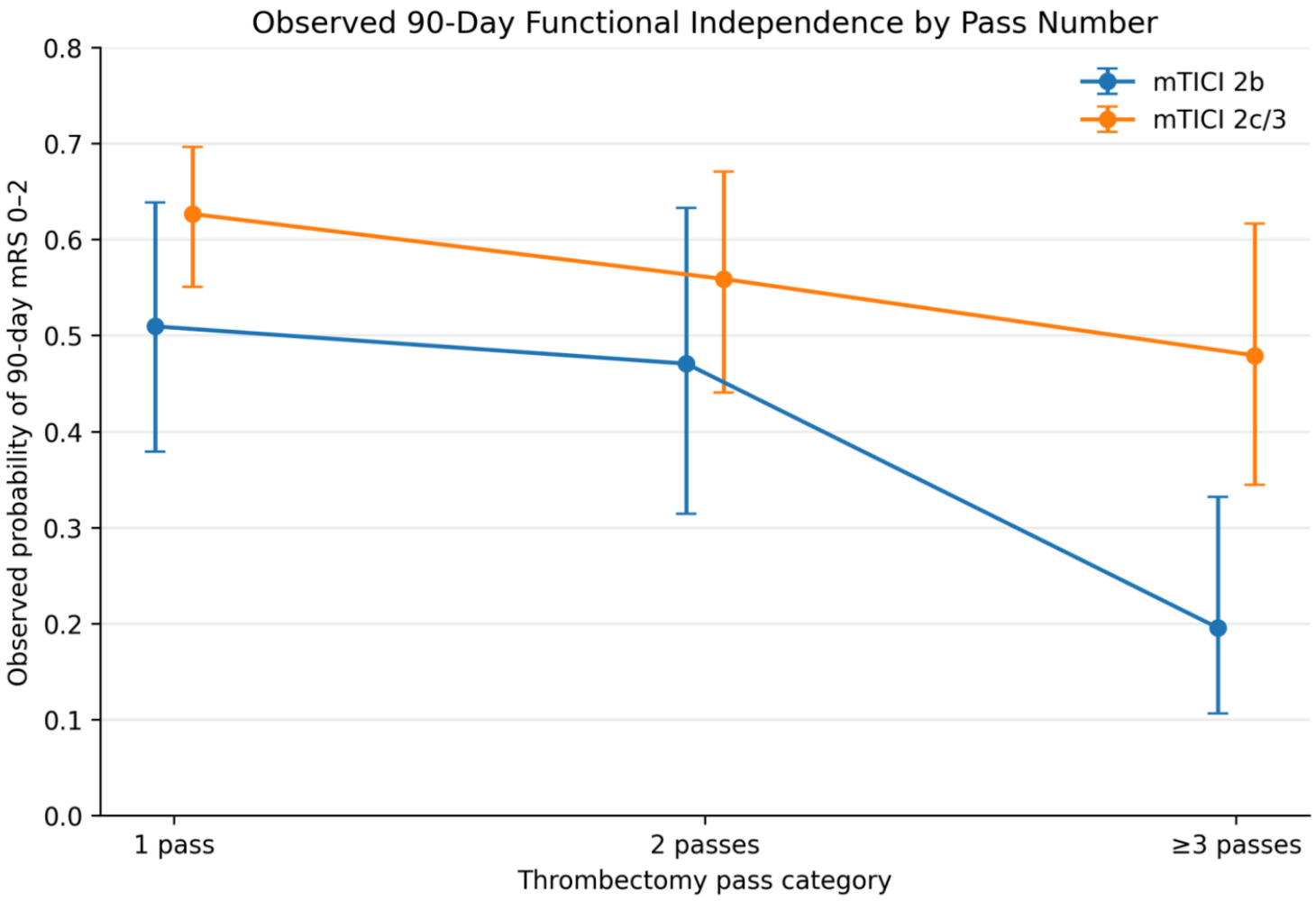

Figure 3

Observed probability of 90-day functional independence by thrombectomy pass category and final reperfusion grade. Points show unadjusted observed proportions; error bars indicate 95% binomial CIs.

Supplementary Files

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- floatimage4.png