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# Incremental Predictive Value of Postoperative Systemic Inflammatory Response Index for Futile Recanalization After Endovascular Therapy

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## Abstract

# Background

Despite high rates of successful recanalization following endovascular therapy (EVT) for large-vessel occlusion (LVO) stroke, many patients still experience poor outcomes, a phenomenon known as futile recanalization (FR).

# Methods

A total of 581 consecutive patients with LVO stroke who underwent EVT were enrolled; of these, 511 achieved successful revascularization (modified Thrombolysis in Cerebral Infarction [mTICI] score ≥2b). FR was defined as a 90-day modified Rankin Scale (mRS) score of ≥ 3. The admission and postoperative natural log-transformed systemic inflammatory response index (ln-SIRI) was analyzed using nested multivariate logistic regression. Incremental predictive value was quantified by net reclassification improvement (NRI), integrated discrimination improvement (IDI), and decision curve analysis (DCA).

# Results

Of 511 successful recanalizations, 306 (59.9%) had FR. Both admission ln-SIRI (adjusted odds ratio [aOR] 2.322, 95% bootstrap confidence interval [CI]: 1.678–3.212, P < 0.001) and postoperative ln-SIRI (aOR 1.403, 95%CI 1.153–1.722, P = 0.001) were independently associated with FR. Adding postoperative ln-SIRI to Model 1 significantly improved discrimination (Area Under the Curve [AUC] 0.718 vs 0.784) and clinical utility. The NRI was 0.350 (95% CI: 0.131–0.574, P = 0.002). The IDI was 0.042 (95% CI: 0.015–0.069, P < 0.001). Decision curve analysis demonstrated net clinical benefit of Model 2 over Model 1 across threshold probabilities of 30%–90%.

# Conclusions

Both admission and postoperative ln-SIRI were independently associated with futile recanalization risk after EVT in AIS patients. Postoperative SIRI provides significant incremental predictive value beyond admission SIRI for FR after EVT.

## Introduction

Large vessel occlusion (LVO)-induced acute ischemic stroke (AIS) is characterized by sudden onset, rapid neurological deterioration, and persistently poor functional outcomes. It remains a leading cause of morbidity, disability, and mortality [1, 2]. Endovascular therapy (EVT) is the established first-line treatment for AIS secondary to LVO, with angiographic success—defined as modified Thrombolysis in Cerebral Infarction (mTICI) scale 2b or 3—achieved in more than 80% of treated patients [3].

Nevertheless, despite successful angiographic recanalization, over half of patients fail to achieve functional independence—defined as a modified Rankin Scale (mRS) score of 0–2—at 90 days, a phenomenon termed “futile recanalization” [3, 4]. This paradox underscores a critical gap between procedural efficacy and clinical benefit. It represents a major unmet therapeutic challenge in the post-mechanical thrombectomy management of AIS, whose underlying pathophysiological mechanisms remain incompletely elucidated [5].

Emerging evidence indicates that immunothrombosis—a tightly coordinated interplay among innate immune activation, platelet aggregation, and the coagulation cascade—serves as a critical host defense mechanism to contain hematogenous pathogen dissemination. However, dysregulated or excessive immunothrombosis contributes to the pathogenesis of thrombotic disorders, including acute myocardial infarction, ischemic stroke, and venous thromboembolism [6]. The systemic inflammatory response index (SIRI) is a novel comprehensive inflammatory biomarker, calculated as (neutrophil count × Monocyte count) / lymphocyte count from routine peripheral blood tests. It can comprehensively reflect the balance between inflammatory response and immune status and has been confirmed as a reliable prognostic biomarker for cerebrovascular diseases [7–9]. Recent studies have demonstrated that an elevated preoperative SIRI is independently associated with adverse clinical outcomes following EVT in patients with AIS, reflecting both the baseline systemic immune-inflammatory burden and the extent of cerebral ischemic injury [10–13]. However, it remains uncertain whether serial SIRI monitoring offers incremental predictive utility for futile recanalization beyond that provided by a single time-point assessment. While existing studies have predominantly relied on static, single-measurement SIRI evaluations [10–13], the dynamic evolution of inflammation that may drive clinical futility remains insufficiently characterized.

Therefore, this study aimed to assess the independent associations of admission ln-SIRI and postoperative ln-SIRI with futile recanalization following EVT, and to quantify the incremental predictive value of postoperative ln-SIRI beyond admission ln-SIRI for futile recanalization using net reclassification improvement (NRI), integrated discrimination improvement (IDI), and decision curve analysis (DCA).

## Methods

# Study Population

This retrospective study enrolled consecutive AIS patients who underwent EVT for LVO at the Stroke Center of the Fourth Affiliated Hospital of Guangxi Medical University between January 2022 and October 2025. The study was approved by the Institutional Review Board of the Fourth Affiliated Hospital of Guangxi Medical University (Approval No. : KY2026637) and conducted in strict adherence to the ethical principles stipulated in the Declaration of Helsinki. As a retrospective observational study based exclusively on anonymized, routinely acquired clinical data with no direct patient contact or intervention, the requirement for written informed consent was waived by the Institutional Review Board.

The inclusion criteria were: (1) Age of ≥ 18 years; (2) Diagnosis of AIS in accordance with the Chinese Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke, and confirmed to have LVO by digital subtraction angiography (DSA) performed within 24 hours of symptom onset [14, 15]; (3) Treatment for acute vascular recanalization consisted of EVT alone or in combination with intravenous thrombolysis (IVT); (4) A pre-stroke modified Rankin Scale (mRS) score of 0–1.

The exclusion criteria were: (1) Intracranial hemorrhage before EVT; (2) Severe hepatic or renal impairment, other life-threatening comorbidities, or severe treatment-related complications; (3) The presence of active malignancy, hematologic disorders, or immunosuppression; (4) Infectious disease before EVT; (5) Major trauma or surgical procedures within 28 days; (6) Incomplete key clinical data or patients lost to follow-up;

## Definitions and Data Collection

Clinical outcomes were assessed at 90 days post-intervention using the mRS. Recanalization efficacy was assessed using the mTICI scale,with successful recanalization defined as an mTICI score ≥2b in the target vessel [3, 15]. Among patients with successful recanalization (mTICI ≥2b), those with 90-day mRS 0–2 were classified as having meaningful recanalization, whereas those with mRS 3–6 were classified as having futile recanalization [3, 4]. SIRI was calculated as (neutrophil count × monocyte count) / lymphocyte count, with all cell counts reported as $\times 10^9$/L [9]. Given its right-skewed distribution, SIRI values were natural log-transformed (ln-SIRI) before all statistical analyses. Preoperative ln-SIRI was calculated from blood samples collected upon hospital admission, before EVT, and postoperative ln-SIRI from samples collected within 24 hours after EVT.

Clinical data were extracted from the hospital electronic medical record system and comprised: demographic characteristics (age and sex); vascular risk factors encompass body mass index (BMI), diabetes mellitus, hypertension, coronary artery disease, valvular heart disease, atrial fibrillation, ischemic stroke, current smoking status, and regular alcohol consumption; laboratory parameters included white blood cell (WBC) count, platelet (PLT) count, absolute lymphocyte, monocyte, and neutrophil counts, blood urea nitrogen (BUN), serum creatinine, fasting blood glucose, high-sensitivity C-reactive protein (hs-CRP), total cholesterol, and low-density lipoprotein cholesterol (LDL-C); Baseline neurological severity assessments included the National Institutes of Health Stroke Scale (NIHSS) [16], the preprocedural Alberta Stroke Program Early CT Score (ASPECTS) [17], and the Glasgow Coma Scale (GCS) score [18] at admission; etiology classification according to the Trial of ORG 10172 in Acute Stroke Treatment (TOAST) [19] classification; procedural and outcome-related variables included the responsible vessel, onset-to-door time, door-to-reperfusion time, recanalization efficacy assessed using the mTICI [20], intravenous thrombolysis (IVT) administration, number of passes, HT [21] diagnosed by noncontrast cranial computed tomography within 24–72 hours after EVT, and the mRS [22] score at 90-day follow-up after EVT.

# Statistical analysis

All statistical analyses were performed using R version 4.5.1. A two-sided P value < 0.05 was considered statistically significant.

## Descriptive and Univariable Analyses

Continuous variables are presented as mean ± standard deviation (SD) for normally distributed data and as median (interquartile range [IQR]) for non-normally distributed data. Categorical variables are expressed as counts (percentages). Baseline characteristics were compared between (1) the successful recanalization and failed recanalization groups, and (2) the effective recanalization and futile recanalization groups, using the independent samples t-test, Mann–Whitney U test, $\chi^2$ test, or Fisher's exact test, as appropriate. Univariable logistic regression was performed to assess the association between each candidate variable and futile recanalization.

## Covariate Selection and Model Specification

Candidate covariates for multivariable logistic regression were selected via a prespecified three-stage approach that balanced statistical rigor and clinical relevance. First, univariable logistic regression was performed to assess the association between each baseline variable and futile recanalization; variables with P < 0.10 were retained for further consideration. Second, key prognostic variables consistently associated with poor outcomes in prior ischemic stroke literature—including age and baseline NIHSS score—were included regardless of univariable significance to maintain model interpretability and clinical validity. Third, multicollinearity among candidate covariates was formally evaluated using variance inflation factors (VIF). Variables with VIF > 5 were excluded. In cases of collinearity, the primary exposure variable (admission ln-SIRI) was explicitly prioritized over highly correlated surrogates (e.g., admission WBC or neutrophil count) to preserve estimation precision.

Nested multivariate logistic regression models were constructed to evaluate the association between ln-SIRI and futile recanalization. Model 1 included admission ln-SIRI and covariates selected based on univariable logistic regression and clinical relevance. Model 2 further included postoperative ln-SIRI based on Model 1 to evaluate its independent association with futile recanalization. Nested model comparisons were conducted using likelihood ratio tests (LRTs); a statistically significant LRT (two-sided P < 0.05) indicated that the additional predictors meaningfully improved model fit.

# Incremental Predictive Value Assessment and Model Validation

To quantify the clinical utility of adding postoperative ln-SIRI to the baseline model, we calculated the category-free net reclassification improvement (NRI) and integrated discrimination improvement (IDI) comparing Model 2 versus Model 1. NRI evaluates the net proportion of patients correctly reclassified by the extended model. At the same time,IDI measures the average increase in predicted probabilities for

events minus the average decrease for non-events. Bootstrap resampling with 5000 iterations was used to estimate bias-corrected 95% confidence intervals for NRI and IDI. Decision curve analysis (DCA) was performed to evaluate the net clinical benefit of Model 1 and Model 2 across a range of threshold probabilities (0%–100%). The reported performance metrics included the apparent area under the receiver operating characteristic curve (AUC), the Akaike and Bayesian information criteria (AIC, BIC), the mean optimism (the average difference between apparent and bootstrap-validated performance), and the optimism-corrected AUC (apparent AUC minus mean optimism). Bootstrap resampling with 5000 iterations was used for optimism correction.

## Results

# Comparative Baseline Characteristics

Of the 699 patients with AIS screened for EVT, 118 were excluded per prespecified criteria, resulting in a final analytic cohort of 581. Of these, 70 (12.0%) had failed recanalization (mTICI < 2b), and 511 (88.0%) achieved successful recanalization (mTICI ≥ 2b). Among those successfully recanalized, 306 (59.9%) had futile recanalization (90-day mRS 3–6), while 205 (40.1%) had a favorable outcome (mRS 0–2), as shown in Fig. 1. Baseline characteristics were compared between the failed and successful recanalization groups (Table 1). No significant differences were observed in age, sex, vascular risk factors, admission clinical severity, laboratory parameters (including admission and postoperative SIRI and ln-SIRI), imaging characteristics, or medical history (all $P > 0.05$). The only significant between-group difference was the number of passes, which was significantly higher in the failed recanalization group than in the successful recanalization group ($P < 0.001$).

Table 1
Baseline characteristics of patients with successful and failed recanalization

| Variables | Successful recanalization (n = 511) | Failed recanalization (n = 70) | P-value |
|---|---|---|---|
| Demographics | | | |
| Age, years, (median ,IQR) | 65.0 (56.0–72.0) | 67.00 (57.00–74.00) | 0.240 |
| Male, n(%) | 350 (68.5) | 46 (65.7) | 0.740 |
| Vascular Risk Factors | | | |
| Hypertension, n(%) | 347 (67.9) | 46 (65.7) | 0.817 |
| Diabetes mellitus, n(%) | 133 (26.0) | 15 (21.4) | 0.495 |
| Coronary heart disease, n (%) | 56 (11.0) | 8 (11.4) | 0.684 |
| AF, n(%) | 132 (25.8) | 20 (28.6) | 0.731 |
| Previous stroke, n (%) | 98 (19.2) | 15 (21.4) | 0.776 |
| Smoking history, n(%) | 150 (29.4) | 17 (24.3) | 0.461 |
| Regular drinker, n(%) | 62 (12.1) | 7 (10.0) | 0.749 |
| BMI, kg/m2, (median ,IQR) | 24.1 (22.1–25.9) | 24.65 (22.30-26.55) | 0.196 |
| Clinical Features | | | |
| Admission NIHSS, (median ,IQR) | 12.0 (8.0–16.0) | 12.00 (9.00–17.00) | 0.510 |
| Admission GCS, (median ,IQR) | 15.0 (12.0–15.0) | 15.00 (12.00–15.00) | 0.652 |
| Intravenous Thrombolysis, n (%) | 100 (19.6) | 10 (14.3) | 0.370 |
| Onset-to-door time, min | 310.0 (173.5–600.0) | 401.00 (203.50-562.50) | 0.611 |
| Number of passes, (median, IQR) | 2.0 (1.0–3.0) | 3.00 (2.00–3.00) | < 0.001 |
| LAA, n(%) | 374 (73.2) | 46(65.71) | 0.363 |
| Laboratory Parameters | | | |
| Admission hs-CRP, mg/L, (median ,IQR) | 3.1 (1.4–6.7) | 3.90 (1.61–7.56) | 0.114 |

Abbreviations:SD, standard deviation; IQR, interquartile range; AF, atrial fibrillation; BMI, Body Mass Index; NIHSS, the National Institutes of Health Stroke Scale; GCS, Glasgow Coma Scale; LAA, Large Artery Atherosclerosis; hs-CRP, high-sensitivity C-reactive protein; WBC, White Blood Cell; SIRI, Systemic Inflammatory Response Index; BUN, blood urea nitrogen; TC, Total cholesterol; LDL-C, low-density lipoprotein cholesterol; ASPECTS, Alberta Stroke Program Early CT Score; HT, Hemorrhagic Transformation.

| Variables | Successful recanalization (n = 511) | Failed recanalization (n = 70) | P-value |
|---|---|---|---|
| Postoperative hs-CRP, mg/L, (median ,IQR) | 9.4 (3.8–30.5) | 9.6 (4.1–30.7) | 0.092 |
| Admission WBC, ×10⁹/L, (median ,IQR) | 9.2 (7.5–11.6) | 9.69 (7.74–11.60) | 0.598 |
| Postoperative WBC, ×10⁹/L, (median ,IQR) | 10.8 (8.8–13.6) | 10.80 (9.12–13.27) | 0.763 |
| Admission Neutrophils, ×10⁹/L, (median ,IQR) | 6.7 (5.0-9.1) | 7.3 (5.5–9.5) | 0.326 |
| Postoperative Neutrophils, ×10⁹/L, (median ,IQR) | 8.7 (6.8–11.3) | 8.7 (7.1–11.3) | 0.440 |
| Admission Lymphocytes, ×10⁹/L, (median ,IQR) | 1.5 (1.0-2.1) | 1.6 (1.1-2.0) | 0.954 |
| Postoperative Lymphocytes, ×10⁹/L, (median ,IQR) | 1.1 (0.8–1.6) | 1.2 (0.9–1.6) | 0.209 |
| Admission Monocytes, ×10⁹/L, (median ,IQR) | 0.6 (0.5–0.8) | 0.6 (0.4–0.9) | 0.649 |
| Postoperative Monocytes, ×10⁹/L, (median ,IQR) | 0.7 (0.5–0.9) | 0.7 (0.50–0.98) | 0.920 |
| Admission Platelets, ×10⁹/L, (median ,IQR) | 240.0 (201.0-282.5) | 232.0 (204.8- 281.3) | 0.903 |
| Postoperative Platelets, ×10⁹/L, (median ,IQR) | 240.0 (198.0-291.5) | 238.0 (199.8-288.3] | 0.881 |
| Admission SIRI, (median ,IQR) | 2.5 (1.5–4.6) | 2.9 (1.5–4.8) | 0.367 |
| Admission ln-SIRI, (median ,IQR) | 0.9 (0.4–1.6) | 1.1 (0.4–1.6) | 0.367 |
| Postoperative SIRI, (median ,IQR) | 5.1 (2.8–9.3) | 4.8 (2.5–8.7) | 0.538 |
| Postoperative ln-SIRI, (median ,IQR) | 1.6 (1.0–2.3) | 1.6 (0.9–2.2) | 0.538 |
| BUN, mmol/L,(median ,IQR) | 5.3 (4.2–6.8) | 5.30 (4.30–6.72) | 0.725 |
| Creatinine, μmol/L,(median ,IQR) | 80.0 (65.0–98.0) | 75.00 (65.00–90.00) | 0.163 |

Abbreviations:SD, standard deviation; IQR, interquartile range; AF, atrial fibrillation; BMI, Body Mass Index; NIHSS, the National Institutes of Health Stroke Scale; GCS, Glasgow Coma Scale; LAA, Large Artery Atherosclerosis; hs-CRP, high-sensitivity C-reactive protein; WBC, White Blood Cell; SIRI, Systemic Inflammatory Response Index; BUN, blood urea nitrogen; TC, Total cholesterol; LDL-C, low-density lipoprotein cholesterol; ASPECTS, Alberta Stroke Program Early CT Score; HT, Hemorrhagic Transformation.

| Variables | Successful recanalization (n = 511) | Failed recanalization (n = 70) | P-value |
|---|---|---|---|
| Blood glucose, mmol/L, (median ,IQR) | 6.8 (5.8–8.7) | 6.71 (5.78–9.02) | 0.723 |
| Albumin, g/L, (median ,IQR) | 41.1 (38.5–43.4) | 41.25 (37.78–44.25) | 0.747 |
| TC, mmol/L, (median, IQR) | 4.5 (3.8–5.2) | 4.40 (3.77–5.16) | 0.739 |
| LDL-C, mmol/L, (median, IQR) | 2.9 (2.2–3.6) | 2.76 (2.19–3.43) | 0.467 |
| Imaging Parameters | | | |
| ASPECTS, (median ,IQR) | 9.0 (8.0–10.0) | 9.00 (8.0–10) | 0.346 |
| HT, n(%) | 52 (10.2) | 9 (12.9) | 0.632 |
| Posterior Circulation, n(%) | 97 (19.0) | 13 (18.6) | 0.986 |

Abbreviations:SD, standard deviation; IQR, interquartile range; AF, atrial fibrillation; BMI, Body Mass Index; NIHSS, the National Institutes of Health Stroke Scale; GCS, Glasgow Coma Scale; LAA, Large Artery Atherosclerosis; hs-CRP, high-sensitivity C-reactive protein; WBC, White Blood Cell; SIRI, Systemic Inflammatory Response Index; BUN, blood urea nitrogen; TC, Total cholesterol; LDL-C, low-density lipoprotein cholesterol; ASPECTS, Alberta Stroke Program Early CT Score; HT, Hemorrhagic Transformation.

Patients with futile recanalization exhibited a significantly more pronounced systemic inflammatory response than those achieving meaningful recanalization, as evidenced by elevated admission levels of hs-CRP, WBC, neutrophil count, SIRI, and ln-SIRI, and by reduced lymphocyte count (all $P < 0.05$). Furthermore, the futile recanalization group was older; had a higher prevalence of atrial fibrillation; presented with more severe baseline neurological deficits; required a greater number of passes; and showed higher incidences of HT and posterior circulation occlusion, as well as elevated admission BUN and glucose levels (Table 2).

Table 2
Baseline characteristics of patients with Futile and Meaningful recanalization

| Variables | Futile Recanalization (n = 306) | Meaningful Recanalization (n = 205) | P-value |
|---|---|---|---|
| Demographics | | | |
| Age, years, (median ,IQR) | 66.0 (58.0–73.0) | 63.0 (55.0–71.0) | 0.033 |
| Male, n(%) | 205 (67.0) | 145 (70.7) | 0.427 |
| Vascular Risk Factors | | | |
| Hypertension, n(%) | 212 (69.3) | 135 (65.9) | 0.473 |
| Diabetes mellitus, n(%) | 82 (26.8) | 51 (24.9) | 0.703 |
| Coronary heart disease, n (%) | 34 (11.1) | 22 (10.7) | 0.996 |
| AF, n(%) | 90 (29.4) | 42 (20.5) | 0.031 |
| Previous stroke, n (%) | 60 (19.6) | 38 (18.5) | 0.852 |
| Smoking history, n(%) | 83 (27.1) | 67 (32.7) | 0.210 |
| Regular drinker, n(%) | 36 (11.8) | 26 (12.7) | 0.862 |
| BMI, $kg/m^2$, (median ,IQR) | 24.1 (22.0-25.6) | 24.2 (22.4–26.4) | 0.157 |
| Clinical Features | | | |
| Admission NIHSS, (median ,IQR) | 13.0 (10.0–18.0) | 9.0 (6.0–13.0) | < 0.001 |
| Admission GCS, (median ,IQR) | 15.0 (11.0–15.0) | 15.0 (13.0–15.0) | < 0.001 |
| Intravenous Thrombolysis, n (%) | 63 (20.6) | 37 (18.0) | 0.551 |
| Onset-to-door time, min | 310.0 (165.0-567.0) | 307.0 (177.5-637.5) | 0.418 |
| Hospital to reperfusion time, min | 189.0 (148.0-230.0) | 186.0 (136.0-232.8) | 0.078 |
| Number of passes, (median, IQR) | 2.0 (2.0–3.0) | 2.0 (1.0–3.0) | 0.003 |
| LAA, n(%) | 219 (71.6) | 155 (75.6) | 0.363 |
| Laboratory Parameters | | | |
| Admission hs-CRP, mg/L, (median ,IQR) | 3.8 (2.1–8.6) | 2.1 (1.2–3.6) | < 0.001 |
| Postoperative hs-CRP, mg/L, (median ,IQR) | 15.1 (5.6–43.2) | 5.6 (2.6–13.9) | < 0.001 |
| Admission WBC, $\times 10^9$/L, (median ,IQR) | 10.3 (8.3–12.6) | 8.2 (6.8–9.5) | < 0.001 |

| Variables | Futile Recanalization (n = 306) | Meaningful Recanalization (n = 205) | P-value |
|---|---|---|---|
| Postoperative WBC, ×10⁹/L, (median ,IQR) | 11.6 (9.7–14.5) | 9.9 (8.2–11.7) | < 0.001 |
| Admission Neutrophils, ×10⁹/L, (median ,IQR) | 7.9 (5.8–10.2) | 5.6 (4.2-7.0) | < 0.001 |
| Postoperative Neutrophils, ×10⁹/L, (median ,IQR) | 9.4 (7.4–12.5) | 7.5 (6.0-9.8) | < 0.001 |
| Admission Lymphocytes, ×10⁹/L, (median ,IQR) | 1.4 (1.0–2.0) | 1.6 (1.1–2.3) | 0.003 |
| Postoperative Lymphocytes, ×10⁹/L, (median ,IQR) | 1.1 (0.7–1.5) | 1.3 (0.9–1.6) | < 0.001 |
| Admission Monocytes, ×10⁹/L, (median ,IQR) | 0.6 (0.5–0.9) | 0.5 (0.4–0.7) | < 0.001 |
| Postoperative Monocytes, ×10⁹/L, (median ,IQR) | 0.7 (0.5-1.0) | 0.7 (0.5–0.9) | 0.004 |
| Admission Platelets, ×10⁹/L, (median ,IQR) | 241.5 (202.0-288.8) | 238.0 (201.0-279.0) | 0.313 |
| Postoperative Platelets, ×10⁹/L, (median ,IQR) | 244.0 (200.2-293.8) | 235.0 (193.0-286.0) | 0.496 |
| Admission SIRI, (median ,IQR) | 3.2 (1.9–5.9) | 1.8 (1.2–2.9) | < 0.001 |
| Admission ln-SIRI, (median ,IQR) | 1.5 (1.1–1.9) | 1.1 (0.8–1.4) | < 0.001 |
| Postoperative SIRI, (median ,IQR) | 6.6 (3.5–11.8) | 3.7 (2.2–6.1) | < 0.001 |
| Postoperative ln-SIRI, (median ,IQR) | 2.0 ( 1.5–2.5) | 1.6 (1.2–1.9) | < 0.001 |
| BUN, mmol/L,(median ,IQR) | 5.5 (4.3–7.1) | 4.8 (4.1–6.1) | < 0.001 |
| Creatinine, μmol/L,(median ,IQR) | 81.0 (64.2–102.0) | 78.0 (66.0–95.0) | 0.106 |
| Blood glucose, mmol/L,(median ,IQR) | 7.1 (6.0-9.1) | 6.4 (5.6–7.8) | < 0.001 |
| Albumin, g/L, (median ,IQR) | 41.0 (38.5–43.1) | 41.4 (38.7–43.7) | 0.099 |
| TC, mmol/L, (median, IQR) | 4.5 (3.8–5.2) | 4.5 (3.7–5.2) | 0.928 |
| LDL-C, mmol/L, (median, IQR) | 2.8 (2.2–3.6) | 2.9 (2.3–3.6) | 0.436 |
| Imaging Parameters | | | |

| Variables | Futile Recanalization (n = 306) | Meaningful Recanalization (n = 205) | P-value |
|---|---|---|---|
| ASPECTS, (median ,IQR) | 8.0 (7.0–9.0) | 9.0 (8.0–10.0) | < 0.001 |
| HT, n(%) | 42 (13.7) | 10 (4.9) | 0.032 |
| Posterior Circulation, n(%) | 71 (23.2) | 26 (12.7) | 0.015 |

# Variable Selection and Multivariable Analysis Results

Univariable logistic regression identified 15 variables significantly associated with futile recanalization (P < 0.10; Supplementary Table 1). The final covariates included in the multivariable models were: age, admission NIHSS score, atrial fibrillation, number of passes, blood urea nitrogen (BUN), and admission ln-SIRI. The VIF values for the final covariates included in the models ranged from 1.031 to1.136 (Supplementary Table 2).

In nested multivariable logistic regression models (Table 3), both admission and postoperative ln-SIRI were independently and significantly associated with futile recanalization. In the baseline model (Model 1), admission ln-SIRI emerged as a robust predictor (adjusted odds ratio [aOR], 2.322; 95% confidence interval [CI], 1.678–3.212; P < 0.001), alongside admission NIHSS score, number of passes, and BUN—all of which remained statistically significant (all P < 0.05). Upon inclusion of postoperative ln-SIRI in Model 2, the magnitude of the association for admission ln-SIRI was attenuated yet remained highly significant (aOR, 1.976; 95% CI, 1.177–2.905; P < 0.001), whereas postoperative ln-SIRI itself demonstrated a statistically significant independent association with futile recanalization (aOR, 1.403; 95% CI, 1.153–1.722; P = 0.001).

Table 3
Nested multivariable logistic regression models for futile recanalization

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | **aOR(95%CI)** | **P Value** | **aOR(95%CI)** | **P Value** |
| Intercept | 0.016 (0.004–0.066) | < 0.001 | 0.010 (0.002–0.044) | < 0.001 |
| age | 1.005 (0.987–1.024) | 0.594 | 1.004 (0.985–1.023) | 0.698 |
| AF | 1.543 (0.953–2.497) | 0.078 | 1.516 (0.932–2.467) | 0.094 |
| Admission NIHSS | 1.048 (1.015–1.083) | 0.004 | 1.039 (1.006–1.073) | 0.018 |
| Number of passes | 1.351 (1.113–1.641) | 0.002 | 1.343 (1.105–1.634) | 0.002 |
| BUN | 1.211 (1.087–1.349) | < 0.001 | 1.214 (1.090–1.354) | < 0.001 |
| Admission ln-SIRI | 2.322 (1.678–3.212) | < 0.001 | 1.976 (1.177–2.905) | < 0.001 |
| Postoperative ln-SIRI | - | - | 1.403 (1.153–1.722) | 0.001 |

# Incremental Predictive Value and Model Performance

Table 4 summarizes the predictive performance and overfitting risk of the nested models. Likelihood ratio tests confirmed significant improvement in model fit (Model 2 vs Model 1: P < 0.001), with decreasing AIC (590.1 vs 581.2) and BIC (619.8 vs 615.0). Model 2 exhibited superior discriminative performance compared with Model 1, as evidenced by both the apparent AUC (0.784 vs. 0.718; Fig. 2) and the bootstrap-corrected AUC (0.768 vs. 0.699). The NRI was 0.350 (95% CI: 0.131–0.574, P = 0.002). The IDI was 0.042 (95% CI: 0.015–0.069, P < 0.001). Decision curve analysis demonstrated that Model 2 conferred greater net clinical benefit than Model 1 across threshold probabilities of 30%–90%, supporting the clinical utility of serial ln-SIRI assessment (Fig. 3).

Table 4
Comparison of Predictive Performance of Two Nested Logistic Regression Models

| Metric | Model 1 | Model 2 | Model 2 vs Model 1 |
|---|---|---|---|
| AUC | 0.718 | 0.784 | - |
| AIC | 590.1 | 581.2 | - |
| BIC | 619.8 | 615.0 | - |
| Bootstrap-corrected AUC | 0.699 | 0.762 | - |
| Optimism | 0.0189 | 0.0217 | - |
| NRI | | | 0.350 (0.131–0.574), P = 0.002 |
| IDI | | | 0.042 (0.015–0.069), P < 0.001 |
| LRT, P Value | - | - | < 0.001 |

Abbreviations: AUC, Area Under the Curve; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; NRI, net reclassification improvement; IDI, integrated discrimination improvement; LRT: Likelihood Ratio Test.

# Discussion

In this study, admission and postoperative ln-SIRI levels did not differ significantly between the successful and failed recanalization groups (Table 1). However, both were significantly elevated in the futile recanalization group compared with the meaningful recanalization group—indicating a more pronounced systemic inflammatory response (Table 1; Supplementary Table 1). These findings suggest that systemic inflammation is not associated with angiographic recanalization success but is strongly associated with the clinical effectiveness of recanalization. The immune-inflammatory response is considered a central pathophysiological mechanism underlying cerebral ischemic injury following AIS [23]. Cerebral ischemia and hypoxia resulting from LVO may trigger innate immune activation, characterized by neutrophil and platelet hyperactivation and lymphopenia—collectively contributing to an elevated SIRI [24, 25]. We found that admission ln-SIRI independently predicted futile recanalization, and adding postoperative ln-SIRI further improved model performance (Table 3; Table 4)—consistent with prior evidence that SIRI is an independent prognostic biomarker in AIS [7, 26, 27].

The principal finding of this study is that postoperative ln-SIRI, measured within 24 hours after EVT, demonstrates statistically significant incremental predictive value (Table 3; Table 4). This improvement extends beyond the predictive information provided by admission ln-SIRI and established clinical predictors. Decision curve analysis showed that Model 2 provides greater net clinical benefit than Model 1 across the clinically meaningful threshold probability range of 30% to 90% ( Fig. 3). These results provide quantitative support for incorporating routine postoperative SIRI assessment into clinical practice. Admission ln-SIRI reflects the pre-intervention immune-inflammatory status in patients with AIS. An elevated admission ln-SIRI signifies a pronounced systemic inflammatory response before EVT

that is independently associated with more severe cerebral ischemic injury and worse neurological outcomes—even following successful recanalization. This finding is consistent with a pathophysiological cascade in which admission-level inflammation drives sustained postprocedural inflammation leading to futile recanalization [28]. Persistently elevated postoperative SIRI may reflect systemic inflammatory activity, which could exacerbate blood–brain barrier disruption, vasogenic cerebral edema, and secondary ischemic injury, contributing to futile recanalization [29, 30]. This inflammatory cascade effect may be mechanistically linked to postprocedural reperfusion injury. Cerebral ischemia–reperfusion injury (CIRI) is a well-established secondary pathological process triggered by the restoration of cerebral perfusion after AIS. Its core mechanisms, including oxidative stress, neuroinflammation, and blood–brain barrier disruption, could potentially contribute to neuronal damage and poor functional outcomes [31, 32]. Following AIS, a rapid inflammatory response is initiated, which contributes to neuronal injury [33]. Subsequent CIRI amplifies this process by driving an inflammatory cascade and oxidative stress, thereby imposing a secondary insult on neurons already compromised by ischemia and exacerbating neurological dysfunction [34]. Therefore, modulating the inflammatory response may represent a potential strategy to improve outcomes after recanalization.

In the nested multivariable model, admission NIHSS, number of passes, and BUN level were independently associated with futile recanalization (Table 3). Elevated admission NIHSS scores signify greater severity of initial neurological impairment [35], and a higher number of thrombectomy passes reflects increased procedural complexity and may contribute to heightened risks of endothelial injury and microembolic dissemination [36, 37]. Elevated BUN levels indicate either renal dysfunction or systemic hypoperfusion—both of which are robustly associated with diminished cerebrovascular reserve and poor functional recovery [38, 39]. These findings were consistent with prior clinical and mechanistic evidence and underscore the multifactorial pathophysiology underlying futile recanalization [30, 31, 40].

This study has several limitations that warrant careful consideration. First, its single-center, retrospective design may introduce selection bias and limit external validity, underscoring the need for prospective, multicenter validation. Second, ln-SIRI was assessed at only two time points; more granular longitudinal sampling would better characterize the dynamic evolution of systemic inflammation following reperfusion. Third, while our analysis demonstrated significant incremental predictive value, the observational design precludes definitive causal attribution between postoperative inflammation and futile recanalization. Finally, the generalizability of the optimal decision thresholds identified by DCA requires validation in independent cohorts.

# Conclusion

Both admission and postoperative ln-SIRI were independently associated with futile recanalization risk after EVT in AIS patients. Postoperative SIRI provides significant incremental predictive value beyond admission SIRI for futile recanalization after EVT. These findings indicate that assessment of postoperative systemic inflammation provides incremental prognostic information for risk stratification.

# Declarations

**Authors' contributions** MY: Conceptualization; methodology; data curation writing – original draft; QQ: Methodology; writing – original draft; data curation. LS: Investigation; conceptualization; writing – original draft; formal analysis. YL: investigation; writing – original draft; formal analysis; data curation. SD: Software; methodology; writing – review and editing; funding acquisition. LW: Conceptualization; funding acquisition; formal analysis; visualization. LC: conceptualization; Writing – review and editing; supervision; funding acquisition; project administration.

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**Data availability** The data underlying this article will be shared upon reasonable request to the corresponding author.

**Ethics Approval and Consent to Participate**

This retrospective study was approved by the Institutional Review Board of the Fourth Affiliated Hospital of Guangxi Medical University (Approval No. KY2026637). Given the retrospective observational nature of the study and the exclusive use of de-identified patient data, the requirement for written informed consent was waived by the Institutional Review Board. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

**Competing interests** The authors declare no competing interests.

**Consent for Publication** Not Applicable.

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## Figures

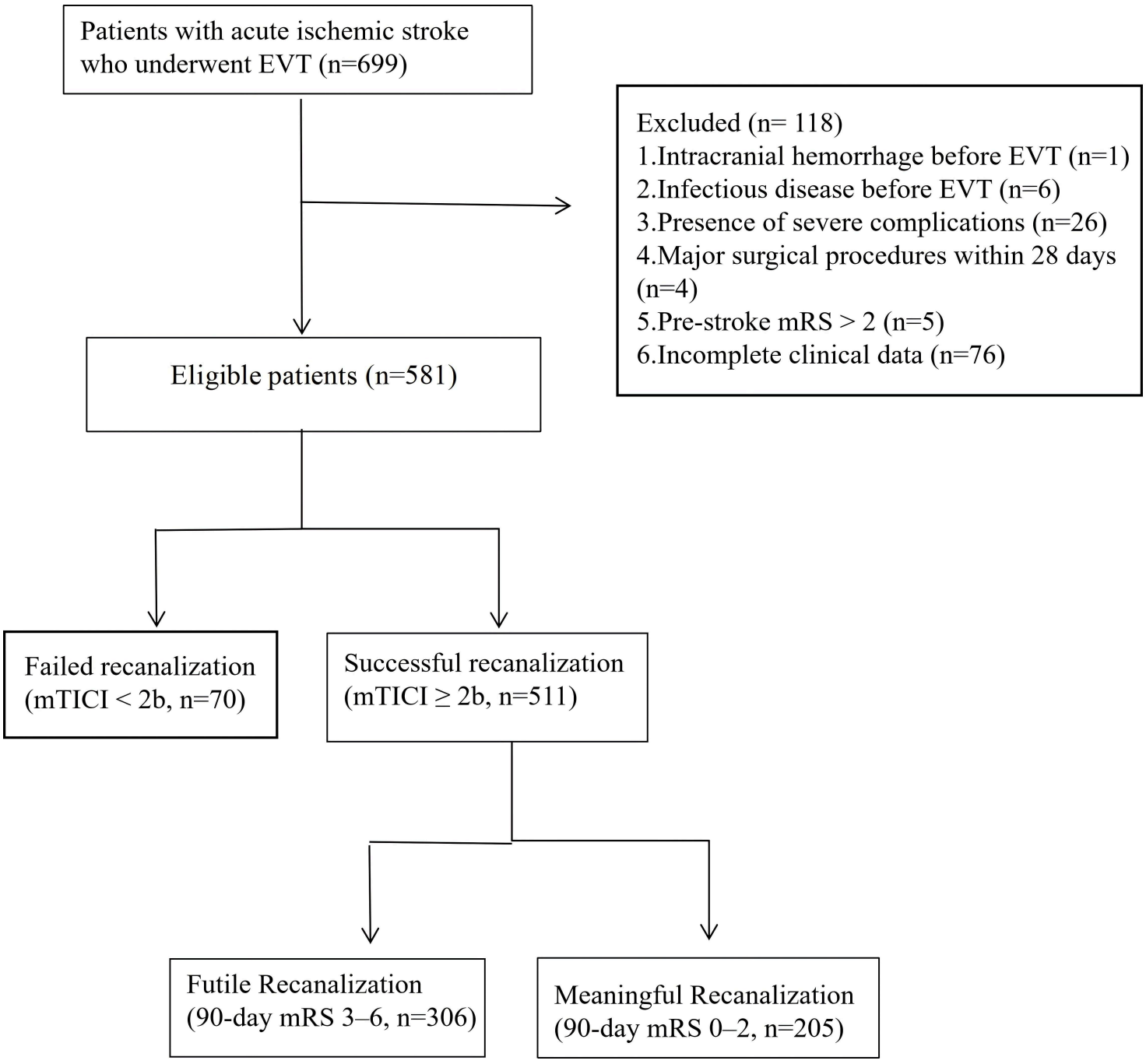



**Figure 1**

Patient selection flow diagram. Abbreviations: EVT—endovascular treatment, mRS—modified Ranking Scale, mTICI—modified Thrombolysis in Cerebral Infarction.

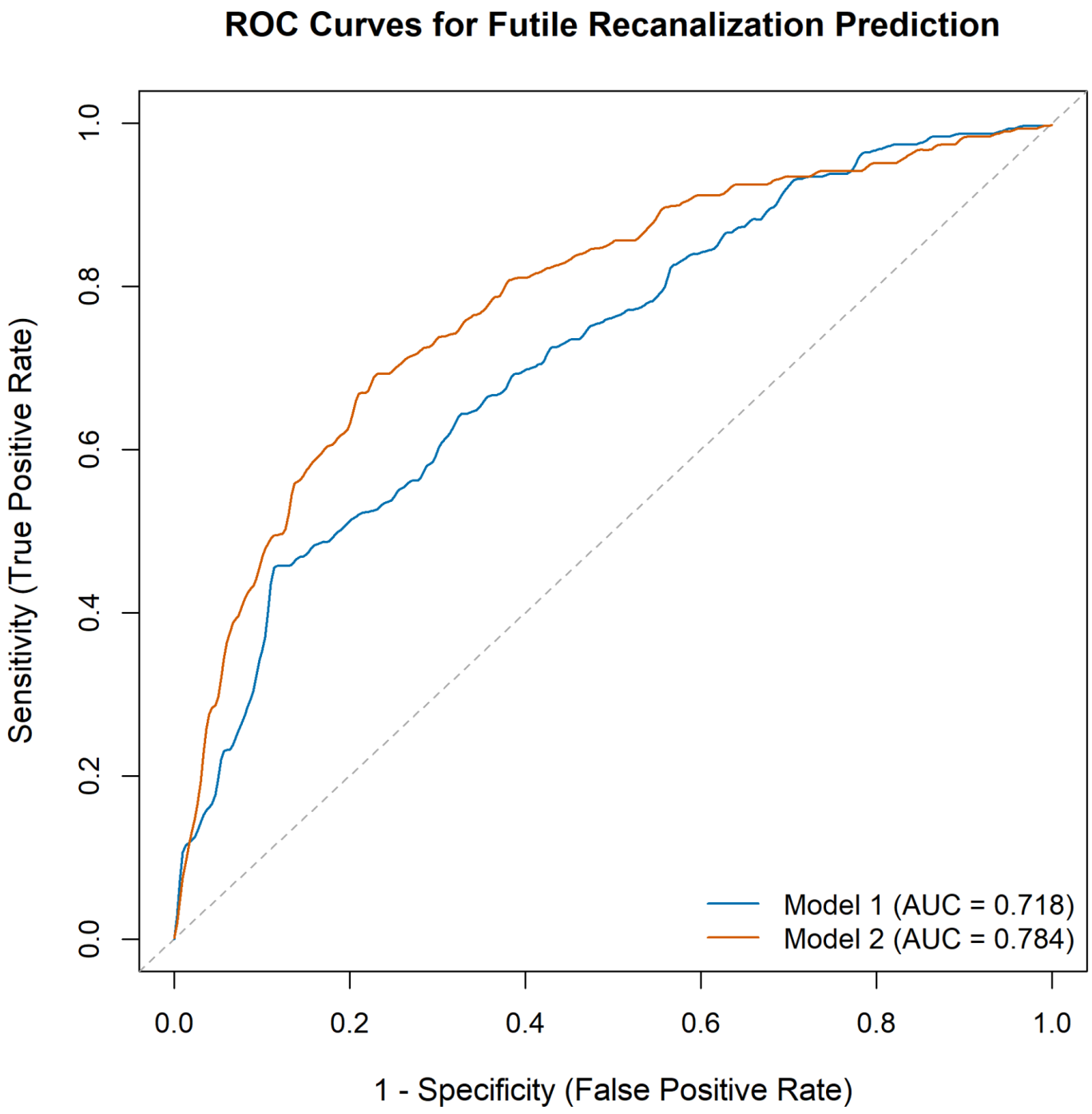



**Figure 2**

**AUC Distribution for Futile Recanalization Prediction.** Abbreviations: AUC, area under the receiver operating characteristic curve.

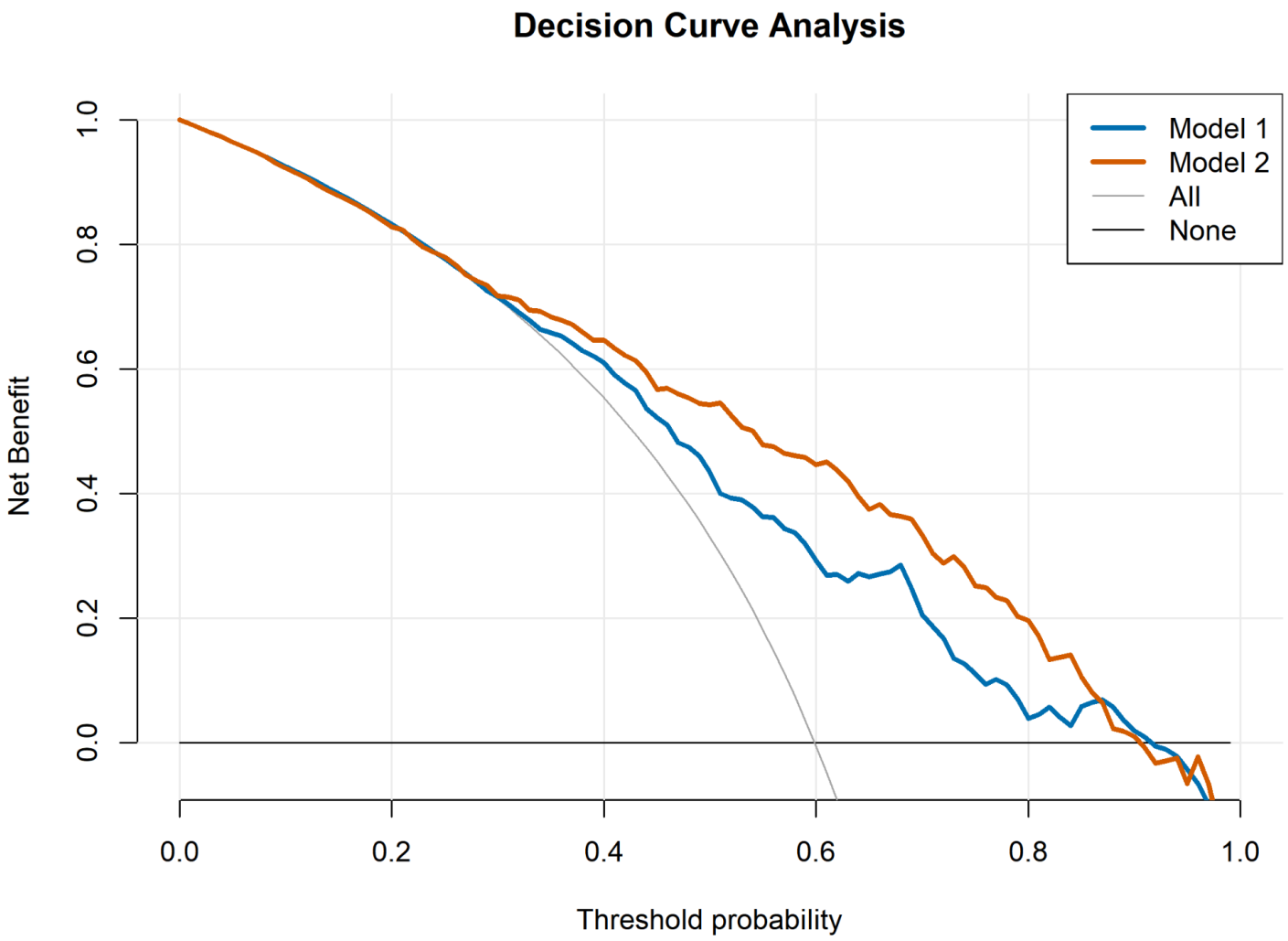



**Figure 3**

Decision Curve Analysis: Net Benefit of the Prediction Model in Patients with Futile Recanalization.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTable1.docx
- SupplementalTable2.docx