

Contact aspiration versus combined thrombectomy in basilar artery occlusion: clinical severity and first-pass recanalization drive outcome

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Abstract

Introduction.

Acute basilar artery occlusion (BAO) carries high morbidity and mortality rates despite endovascular therapy, and the optimal technique and outcome predictors remain unclear. We compared contact aspiration (CA) alone with CA combined with stent retriever (CA + SR) and identified predictors of first-pass reperfusion and 3-month functional outcome.

Methods.

We analyzed the prospective multicenter SARA-3 registry, comparing first-pass recanalization (modified Treatment in Cerebral Infarction [mTICI] 2b–3), procedural time, safety, and 3-month functional outcome for CA and CA + SR. Predictors of unfavorable outcome (modified Rankin Scale [mRS] 3–6) were assessed using multivariable logistic regression for risk stratification.

Results.

Among 68 patients (median age 73 years; median admission National Institutes of Health Stroke Scale [NIHSS] score 11), 50 (73.5%) received CA and 18 (26.5%) CA + SR. Both techniques had similar efficacy, safety, and 3-month unfavorable outcome (48% vs. 53%), but CA was faster (21 vs. 38 min; $P = 0.007$). Admission NIHSS (odds ratio (OR) 1.08 per point; $P < 0.001$) and first-pass mTICI 2b–3 (OR 0.06; $P < 0.001$) independently predicted outcome, and their combination discriminated well (area under the curve 0.83). Patients with NIHSS ≤ 10 and first-pass mTICI 2b–3 fared best, whereas those with NIHSS ≥ 11 and first-pass mTICI 0–2a fared worst, with two-thirds dying. No clinical or imaging characteristics independently predicted first-pass reperfusion.

Conclusions.

CA and CA + SR achieved similar 3-month outcomes in acute BAO, but CA was faster. Admission NIHSS and first-pass recanalization, rather than first-line technique, best predicted functional outcome and together defined prognostic groups that may guide management if validated.

INTRODUCTION

Acute basilar artery occlusion (BAO) accounts for approximately 4% of ischemic strokes but is among the most devastating large-vessel occlusions, as brainstem ischemia can rapidly lead to severe disability or death, and most medically treated patients historically died or remained dependent [1, 2]. After initial neutral studies, two randomized trials, ATTENTION and BAOCHÉ, showed benefit of mechanical thrombectomy (MT) over medical management in selected patients, whereas the earlier BEST and

BASICS trials were neutral, largely because of crossover and inclusion of milder deficits [3–6]. Meta-analyses confirmed that MT improves 90-day functional outcome and reduces mortality despite a higher risk of symptomatic intracranial hemorrhage (sICH), establishing MT as standard care for selected patients, although optimal selection criteria remain debated [7–9]. Nonetheless, many patients still fail to regain functional independence after thrombectomy, underscoring the need for rapid, complete reperfusion.

First-line MT for BAO is usually performed with contact aspiration (CA), a stent retriever (SR), or a combination of both. SR enables direct clot engagement but requires crossing the thrombus in a perforator-rich territory, whereas CA advances a large-bore catheter to the clot face and applies suction, potentially limiting manipulation across the occlusion and shortening groin-to-recanalization time; its effectiveness partly depends on the catheter-to-vessel diameter ratio [10, 11]. Combined thrombectomy integrates SR-based clot engagement with aspiration-mediated flow arrest and capture to enhance reperfusion and minimize distal embolization [12].

Evidence remains heterogeneous. Head-to-head studies of first-line CA versus SR showed similar functional outcomes but faster procedures, higher first-pass and complete reperfusion, and fewer hemorrhagic complications with aspiration [13–22]. Data on CA alone versus combined CA + SR approach are limited; few studies with a combined arm suggested higher complete or first-pass reperfusion without functional benefit [12, 23], and the largest meta-analysis excluded combined-technique cohorts, leaving this question unanswered [22]. First-pass effect (FPE), defined as complete or near-complete reperfusion after a single pass, is an attractive composite endpoint integrating device choice, clot-vessel interaction, anatomy, and speed, and shorter procedures with fewer passes are associated with better BAO outcomes [24, 25], but BAO-specific evidence on FPE predictors is confined to retrospective and post hoc analyses.

Using the prospective, multicenter SARA-3 registry, we therefore compared first-line CA alone with CA + SR in acute BAO, focusing on first-pass and final reperfusion, procedural time, safety, and 3-month functional outcome. We also sought to identify independent predictors of successful first-pass reperfusion and 3-month outcome and to explore a simple risk-stratification model.

Materials and Methods

We used data from the SARA-3 registry, an investigator-initiated, prospective, multicenter, observational registry of adults treated with MT for acute ischemic stroke at 23 comprehensive stroke centers in Spain between January and December 2024. For this analysis, the cohort was restricted to patients aged > 18 years with documented acute BAO treated with first-line CA alone or a combined technique (CA + SR); patients treated with other first-line techniques or with non-basilar occlusions were excluded. All patients or their legal representatives provided written informed consent, and the study was approved by the Institutional Ethics Committee. Treatment indications followed the European Stroke Organisation–

European Society for Minimally Invasive Neurological Therapy guidelines [26], and reporting followed the STROBE statement [27].

Procedures were performed by experienced interventional neuroradiologists under conscious sedation or general anesthesia per local protocol, with the first-line technique chosen by the treating operator. In the CA group, an aspiration catheter was advanced to the clot interface and continuous aspiration was applied; in the CA + SR group, aspiration was applied through the catheter while the deployed SR and captured thrombus were withdrawn. Rescue maneuvers were performed when first-pass reperfusion was inadequate. Reperfusion was graded using the modified Treatment in Cerebral Infarction (mTICI) scale after the first pass and at the end of the procedure. Baseline variables included age, sex, pre-stroke modified Rankin Scale (mRS), admission National Institutes of Health Stroke Scale (NIHSS), baseline posterior circulation ASPECTS, last time seen well, unknown onset, intravenous thrombolysis, and anesthetic management. sICH was defined as intracranial hemorrhage with a ≥ 4 -point NIHSS increase within 24 h attributable to hemorrhage. Functional outcome was assessed at 90 days by certified neurologists.

The two primary outcomes were first-pass reperfusion and 3-month functional independence rates. FPE was defined as complete/near-complete reperfusion after a single pass (mTICI 2c–3); successful first-pass reperfusion (mTICI 2b–3) was also evaluated as a candidate predictor. Functional independence was defined as mRS 0–2 at 3 months. Secondary and safety outcomes included final reperfusion, groin-to-recanalization time, 24-h NIHSS, sICH, embolization to a new territory, procedure-related complications, and 3-month mortality.

Statistical Analysis. Continuous variables are summarized as medians (interquartile range [IQR]), and categorical variables are summarized as counts (%). Groups were compared using the Wilcoxon rank-sum, χ^2 , or Fisher's exact tests. Variables associated with outcomes in the univariable analysis were candidates for a multivariable model of unfavorable outcomes. To limit small sample size and separation bias, the multivariable model was fitted with Firth penalized (bias-reduced) logistic regression, reporting odds ratios (OR) with profile-penalized-likelihood 95% confidence intervals (CI); there were 11.5 events per candidate variable. Discrimination was assessed by receiver operating characteristic (ROC) curves and the area under the curve (AUC) with optimal cut-offs and predictive values. The model was internally validated by bootstrapping (1000 resamples) to estimate an optimism-corrected AUC and calibration slope; model-predicted probabilities of unfavorable outcome were plotted against admission NIHSS for each first-pass reperfusion status. Missing data were not imputed in this study. Significance was set at $P < 0.05$; analyses used R version 4.5.0 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

We included 68 patients with acute BAO treated with first-line CA alone or CA + SR. Median age was 73 years (IQR 60–81), 27 (40%) were women, and median admission NIHSS score was 11 (IQR 7–24). Most

had baseline ASPECTS ≥ 7 (54/68, 79%); 13 (19%) had unknown onset, 12 (18%) received thrombolysis, and 46 (68%) underwent MT under general anesthesia. First-line CA alone was used in 50 patients (73.5%) and CA + SR in 18 (26.5%). Baseline characteristics were generally balanced, although women were more frequent in the CA group (48% vs. 17%; $P = 0.02$) (Table 1).

Table 1
Cohort characteristics according to first-line endovascular technique to treat acute basilar artery occlusion.

Age, years, median (IQR)	Whole cohort (n = 68)	Contact aspiration alone (n = 50; 73.5%)	Combined Contact aspiration + SR (n = 18; 26.5%)	p-value
	73 (60–81)	74 (61–81)	71 (57–79)	0.4
Female, n (%)	27 (40)	24 (48)	3 (17)	0.02
Pre-stroke mRS 0 / 1 / 2, n (%)				0.3
0	45 (66.1)	32 (64)	13 (72)	
1	16 (23.5)	11 (22)	5 (28)	
2	7 (10.2)	7 (14)	0 (0)	
Admission NIHSS, median (IQR)	11 (7–24)	11 (6–25)	14 (10–23)	0.6
ASPECTS ≥ 7 , n (%)	54 (79)	42 (84)	12 (67)	0.2
Last seen well, min, median (IQR)	254 (165–360)	242 (157–331)	296 (238–698)	0.068
Unknown onset, n (%)	13 (19)	11 (22)	2 (11)	0.5
IV thrombolysis, n (%)	12 (18)	8 (16)	4 (22)	0.7
General anaesthesia, n (%)	46 (68)	37 (74)	9 (50)	0.076
Groin-to-recanalization [min], median (IQR)	26 (15–43)	21 (13–36)	38 (21–62)	0.007
First-pass mTICI 2c–3, n (%)	47/66 (71)	34/48 (71)	13 (72)	> 0.9
First-pass mTICI 2b–3, n (%)	54/66 (82)	39/48 (81)	15 (83)	> 0.9
Final mTICI 2c–3, n (%)	57/61 (93)	42/45 (93)	15/16 (94)	> 0.9
Final mTICI 2b–3, n (%)	59/61 (97)	43/45 (96)	16/16 (100)	> 0.9
Number of passes, n (%)			/	0.8
1	29/53 (55)	22/38 (58)	7/15 (47)	
2	12/53 (22.5)	8/38 (21)	4/15 (27)	
CA, contact aspiration; SR, stent retriever; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Alberta Stroke Program Early CT Score; mTICI, modified Treatment in Cerebral Infarction; mRS, modified Rankin Scale; IQR, interquartile range; sICH, symptomatic intracerebral hemorrhage.				

Age, years, median (IQR)	Whole cohort (n = 68)	Contact aspiration alone (n = 50; 73.5%)	Combined Contact aspiration + SR (n = 18; 26.5%)	p-value
	73 (60–81)	74 (61–81)	71 (57–79)	0.4
> 2	12/53 (22.5)	8/38 (21)	4/15 (27)	
Embolization to new territory, n (%)	1 (1.5)	0 (0)	1 (5.6)	0.3
Dissection, n (%)	1 (1.5)	1 (2)	0 (0)	> 0.9
24-h NIHSS, median (IQR)	2 (0–7)	1 (0–7)	3 (2–7)	0.11
sICH, n (%)	2 (2.9)	2 (4)	0 (0)	> 0.9
Differential NIHSS score 24 h to baseline, median (IQR)	-7 (-14, -2)	-7 (-14, 2)	-7 (-14, 2)	0.9
mRS 0–2 at 3 months, n (%)	31/61 (51)	24/46 (52)	7/15 (47)	0.5
Mortality at 3 months, n (%)	16/61 (26)	13/46 (28)	3/15 (20)	0.7
CA, contact aspiration; SR, stent retriever; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Alberta Stroke Program Early CT Score; mTICI, modified Treatment in Cerebral Infarction; mRS, modified Rankin Scale; IQR, interquartile range; sICH, symptomatic intracerebral hemorrhage.				

Recanalization rates at first pass and procedure end were high. First-pass mTICI 2c–3 was achieved in 47 of 66 patients (71%), and first-pass mTICI 2b–3 in 54 of 66 (82%). Final mTICI 2c–3 and 2b–3 were achieved in 57 of 61 (93%) and 59 of 61 (97%) patients. Recanalization after the first pass and at procedure end and ordinal 3-month mRS were similar between CA alone and CA + SR groups (Supplementary Figure S1). However, groin-to-recanalization time was shorter with CA alone (21 [13–36] vs. 38 [21–62] min; $P = 0.007$). Embolization to a new territory occurred in one patient (1.5%), dissection in one (1.5%), and sICH in two (2.9%), without differences between techniques. Functional independence at 3 months was achieved in 31 of 61 patients (50.8%), and 3-month mortality was 26% (Table 1). Effect estimates for combined CA + SR versus CA alone across reperfusion and 3-month outcome endpoints were consistent, with no significant between-technique differences (Supplementary Figure S2).

Complete/near-complete first-pass (mTICI 2c–3) reperfusion was not associated with 3-month functional independence (58% vs. 46%; $P = 0.4$) or mortality (21% vs. 38%; $P = 0.3$). However, first-pass mTICI 2b–3 was strongly associated with outcome. These patients had higher functional independence (62.5% vs. 9.1%; $P = 0.022$), lower mortality (19% vs. 55%; $P = 0.023$), and lower 24-h NIHSS (1 [0–5] vs. 6 [2–12]; $P = 0.05$) than patients with mTICI 0/2a on the first pass (Supplementary Table S1).

No baseline clinical or imaging characteristics independently predicted first-pass reperfusion. Patients who achieved first-pass mTICI 2b-3 did not differ from those with mTICI 0-2a in age, sex, admission NIHSS, ASPECTS, pre-stroke mRS, intravenous thrombolysis, anesthetic management, or first-line technique; only shorter time from last known well was associated with successful first-pass reperfusion (245 vs. 470 min; $P = 0.034$), and no independent predictor emerged on multivariable analysis (Supplementary Table S1).

On univariable analysis, patients achieving functional independence had lower admission NIHSS (9 [4–15] vs. 17 [10–26]; $P = 0.005$), lower 24-h NIHSS (1 [0–2] vs. 7 [3–20]; $P < 0.001$), and a higher differential NIHSS score from 24h to baseline (-7 [-14, -2] vs. -3 [-11, 0]; $P = 0.066$). No patient with mRS 0–2 had first-pass mTICI 0, versus 25% with mRS 3–6 ($P = 0.003$), and first-pass mTICI 2b–3 was more frequent in patients with functional independence than in those without (97% vs. 64%; $P = 0.001$). Final reperfusion was high in both groups and not associated with the 3-month mRS score (Table 2). Combined stratification by admission NIHSS and first-pass mTICI 2b–3 showed a progressively worse ordinal mRS distribution in patients with NIHSS scores ≥ 11 and/or failure to achieve mTICI 2b–3 after the first pass ($P = 0.034$) (Fig. 1A). The model-predicted probability of an unfavorable 3-month outcome rose steadily with admission NIHSS and was consistently higher in patients without successful first-pass reperfusion (Fig. 1B). Across candidate baseline and procedural variables, only admission NIHSS and first-pass mTICI 2b-3 were significantly associated with outcome; the first-line technique and remaining variables were not (Fig. 3).

Table 2
Univariate analysis for functional outcome at 3 months.

Age, years, median (IQR)	mRS 0–2 (n = 31; 50.8%)	mRS 3–6 (n = 30; 49.1%)	p-value
	70 (61, 79)	74 (60, 80)	0.5
Female gender, n (%)	14 (45)	9 (30)	0.2
Previous mRS, n (%)			0.5
0	23 (74)	19 (63)	
1	6 (19)	6 (20)	
2	2 (6.5)	5 (17)	
Admission NIHSS, median (IQR)	9 (4, 15)	17 (10, 26)	0.005
Admission ASPECTS ≥ 7 , n (%)	26 (84)	23 (77)	0.5
Last time seen well [min], median (IQR)	245 (156, 331)	295 (211, 449)	0.14
Unknown symptoms onset, n (%)	5 (16)	6 (20)	0.7
IV thrombolysis, n (%)	4 (13)	7 (23)	0.3
General anesthesia, n (%)	23 (74)	18 (60)	0.5
Endovascular technique			0.7
Contact aspiration alone	7 (23)	8 (27)	
Combined contact aspiration + SR	24 (77)	22 (73)	
Groin-to-recanalization [min], median (IQR)	21 (14, 36)	28 (15, 50)	0.3
Recanalization after first-pass, n (%)			
mTICI 0	0 (0)	7 (25)	0.003
mTICI 1	0 (0)	2 (7.1)	0.2
mTICI 2a	1 (3.2)	1 (3.6)	> 0.9
mTICI 2b	5 (16)	0 (0)	0.054
mTICI 2c	4 (13)	2 (7.1)	0.7
mTICI 3	21 (68)	16 (57)	0.4
mTICI 2c-3	25 (81)	18 (64)	0.2
CA, contact aspiration; SR, stent retriever; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Alberta Stroke Program Early CT Score; mTICI, modified Treatment in Cerebral Infarction; mRS, modified Rankin Scale; IQR, interquartile range; sICH, symptomatic intracerebral hemorrhage.			

Age, years, median (IQR)	mRS 0–2 (n = 31; 50.8%)	mRS 3–6 (n = 30; 49.1%)	p-value
	70 (61, 79)	74 (60, 80)	
mTICI 2b-3	30 (97)	18 (64)	0.001
Final recanalization, n (%)			
mTICI 0	0 (0)	1 (3.7)	> 0.9
mTICI 1	0 (0)	0 (0)	
mTICI 2a	0 (0)	1 (3.7)	> 0.9
mTICI 2b	2 (7.4)	0 (0)	0.5
mTICI 2c	4 (15)	3 (11)	> 0.9
mTICI 3	21 (78)	22 (81)	0.7
mTICI 2c-3	25 (93)	25 (93)	> 0.9
mTICI 2b-3	27 (100)	25 (93)	0.5
Number of passes, n (%)			0.5
1	15 (68)	12 (50)	
2	4 (18)	6 (25)	
> 2	3 (14)	6 (25)	
Embolism to new territory, n (%)	1 (3.2)	0 (0)	> 0.9
Procedure related-complications, n (%)			
Vasospasm	0	0	
Dissection	0 (0)	1 (3.3)	0.5
Arterial rupture	0	0	
NIHSS score at 24 h, median (IQR)	1 (0, 2)	7 (3, 20)	< 0.001
Differential NIHSS score 24 h to baseline, median (IQR)	-7 (-14, -2)	-3 (-11, 0)	0.066
Symptomatic intracerebral hemorrhage, n (%)	0 (0)	2 (6.7)	0.2
CA, contact aspiration; SR, stent retriever; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Alberta Stroke Program Early CT Score; mTICI, modified Treatment in Cerebral Infarction; mRS, modified Rankin Scale; IQR, interquartile range; sICH, symptomatic intracerebral hemorrhage.			

In multivariable prediction of poor 3-month functional outcome, admission NIHSS and first-pass mTICI 2b-3 were the key predictors. Using Firth penalized logistic regression, admission NIHSS was independently associated with unfavorable outcome (OR 1.08 per point; 95% CI 1.02–1.16; $P < 0.001$; AUC 0.72; optimal cut-off 11 points), and first-pass mTICI 2b–3 was strongly protective (OR 0.06; 95% CI 0.01–0.32; $P < 0.001$; AUC 0.66). The combined model achieved the best discrimination (AUC 0.83; 95% CI 0.72–0.93; sensitivity 0.78, specificity 0.74, negative predictive value 0.82, positive predictive value 0.69), confirmed by internal bootstrap validation (optimism-corrected AUC 0.83; calibration slope 0.90) (Table 3 and Fig. 2).

Table 3

Multivariable prediction of unfavourable 3-month functional outcome (mRS 3–6) for patients with acute basilar artery occlusion treated with mechanical thrombectomy.

Admission NIHSS	AUC (95% CI)	Cut-off	Sens / Spec	NPV / PPV	OR (95% CI)	p-value
	0.72 (0.57–0.84)	11	0.68 / 0.68	0.72 / 0.63	1.08 (1.02–1.16)	< 0.001
First-pass mTICI 2b–3	0.66 (0.55–0.76)	0.5	0.64 / 0.03	0.09 / 0.38	0.06 (0.01–0.32)	< 0.001
Combined model	0.83 (0.72–0.93)	0.33	0.78 / 0.74	0.82 / 0.69	—	< 0.001
AUC, area under the curve; CI, confidence interval; NIHSS, National Institutes of Health Stroke Scale; mTICI, modified Treatment in Cerebral Infarction; OR, odds ratio; Sens, sensitivity; Spec, specificity; NPV, negative predictive value; PPV, positive predictive value. Odds ratios are from Firth penalized logistic regression; the combined-model AUC was internally validated by bootstrapping (optimism-corrected AUC 0.83, calibration slope 0.90).						
Supplementary Table S1. Characteristics and outcomes according to first-pass reperfusion status.						

DISCUSSION

In this multicenter SARA-3 analysis of acute BAO, first-line CA alone and combined CA + SR yield similar first-pass recanalization, final recanalization, safety, and 3-month functional independence, but CA alone was significantly faster. Functional outcome at 3 months was driven by baseline severity (admission NIHSS) and early angiographic success (first-pass mTICI 2b–3), whose combination best identified poor functional outcome (AUC 0.83).

The main procedural difference was speed: CA alone shortened groin-to-recanalization time (21 vs 38 minutes; $P = 0.007$), likely because vertebrobasilar anatomy often allows a direct catheter route without SR deployment and retrieval. This aligns with posterior circulation data, where first-line CA reduces

procedure time versus SR or combined techniques and a meta-analysis shows ~ 30-minute shorter duration and fewer passes with aspiration [13, 21–23]. Our results extend these findings by showing that CA alone remained faster than CA + SR, without sacrificing first-pass reperfusion or 3-month functional independence.

Our recanalization outcomes were favorable and comparable between techniques. First-pass mTICI 2b–3 and 2c–3 were achieved in 82% and 71% of patients, and final grades reached 97% and 93%. In comparison, final mTICI 2b–3 in RCTs was 72% in BASICS, 71% in BEST, 93% in ATTENTION, and 88% in BAOCHE, and 85–94% in large observational cohorts [3–6, 17, 23]. Neither first-pass nor final angiographic results differed between CA alone and combined approaches. This contrasts with series reporting higher complete or first-pass success with combined SR + CA or SR-assisted aspiration [12, 23]; in our cohort, routinely adding an SR conferred no angiographic advantage once a modern aspiration catheter reached the thrombus face, suggesting that in the vertebrobasilar circulation a single, well-executed aspiration pass can match combined approaches.

Safety was also similar. sICH occurred in 2.9% of patients, new-territory embolization in 1.5%, and dissection in 1.5%, at or below the rates reported in the RCTs (sICH 4–8%) and comparable to aspiration-first series [3–6, 14, 16]. This agrees with meta-analytic evidence that first-line aspiration carries a lower risk of sICH than SR thrombectomy (OR 0.56) and of new-territory embolization [16, 22]. The low event rate with either CA alone or combined CA + SR supports an aspiration-based approach and argues against a safety penalty from adding a SR, although the few events limit firm conclusions.

At 3 months, 51% of patients achieved functional independence (mRS 0–2), and mortality was 26%. By comparison, endovascular arms of the RCTs reported functional independence rates of approximately 33–39% and mortality of 31–38%, while observational BAO series reported mRS 0–2 in 27–45% [3–6, 14, 17, 23, 29]. The favorable outcomes in our cohort may reflect high final reperfusion, exclusion of substantial prestroke disability, treatment at experienced comprehensive stroke centers, and moderate baseline severity (median NIHSS 11). These differences, rather than the first-line device, warrant caution in cross-study comparisons.

Despite shorter procedures with CA, functional outcomes did not differ by technique. BAO outcome also depends on baseline severity, brainstem ischemic burden, collateral status, occlusion segment, thrombus characteristics, and time to puncture. Moreover, both groups achieved very high final recanalization and similar first-pass reperfusion, potentially attenuating any effect of procedural speed. Speed alone may therefore be insufficient to outweigh the prognostic importance of baseline severity and successful first-pass reperfusion

Taken together, These findings favor a selective rather than universal first-line use of combined thrombectomy. Prior studies are mixed: some reported higher complete revascularization with SR + CA [12], whereas others found more first-pass reperfusion without better 3-month outcomes [23]. Technique selection may therefore be guided by anatomy and presumed etiology. The clot meniscus sign may identify embolic distal occlusions more amenable to aspiration [19], whereas intracranial atherosclerotic

disease often requires rescue angioplasty or stenting regardless of the first-line device [28]. A recent meta-analysis found similar functional outcome and mortality with first-line CA and SR, with lower sICH after aspiration, but excluded combined-technique cohorts [22]. Our direct comparison of CA with CA + SR begins to address this gap.

The most clinically relevant finding was that outcome related more closely to baseline severity and first-pass reperfusion than to first-line technique. Admission NIHSS independently predicted unfavorable outcome, with an optimal threshold of 11, consistent with BAO series linking admission NIHSS and complete recanalization to outcome and showing approximately twofold higher odds of functional independence after reperfusion within one or two passes [17, 23, 25, 29]. First-pass mTICI 2b-3 was more informative for functional independence and mortality than mTICI 2c-3, suggesting that any successful first-pass reperfusion may be decisive in the posterior circulation [24, 25]. However, it could not be reliably predicted from baseline variables.

First-pass mTICI 2b-3 was strongly associated with 3-month outcome but had limited stand-alone discrimination for unfavorable outcome (AUC 0.66; specificity 0.03; negative predictive value 0.09; Table 3). This reflects its high prevalence: 82% achieved successful first-pass reperfusion, including many with poor outcomes. Angiographic success should therefore not, by itself, prompt prognostic reassurance because it cannot reverse established tissue injury or offset severe baseline deficits; conversely, failure to reperfuse on the first pass, particularly in a severely affected patient, identified a very high-risk group. Adding admission NIHSS improved specificity to 0.74 and negative predictive value to 0.82 (AUC 0.83). These findings support pursuing rapid, complete reperfusion while maintaining neurocritical vigilance after early angiographic success.

Admission NIHSS and first-pass reperfusion also provide a simple real-time risk-stratification framework. Stratification by NIHSS (≤ 10 vs > 11) and first-pass mTICI 2b-3 defined four distinct 3-month trajectories (Fig. 1A), with predicted risk rising with NIHSS and remaining higher at every severity level when first-pass reperfusion was not achieved (Fig. 1B). Low NIHSS with successful first-pass reperfusion had the best outcome, high NIHSS without it the worst, and the other two groups intermediate outcomes. Because both variables are available during acute care, this framework may help identify high-risk patients, guide rescue strategies, avoid prolonged ineffective passes, and improve prognostic communication. It remains hypothesis-generating pending external validation; if validated, it could support more individualized acute BAO thrombectomy.

This study has several limitations. Its observational, nonrandomized design leaves residual confounding and operator-selection bias, and the modest, unbalanced sample (50 CA vs 18 CA + SR), missing 90-day outcomes, and few events limited power, particularly for subgroup and multivariable analyses. Important anatomical, thrombus, device, and rescue-treatment variables were unavailable, reperfusion was locally graded without core-lab adjudication, and care, including devices, rescue strategies, and anesthetic management, varied across 23 centers. Multiple univariable comparisons without formal correction also increase the risk of false-positive findings. Firth penalized regression reduced small-sample and

separation bias, and bootstrap validation showed little optimism (corrected AUC 0.83; calibration slope 0.90), but the model was derived and internally validated in the same cohort and requires external validation. Finally, the high final reperfusion rate may have obscured associations with final mTICI, while enrollment at experienced centers over one year limits generalizability.

Conclusion

In the SARA-3 registry, first-line CA alone and combined CA + SR achieved similar reperfusion, safety, and 3-month functional outcomes in acute BAO, although CA alone was faster. Admission NIHSS and first-pass mTICI 2b-3 were more strongly associated with outcome than first-line technique, and their combination improved prediction of poor outcome. Larger prospective studies are needed to validate this model and determine whether specific patients benefit from a combined approach over CA alone.

Declarations

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Author Contribution

J.V.-V., P.N. and J.P. conceived and designed the study. J.V.-V., J.P. and P.N. wrote the main manuscript text. M.C.-C. performed the statistical analysis, A.J.B.-L., A.M.R.-J., R.B.-G., C.D.-R., A.F.-L., C.d.I.R., J.O.-Q., M.S.-D., C.T., A.R.-B., O.B., C.O., J.D.-P., J.L.T., P.A.P.-R., C.H.-B., M.G.-R., E.M., J.C.M.-C., M.M.-G., M.A.-L., F.A.-R. and J.Z. recruited patients, performed the endovascular procedures and collected the clinical, imaging, procedural and 90-day follow-up data at their respective centres. P.N. and J.P. supervised the project, and P.N. coordinated the multicentre registry, and J.P. the submission as corresponding author. All authors reviewed, critically revised and approved the final manuscript.

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Figures

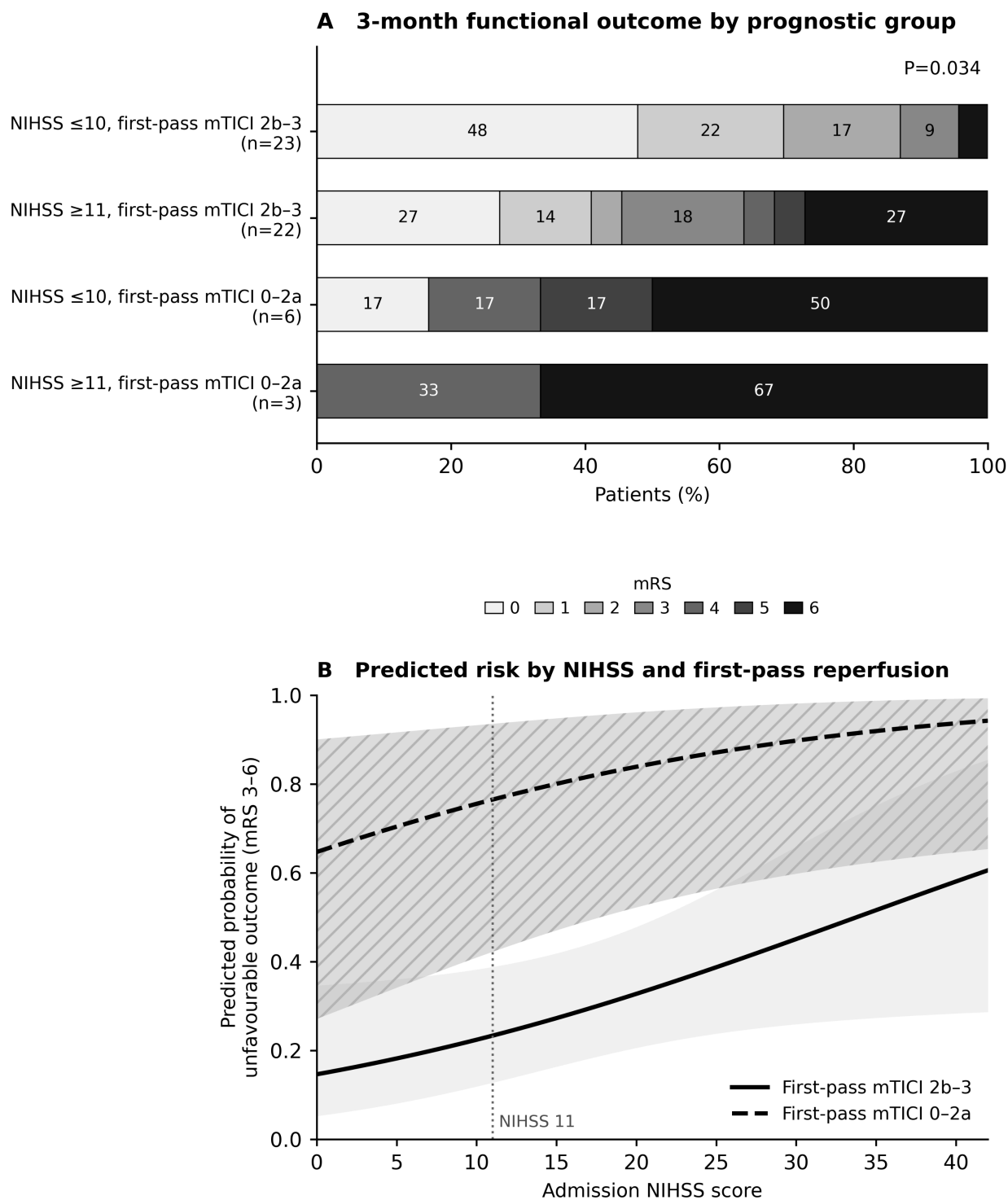


Figure 1

Admission NIHSS, first-pass reperfusion and 3-month functional outcome. (A) Distribution of the 3-month modified Rankin Scale (mRS) across the four prognostic groups defined by admission NIHSS (≤ 10 vs ≥ 11) and successful first-pass reperfusion (mTICI 2b-3 vs 0-2a); shading from light (mRS 0) to dark (mRS 6) denotes increasing disability, and P is the ordinal comparison across groups. (B) Predicted probability of an unfavourable 3-month outcome (mRS 3-6) as a function of admission NIHSS for

patients with (solid line) and without (dashed line) successful first-pass reperfusion, derived from the Firth penalized logistic model; shaded bands are 95% confidence intervals and the dotted vertical line marks the admission-NIHSS cut-off of 11.

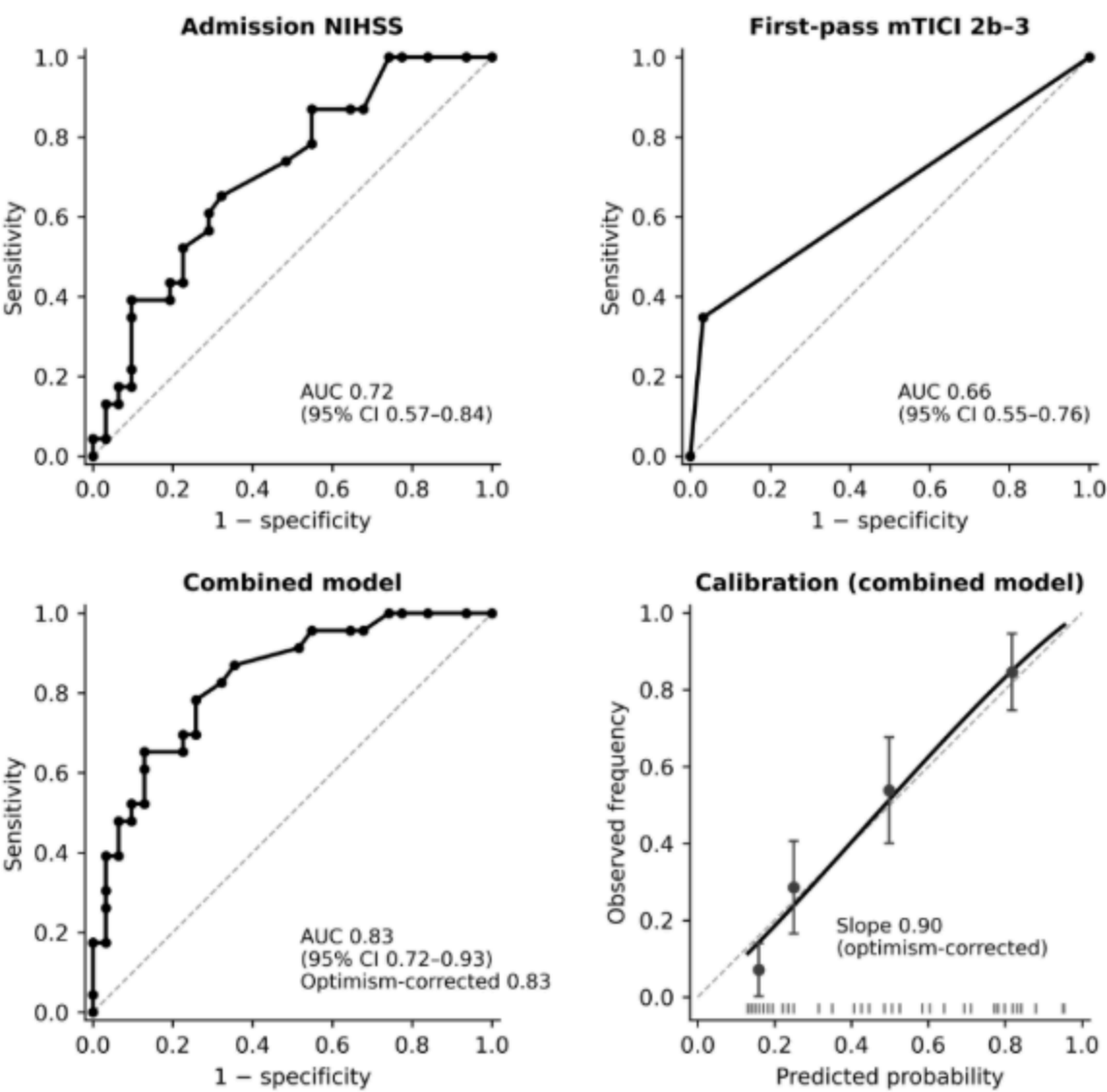


Figure 2

Receiver-operating-characteristic curves for prediction of unfavourable 3-month outcome (modified Rankin Scale 3–6): admission NIHSS (top left), first-pass mTICI 2b–3 (top right) and the combined model (bottom left), with the internal bootstrap calibration of the combined model (bottom right). The combined model showed the best discrimination (AUC 0.83; optimism-corrected 0.83) with adequate calibration (slope 0.90).

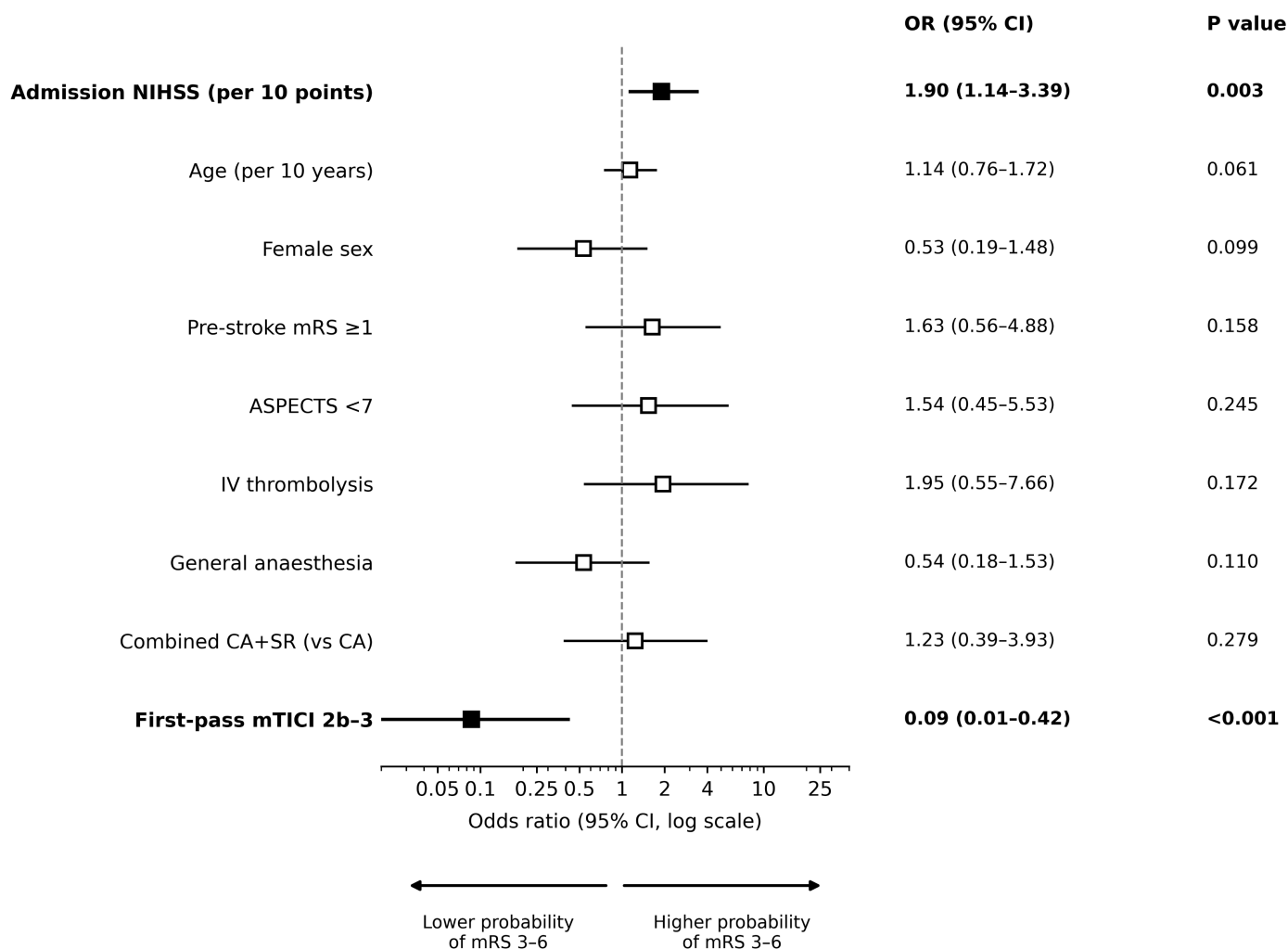


Figure 3

Univariable predictors of unfavourable 3-month functional outcome (modified Rankin Scale 3–6). Squares are odds ratios and horizontal bars 95% confidence intervals from Firth penalized logistic regression; the dashed line marks an odds ratio of 1, with values to the left indicating a lower and to the right a higher probability of unfavourable outcome, and filled squares with bold type denoting statistically significant predictors ($P < 0.05$). Only admission NIHSS (per 10-point increment) and first-pass mTICI 2b–3 were significantly associated with outcome, whereas the frontline technique (combined CA+SR) and the remaining variables were not.

Supplementary Files

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