Kim et al. BMC Neurology (2026) 26:129
https://doi.org/10.1186/s12883-026-04675-1

BMC Neurology

RESEARCH Open Access

Impact of balloon guiding catheter in contact aspiration thrombectomy using large bore aspiration catheter for acute anterior circulation stroke patients: a case-control study

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Abstract

Background Balloon guiding catheters (BGCs) have been shown to reduce distal embolization during mechanical thrombectomy with stent retrievers, but their benefit in contact aspiration thrombectomy (CAT) is not well established. We aimed to evaluate the impact of BGC use during CAT with large-bore aspiration catheters in acute anterior circulation large-vessel occlusion (LVO) stroke.

Methods We retrospectively reviewed acute ischemic stroke patients with anterior circulation LVO treated with first-line CAT at two tertiary hospitals. Patients were grouped by whether a BGC was used. The predefined primary outcome was first-pass successful reperfusion, defined as achieving mTICI 2b–3 with a single thrombectomy device pass. Baseline characteristics, angiographic outcomes, and clinical outcomes were compared between groups. Subgroup analysis was performed for internal carotid artery (ICA)-involved versus isolated middle cerebral artery (MCA) occlusions.

Results A total of 172 patients were included (101 with BGC, 71 without). The BGC group achieved a higher rate of complete reperfusion (mTICI 3: 60.4% vs. 47.9%, $P=0.047$) and first-pass successful reperfusion (63.4% vs. 46.5%, $P=0.045$) compared to the non-BGC group. BGC use was associated with shorter procedure time (median 51 vs. 65 min, $P=0.023$) and less frequent need for device switching (26.7% vs. 46.5%, $P=0.007$). At 3 months, favourable functional outcome (mRS 0–2) was more frequent with BGC (50.5% vs. 36.62%), although this difference did not reach statistical significance ($P=0.071$). There were no significant differences in 90-day mortality or symptomatic intracranial hemorrhage between the groups. In patients with ICA-involving occlusions, BGC use yielded significantly higher rates of favorable outcome (50.8% vs. 30.0%, $P=0.030$) and first-pass complete reperfusion (59.3% vs. 30.0%, $P=0.010$) compared to no BGC. In contrast, outcomes in MCA-only occlusions were similar with or without BGC.

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Conclusions The use of a BGC during CAT for anterior circulation stroke was associated with improved reperfusion success and more efficient procedures. BGCs may enhance first-pass recanalization and possibly functional outcomes, particularly in ICA terminus occlusions, without increasing adverse events. These findings support the incorporation of BGCs as a valuable adjunct to CAT in appropriate patients.

Keywords Acute ischemic stroke, Large vessel occlusion, Contact aspiration thrombectomy, Balloon guiding catheter

Background

Endovascular treatment for acute ischemic stroke (AIS) due to large vessel occlusion (LVO) has rapidly evolved over the past two decades, allowing neurointerventionalists to achieve high rates of reperfusion in appropriately selected patients [1–3]. Many randomized clinical trials revealed that both stent retriever mediated mechanical thrombectomy (SR-MT) and contact aspiration thrombectomy (CAT) are considered as frontline endovascular method for selected patients with acute LVO in the anterior circulation [4–7]. As a result, current guidelines consider both techniques as standard of care for eligible patients.

During endovascular thrombectomy procedures, some degree of clot fragmentation is common, which can lead to distal embolization and new infarcts in previously unaffected territories [8, 9]. A balloon guiding catheter (BGC) is a guide catheter with an inflatable balloon at its tip that is positioned in the proximal cervical artery and temporarily inflated during thrombectomy. Inflating the BGC arrests antegrade flow, which has been shown to reduce clot migration and prevent distal embolization caused by fragmentation [10]. Several studies in stent-retriever thrombectomy have demonstrated that using a BGC improves recanalization rates and clinical outcomes, and BGC use is recommended in mechanical thrombectomy guidelines [11–14]. However, much less is known about the benefits of BGC use during CAT. Aspiration thrombectomy is a safe and effective treatment option for LVO stroke, but vigorous suction and multiple catheter passes through the clot can also generate embolic fragments [5, 6].

In this study, we aimed to investigate the impact of BGC use on angiographic and clinical outcomes in patients with anterior circulation LVO stroke treated with large-bore aspiration catheters as the first-line thrombectomy approach.

Methods

Patients

We retrospectively reviewed consecutive patients with AIS who underwent CAT between March 2018 and September 2022 at two tertiary hospitals. Patients who met al.l the following criteria were included in this study: Patients aged 18 years or older; baseline score of 0 or 1 on the modified Rankin Scale (mRS) [15], occlusion of the intracranial segment of the internal carotid artery or the first or proximal second segment of the middle cerebral artery, or both; able to receive endovascular thrombectomy within 24 h after symptom onset; initial severity of the neurological deficit on the National Institutes of Health Stroke Scale (NIHSS; ranging from 0 [no symptoms] to 42 [most severe neurological impairment]) [16] ≥ 4; and available mRS score at 3 months after stroke onset. Baseline infarct extent on non-contrast CT was assessed using the Alberta Stroke Program Early CT Score (ASPECTS), a validated 10-point quantitative topographic scoring system for early ischemic changes, as previously described [17].

Patients with intracranial artery dissections and with multiple vascular territory occlusions were excluded. The study was approved by the Ajou University Hospital Institutional Review Board (AJOUIRB-DB-2023-107), and the requirement for written informed consent was waived because of the retrospective study design. All methods were performed in accordance with the relevant guidelines and regulations.

Endovascular procedure

For patients eligible for intravenous tissue-type plasminogen activator treatment, the tissue-type plasminogen activator (0.9 mg/kg) was administered. All endovascular procedures were performed under local anesthesia and performed by experienced neurointerventionalists using a biplanar Allura Xper FD scanner (Philips Healthcare).

The CAT procedures were performed with 6-F regular guide catheter (Shuttle Guiding Sheath [Cook Medical, Bloomington, IN]; Neuron Max [Penumbra, Alameda, CA]) or 8-F BGC (Optimo; Tokai Medical, Aichi, Japan). The decision to use a BGC was made at the operator's discretion based on patient-specific anatomical and clinical considerations (e.g., vessel tortuosity or clot burden), rather than a randomized assignment. Aside from the presence of the BGC, the CAT technique was uniform across all cases and operators. After the guide catheter or BGC was optimally positioned in the cervical ICA, a large bore aspiration catheter (Penumbra ACE 68 [Penumbra, Alameda, CA]; or Sofia 6 F [MicroVention, Tustin, CA]; or React 68 [Medtronic, Minneapolis, MN) was advanced as close as possible to the proximal end of the thrombus using a coaxial technique with a 0.021- to 0.027-in microcatheter over a microwire. CAT was then performed with manual aspiration using a 50-mL syringe. Among aspiration catheters used, the Penumbra

ACE 68 catheter was predominantly used for CAT during the study period. For cases using BGCs, the balloon of the BGC was first inflated, then the aspiration catheter was cautiously retrieved under constant aspiration with syringe. This process was repeated until an mTICI grade 2b or 3 was achieved. The timing to stop the CAT attempts or to switch to another endovascular modality (stent retriever thrombectomy, or a combination of both) was determined according to the operator's judgment, taking into consideration the relevant factors.

Outcome measurement

The predefined primary outcome of this study was first-pass recanalization (FPR), defined as achieving successful recanalization (mTICI 2b–3) with a single thrombectomy device pass. For secondary outcome evaluation, we included the following results; final complete or successful recanalization, number of thrombectomy trials, device conversion rate during the procedure, and other territory embolization that was newly observed after thrombectomy. Recanalization status was assessed on the final angiogram and was classified according to the modified thrombolysis in cerebral infarction (mTICI) [18–21] scale; successful recanalization was defined as modified TICI 2b or 3. First pass recanalization (FPR) was defined as achieving successful recanalization (mTICI 2b-3) with a single thrombectomy device pass.

Clinical outcomes included patients' functional outcomes, mortality, and the occurrence of symptomatic intracerebral haemorrhage (ICH). Favourable outcome was defined as a mRS score of 0 to 2 at 3 months after stroke onset. Mortality was also assessed by the mRS score at that time. An ICH was classified according to the second European-Australasian Acute Stroke Study classification, and symptomatic ICH was defined as any CT documented hemorrhage that was temporally related to deterioration in the patient's clinical condition and a ≥ 4-point in NIHSS [22]. For the subgroup analysis, occlusion location was dichotomized by the existence of ICA occlusion (ICA included occlusion [distal ICA occlusion or ICA/MCA tandem occlusion] vs. MCA only occlusion).

Statistical analysis

Baseline clinical characteristics, endovascular procedural variables, angiographic results after thrombectomy, and clinical outcomes were compared between the BGC (+) and BGC (−) groups.

Categorical variables were summarized using frequencies and percentages and were compared using the χ2 test or Fisher's exact test. Continuous variables were summarized using means and SD or median and IQR and compared using the independent two-sample t-test or Wilcoxon rank sum test. The Shapiro–Wilk test was used to test the normality of the distribution. To determine whether the benefits afforded by BGCs were significant in the CAT, the use of BGC as a key variable was entered into the multivariate models in addition to variables with a *P*-value < 0.20 in the univariate analyses. Because first-pass recanalization was the predefined primary outcome, logistic regression models were primarily constructed with FPR as the dependent variable, and favourable functional outcome (mRS 0–2 at 3 months) was analysed as a key secondary endpoint. Using this process, we evaluated the use of BGCs as an independent factor contributing to first pass effect or favourable outcomes in CAT. To analyse the influence of the occlusion location on outcome, subgroup analyses were also performed according to the occlusion location. All statistical tests were two-sided and P values < 0.05 were considered statistically significant. Each parameter was evaluated using logistic regression in the LOGISTIC procedure of SAS (Version 9.4; SAS Institute, Cary, North Carolina, USA) using observed data from each patient with no imputation for missing data.

Results

Patient characteristics

A total of 172 patients met the inclusion criteria, with 101 patients (58.7%) treated using a BGC and 71 (41.3%) treated without a BGC. The mean age was 70.1 ± 13.9 years, and 65.4% were male. Baseline clinical characteristics were similar between the two groups (Table 1). There were no significant differences in age (BGC vs. no BGC: 69.8 ± 13.9 vs. 68.6 ± 15.7 years), sex distribution, vascular risk factors (hypertension, diabetes, hyperlipidemia, smoking, coronary artery disease, prior stroke), ASPECTS, initial NIHSS, use of IV tPA, onset-to-door time, or door-to-puncture time (*P* > 0.1 for all). The only baseline difference was a higher prevalence of atrial fibrillation in the BGC group (58.4% vs. 42.2%, *P* = 0.036), reflecting a possible difference in stroke etiology between groups.

Angiographic and clinical outcomes

Angiographic and clinical outcomes according to BGC use are summarized in Table 2. The predefined primary outcome, first-pass recanalization (FPR), was significantly more frequent in the BGC group than in the non-BGC group (63.4% vs. 46.5%, *P* = 0.045). Among the secondary angiographic outcomes, the BGC group also achieved a higher rate of complete reperfusion (final mTICI 3: 60.4% vs. 47.9%, *P* = 0.047) and required fewer thrombectomy passes on average (2.71 ± 1.71 vs. 1.85 ± 1.43, *P* < 0.001). Device conversion to an additional thrombectomy modality was less often needed when a BGC was used (26.7% vs. 46.5%, *P* = 0.007), and the mean procedure time from puncture to final reperfusion was shorter

Table 1 Comparison of baseline characteristics between patients treated with and without balloon guiding catheter

Characteristics	without BGC (*n* = 71)	with BGC (*n* = 101)	*P*-value
Sex(male) (%)			0.876
Male	47 (66.2)	68 (67.3)	
Female	24 (33.8)	33 (32.6)	
Age (Mean SD)	68.5 (± 15.7)	69.8 (± 13.9)	0.587
Smoking (%)	11 (15.4)	23 (22.7)	0.237
Hypertension (%)	44 (61.9)	65 (64.3)	0.749
Diabetes mellitus (%)	13 (18.3)	17 (16.8)	0.801
Hyperlipidemia (%)	19 (26.7)	17 (16.8)	0.115
Atrial fibrillation (%)	30 (42.2)	59 (58.4)	0.036
Coronary artery disease (%)	15 (21.1)	13 (12.8)	0.148
Previous stroke (%)	15 (21.1)	19 (18.8)	0.707
Use of IV tPA (%)	20 (28.1)	38 (37.6)	0.196
Occlusion location			0.075
0: MCA (%)	41 (57.7)	42 (41.5)	
1: distal ICA (%)	25 (35.2)	44 (43.5)	
2: tandem (%)	5 (7.0)	15 (14.8)	
Occlusion etiology			0.076
0: CAE (%)	36 (50.7)	61 (61)	
1: LAA (%)	18 (25.3)	28 (28)	
2: Other or Unknown (%)	17 (23.9)	11 (11)	
CT ASPECT (Median IQR)	8 (6, 10)	8	0.092
Initial NIHSS (Median IQR)	17 (13, 20)	17	0.522
Onset to door time (min)	311 (± 361)	251 (± 283)	0.253
Door to puncture time (min)	106 (± 54)	109.257 (± 107)	0.803

IV tPA intravenous tissue plasminogen activator, *MCA* middle cerebral artery, *ICA* internal carotid artery, *ASPECT* Alberta Stroke Program Early CT Score, *NIHSS* National Institute of Health Stroke Scale

in the BGC group (51 ± 38 vs. 65 ± 42 min, *P* = 0.023). The frequency of angiographically evident other territory embolization was numerically lower with BGC but did not differ significantly between groups (5.0% vs. 9.9%, *P* = 0.237). Regarding clinical outcomes at 3 months, a favourable functional outcome (mRS 0–2) was observed more often in the BGC group than in the non-BGC group (50.5% vs. 36.6%), although this difference did not reach statistical significance (*P* = 0.071). Rates of symptomatic ICH (8.9% vs. 12.7%, *P* = 0.427) and mortality (5.0% vs. 9.9%, *P* = 0.405) were similar between the two groups, indicating that the use of a BGC was not associated with an increased risk of haemorrhagic complications or death. No complications directly attributable to balloon inflation, such as arterial dissection or vessel rupture, were observed in the BGC group.

Subgroup analysis by occlusion site

Subgroup analyses revealed that the benefits of BGC were particularly pronounced in patients with proximal occlusions involving the ICA (Table 3). Among patients with an ICA terminus or tandem ICA/MCA occlusion, those treated with a BGC had a significantly higher rate of favorable 3-month outcome than those treated without a BGC (50.8% vs. 30.0%, *P* = 0.030). The first-pass effect — defined as achieving complete recanalization (mTICI 3) with a single pass — was also markedly improved in the ICA-involved occlusion subgroup when a BGC was used (59.3% vs. 30.0%, *P* = 0.010). By contrast, in the subgroup of patients with isolated MCA occlusions, there were no significant differences in outcomes between the BGC(+)

Table 2 Primary and secondary angiographic and clinical outcomes in patients treated with and without balloon guiding catheter

		without BGC (*n* = 71)	with BGC (*n* = 101)	*P*-value
Primary outcome	**FPR (%)**	**33 (46.5)**	**64 (63.4)**	**0.045**
Secondary angiograpahic outcome	Final mTICI 3 (%)	34 (47.9)	61 (60.4)	0.047
	Final mTICI 2b-3 (%)	61 (85.9)	93 (92.1)	0.182
	No. of thrombectomy trial (mean ± SD)	2.71 ± 1.71	1.85 ± 1.43	< 0.001
	Device conversion during procedure (%)	33 (46.5)	27 (26.7)	0.007
	Other territory embolization (%)	7 (9.9)	5 (4.6)	0.237
	Procedure time, min (SD)	65 (± 42)	51 (± 38)	0.023
Secondary clinical outcome	Favorable outcome (%)	26 (36.6)	51 (50.5)	0.071
	Symptomatic ICH (%)	9 (12.7)	9 (8.9)	0.427
	Mortality (%)	7 (9.8)	5 (4.9)	0.405

mTICI modified thrombolysis in cerebral infarction, *ICH* intracerebral haemorrhage, *FPR* first pass recanalization

Table 3 Subgroup analysis of outcome by occlusion location between patients treated with and without balloon guiding catheter

	MCA only occlusion (*n* = 83)			ICA-involving occlusion (*n* = 89)		
	without BGC (*n* = 41)	with BGC (*n* = 42)	*P*-value	without BGC (*n* = 30)	with BGC (*n* = 59)	*P*-value
Favorable outcome	17 (41.5)	21 (50)	0.195	9 (30)	30 (50.8)	0.030
Symptomatic ICH	3 (7.3)	2 (4.8)	0.571	6 (20)	7 (11.9)	0.247
Mortality	3 (4.8)	2 (4.8)	0.811	4 (13.3)	3 (5.1)	0.095
FPR	24 (58.5)	29 (69)	0.096	9 (30)	35 (59.3)	0.010

ICH intracerebral haemorrhage, *FPR* first pass recanalization and BGC(−) groups. For MCA-only occlusions, the rates of favorable outcome (50.0% vs. 41.4%, $P=0.196$) and first-pass effect (52.2% vs. 41.4%, $P=0.244$) were similar with versus without BGC.

Multivariate analysis

On univariate analysis, BGC use was strongly associated with better angiographic outcomes. After adjustment for potential confounders in multivariate logistic regression, BGC use remained an independent predictor of first-pass reperfusion success (Table 4). In the multivariate model, BGC utilization was significantly associated with achieving successful reperfusion on the first attempt ($P<0.01$). In contrast, BGC use was not an independent predictor of 90-day favourable outcome when baseline variables were accounted for ($P>0.1$) (Table 5). These analyses suggest that while BGCs clearly improve the technical success of thrombectomy, the translation into clinical outcome is influenced by other factors as well.

Discussion

In this retrospective study of aspiration thrombectomy for anterior circulation stroke, we found that the use of a BGC was associated with improved procedural efficacy and a trend toward better clinical outcomes in CAT. BGC use significantly enhanced angiographic reperfusion rates, including a higher frequency of complete recanalization and a higher likelihood of successful reperfusion on the first pass. Correspondingly, the BGC group required fewer thrombectomy passes, had less need for rescue device use, and achieved reperfusion faster than procedures without a BGC. These findings suggest that proximal flow arrest with a BGC can make aspiration thrombectomy more efficient and effective.

Although the BGC group showed a higher proportion of patients with favorable 3-month outcome in univariate analysis, BGC use did not remain an independent predictor of good functional outcome after adjustment for baseline clinical and imaging variables. This discrepancy between clear technical benefit and a non-significant independent effect on mRS likely reflects the dominant influence of factors such as age, baseline NIHSS, ASPECTS, onset-to-treatment times, and comorbidities on long-term recovery. In our cohort, the higher prevalence of atrial fibrillation in the BGC group also suggests differences in stroke etiology that may affect clot characteristics, collateral status, and infarct dynamics, and these potential confounders may have attenuated

Table 4 Univariate and multivariate logistic regression analysis for FPR

Characteristics	Univariate				Multivariate ($p<0.2$)			
	Odds ratio	95% CI		*P*-value	Odds ratio	95% CI		*P*-value
Sex								
Male	1							
Female	0.849	0.446	1.617	0.618				
Age	0.991	0.971	1.011	0.380				
Smoking (%)	2.591	1.197	5.607	0.015	2.328	0.813	6.666	0.115
Hypertension (%)	1.529	0.810	2.889	0.190	2.124	0.954	4.728	0.065
Diabetes Mellitus (%)	0.860	0.386	1.919	0.713				
Hyperlipidemia (%)	0.806	0.38	1.708	0.573				
Atrial fibrillation (%)	0.885	0.483	1.619	0.690				
Coronary artery disease (%)	0.992	0.438	2.248	0.984				
Previous stroke (%)	0.569	0.258	1.258	0.163	0.516	0.195	1.366	0.183
Use of IV tPA (%)	0.904	0.476	1.714	0.756				
Occlusion location								
0: MCA	1							
1: distal ICA	1.004	0.527	1.913	0.833				
2: tandem	0.870	0.322	2.353	0.771				
Occlusion etiology								
0: CAE (cardioembolism)	1							
1: LAA (Large Artery Atherosclerosis)	1.555	0.768	3.149	0.086	1.422	0.576	3.51	0.274
2: Other or Unknown (Undetermined & Other)	0.675	0.277	1.644	0.166	0.725	0.226	2.33	0.384
CT ASPECT	1.240	1.056	1.455	0.008	1.125	0.913	1.388	0.2691
Initial NIHSS	0.928	0.880	0.979	0.006	0.946	0.881	1.016	0.127
Onset to door time (min)	1.000	0.999	1.001	0.691				
Door to puncture time (min)	1.000	0.996	1.003	0.862				
Use of BGC	10.551	4.829	23.055	< 0.0001	10.343	4.458	23.996	< 0.0.001

IV tPA intravenous tissue plasminogen activator, *MCA* middle cerebral artery, *ICA* internal carotid artery, *ASPECT* Alberta Stroke Program Early CT Score, *NIHSS*National Institute of Health Stroke Scale, *BGC* balloon guiding catheter

Table 5 Univariate and multivariate logistic regression analysis for favourable outcome

Characteristics	Univariate				Multivariate ($p < 0.2$)			
	Odds ratio	95% CI		*P*-value	Odds ratio	95% CI		*P*-value
Sex								
Male	1							
Female	1.053	0.556	1.992	0.875				
Age	0.958	0.936	0.98	< 0.001	0.957	0.924	0.992	0.016
Smoking (%)	5.544	2.335	13.161	< 0.001	8.671	2.308	32.573	0.001
Hypertension (%)	0.452	0.24	0.851	0.014	0.758	0.279	2.058	0.587
Diabetes Mellitus (%)	0.56	0.245	1.28	0.169	0.604	0.196	1.86	0.379
Hyperlipidemia (%)	0.467	0.213	1.023	0.057	0.29	0.081	1.035	0.056
Atrial fibrillation (%)	0.765	0.419	1.397	0.383				
Coronary artery disease (%)	0.435	0.18	1.051	0.064	0.819	0.226	2.962	0.761
Previous stroke (%)	0.522	0.236	1.152	0.108	0.895	0.288	2.782	0.849
Use of IV tPA (%)	0.903	0.478	1.708	0.755				
Occlusion location								
0: MCA	1							
1: distal ICA	0.966	0.509	1.835	0.811				
2: tandem	0.789	0.292	2.132	0.651				
3: ACA								
Occlusion etiology								
0: CAE (cardioembolism)	1							
1: LAA (Large Artery Atherosclerosis)	1.151	0.57	2.327	0.641				
2: Other or Unknown (Undetermined & Other)	0.942	0.403	2.201	0.757				
CT ASPECT	1.62	1.329	1.974	< 0.001	1.382	1.058	1.806	0.018
Initial NIHSS	0.804	0.746	0.867	< 0.001	0.804	0.725	0.892	< 0.001
Onset to door time (min)	0.999	0.998	1	0.028	0.998	0.996	1	0.018
Door to puncture time (min)	1.003	0.999	1.007	0.162	1.001	0.996	1.006	0.671
Use of BGC	1.765	0.949	3.284	0.073	2.068	0.824	5.189	0.122

IV tPA intravenous tissue plasminogen activator, *MCA* middle cerebral artery, *ICA* internal carotid artery, *ASPECT* Alberta Stroke Program Early CT Score, *NIHSS* National Institute of Health Stroke Scale, *BGC* balloon guiding catheter

the measurable impact of BGC use on functional outcome in the multivariable model.

The most plausible mechanism by which BGC use improves angiographic results is flow arrest and counteraction at the proximal cervical ICA, which reduces the pressure gradient across the thrombus and may limit clot fragmentation and distal embolization during aspiration. Previous in vitro and clinical studies in the stent-retriever era have shown that proximal flow control reduces distal emboli and is associated with higher recanalization rates and better outcomes [10–14].

However, in the present study we did not directly quantify new ischemic lesions in other territories with advanced imaging such as systematic post-procedural diffusion-weighted MRI to assess new distal emboli was not incorporated into our protocol, and therefore the proposed mechanism remains inferential rather than directly demonstrated by our data. Future studies that combine CAT with BGC and standardized post-procedural MRI assessment of distal embolic burden would be valuable to confirm whether the higher first-pass reperfusion rates observed with BGC use are truly mediated by a reduction in distal embolization.

Our subgroup analysis revealed that the benefit of BGC was most pronounced in ICA-involved occlusions. In the ICA-involved occlusion subgroup, BGC use led to significantly higher rates of both first-pass complete recanalization and favorable 3-month outcomes, whereas in isolated MCA occlusions the differences were negligible. This discrepancy can be explained by cerebral hemodynamics and collateral circulation. For an M1 occlusion with the ICA otherwise intact, inflating a balloon in the ICA stops direct antegrade flow, but collateral flow through the circle of Willis (via anterior or posterior communicating arteries) may continue to perfuse distal MCA branches beyond the clot (Fig. 1A and B). These collateral pathways can still carry away clot fragments or maintain some distal perfusion pressure, making proximal flow arrest by the BGC less effective in an MCA-only occlusion. In contrast, if the occlusion involves the ICA terminus, a large clot often blocks flow into both the MCA and anterior cerebral artery, and balloon inflation in the proximal ICA effectively halts nearly all inflow to the occluded segment. With proximal flow completely arrested, the aspiration catheter can engage the clot under static or aspiration-dominant conditions,

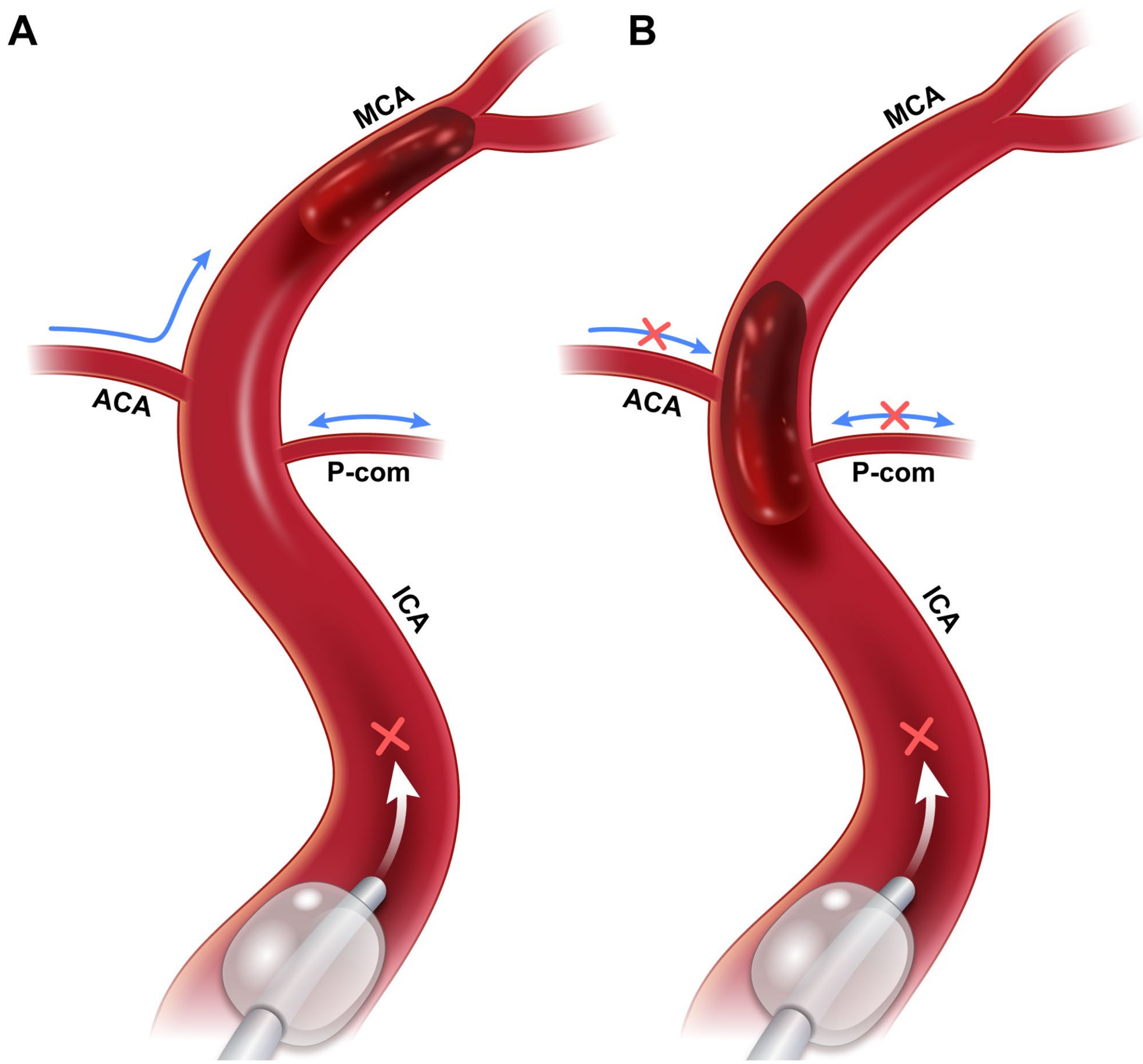

Fig. 1 Hemodynamic schematics during contact aspiration thrombectomy (CAT) with a balloon guiding catheter (BGC), illustrating occlusion location–dependent flow control. **A**: Isolated middle cerebral artery (MCA) occlusion. BGC inflation in the cervical internal carotid artery (ICA) partially reduces antegrade ICA flow; however, collateral inflow via the anterior cerebral artery (ACA) and posterior communicating artery (P-com) may persist, potentially limiting the effectiveness of proximal flow arrest in MCA-only occlusions. **B**: ICA-involving occlusion. The large clot burden at the ICA terminus functionally abolishes collateral inflow through the ACA and P-com, allowing BGC inflation in the cervical ICA to achieve near-complete proximal flow arrest. Symbols: White arrows indicate predominant antegrade flow; blue arrows indicate collateral flow via the circle of Willis; × denotes the site of thrombus/flow interruption

which likely facilitates en bloc removal of the thrombus. Thus, the anatomical involvement of the ICA may create a scenario where the BGC's benefit is fully realized, accounting for the superior outcomes observed in those cases. This finding underscores the importance of considering occlusion location when deciding on thrombectomy strategy, and it suggests that BGCs are particularly valuable for proximal large clots. Our results are consistent with prior studies that demonstrated advantages of using BGCs in stent-retriever thrombectomy. For example, previous analyses have shown that BGC use during stent retriever thrombectomy improves recanalization success and can lead to better clinical outcomes. Several former studies by Zaidat et al. [11] and Brinjikji et al. [23] reported that BGC use was associated with higher rates of complete reperfusion and increased odds of good neurologic outcome in patients treated with mechanical thrombectomy. Our study expands on these findings by focusing on CAT as the primary modality, and it suggests that the benefits of flow arrest with a BGC extend to direct aspiration approaches, not just stent retrievers. This is an important contribution, as aspiration is now widely used either alone or in combination with stent retrievers as a frontline therapy. These findings have practical implications for endovascular stroke therapy. The combined use of a BGC with a large-bore aspiration catheter should be considered to maximize thrombectomy efficacy, especially in challenging occlusions involving the carotid terminus.

Additionally, recent studies have provided evidence supporting the use of BGCs in conjunction with aspiration and combined techniques. Kang et al. [24] reported in a multicenter study that employing a BGC during aspiration thrombectomy significantly improved final and first-pass recanalization rates and reduced the incidence of distal embolization events compared to using a conventional guide catheter. The PROTECT PLUS technique described by Maegerlein et al. [25] – a combined approach of proximal flow arrest with a BGC together with simultaneous stent retriever deployment and distal aspiration – achieved a substantially higher first-pass complete reperfusion rate than the standard Solumbra approach without a BGC, highlighting the benefit of adding flow control to combined thrombectomy strategies. Furthermore, Baek et al. [26] demonstrated that BGC use was associated with improved revascularization success and better clinical outcomes in endovascular therapy regardless of whether a stent retriever or aspiration was used as the primary modality.

The latest generation of BGCs are more trackable and have larger inner lumens than earlier designs, which allows them to accommodate contemporary aspiration catheters without compromising deliverability. For instance, the 8 F Optimo BGC used in our study has an inner diameter of 0.087 inches, sufficient for all commonly used aspiration catheters. This technological improvement addresses prior concerns about difficulty in navigating bulky balloon catheters and makes routine use of BGCs more feasible. Our experience indicates that when anatomically and logistically possible, employing a BGC can improve first-pass success and reduce the need for rescue maneuvers, thereby streamlining the thrombectomy procedure.

While the study provides significant insights, this study has several limitations. The retrospective design may introduce selection bias and limit the control over confounding variables. In particular, the use of BGC was not randomized or standardized in our cohort, introducing potential selection bias despite our multivariate adjustments; a propensity-matched or randomized study would provide stronger evidence of efficacy. Additionally, the sample size, while relatively large, may not be sufficient to generalize the findings to all populations. Future prospective studies with larger sample sizes are needed to validate these findings and explore the long-term benefits of BGC use in CAT.

Future research should focus on multicenter, prospective trials to confirm the benefits of BGCs in diverse clinical settings. Additionally, studies should investigate the cost-effectiveness of BGCs and explore their impact on long-term neurological outcomes and quality of life. Research into optimizing BGC design and developing standardized guidelines for their use in various clinical scenarios will also be valuable.

Conclusion

In summary, this study demonstrates that using a BGC during CAT with a large-bore aspiration catheter can significantly improve technical success in revascularizing anterior circulation LVO strokes. BGC use led to higher complete reperfusion rates and more frequent FPR, translating into more efficient procedures. While overall functional outcomes were not significantly different in this cohort, patients with ICA terminus occlusions in particular showed markedly better outcomes with BGC support. Our findings support the incorporation of BGCs as a useful adjunct to CAT, especially for proximal occlusions, to enhance clot removal and potentially improve patient recovery. Further research, including prospective trials, is encouraged to confirm these benefits and to refine best practices for the use of BGCs in acute stroke intervention.

Abbreviations

AIS	Acute ischemic stroke
LVO	Large vessel occlusion
BGC	Balloon guiding catheter
CAT	Contact aspiration thrombectomy
ICA	Internal carotid artery
MCA	Middle cerebral artery
mRS	Modified rankin scale
mTICI	Modified thrombolysis in cerebral infarction
NIHSS	National institutes of health stroke scale
FPR	First pass recanalization

Acknowledgements

Not applicable.

Authors' contributions

HIK contributed to this work as first author. WSJ contributed to this work as the corresponding author and responsible for the overall content as guarantor. K-CC, SHS, JWC and WSJ gathered the data and collaboratively drafted the manuscript. N-HS contributed to the statistical analysis of the data. All authors approved the final version of the manuscript.

Funding

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. RS-2023-00212144).

Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This retrospective study conformed to the principles of the Declaration of Helsinki and ethical approval was obtained from the Ajou University Hospital Institutional Review Board (AJOUIRB-DB-2023-107). The requirement for written informed consent was waived because of the retrospective nature of this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 24 April 2025 / Accepted: 23 January 2026
Published online: 28 January 2026

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