Balloon Guide Catheter in Endovascular Treatment for Acute Ischemic Stroke: Results from the MR CLEAN Registry

Robert-Jan B. Goldhoorn, MD, Nele Duijsters, MD, Charles B.L.M. Majoie, MD, PhD, Yvo B.W.E.M. Roos, MD, PhD, Diederik W.J. Dippel, MD, PhD, Adriaan C.G.M. van Es, MD, PhD, Jan Albert Vos, MD, PhD, Jelis Boiten, MD, PhD, Robert J. van Oostenbrugge, MD, PhD, and Wim H. van Zwam, MD, PhD, on behalf of the MR CLEAN Registry Investigators

ABSTRACT

Purpose: To compare outcomes after endovascular treatment (EVT) for acute ischemic stroke with and without the use of a balloon guide catheter (BGC) in clinical practice.

Materials and Methods: Data from the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in The Netherlands (MR CLEAN) Registry were used, in which all patients who underwent EVT for anterior-circulation stroke in The Netherlands between 2014 and 2016 were enrolled. Primary outcome was modified Rankin scale (mRS) score at 90 days. Secondary outcomes included reperfusion grade (extended Thrombolysis In Cerebral Infarction [eTICI] score) and National Institutes of Health Stroke Scale (NIHSS) score 24–48 hours after intervention. The association between the use of a BGC and outcomes was estimated with logistic regression adjusted for age, sex, prestroke mRS score, NIHSS score, collateral grade, and time from onset to EVT.

Results: A total of 887 patients were included. Thrombectomy was performed with the use of a BGC in 528 patients (60%) and without in 359 patients (40%). There was no significant association between use of a BGC and a shift on the mRS toward better outcome (adjusted common odds ratio, 1.17; 95% confidence interval [CI], 0.91–1.52). Use of a BGC was associated with higher eTICI score (adjusted common OR, 1.33; 95% CI, 1.04–1.70) and improvement of $\geq$ 4 points on the NIHSS (adjusted OR, 1.40; 95% CI, 1.04–1.88).

Conclusions: In clinical practice, use of a BGC was associated with higher reperfusion grade and early improvement of neurologic deficits, but had no positive effect on long-term functional outcome.

ABBREVIATIONS

BGC = balloon guide catheter, CI = confidence interval, aOR = adjusted odds ratio, acOR = adjusted common odds ratio, eTICI = extended Thrombolysis In Cerebral Infarction, EVT = endovascular treatment, ICA = internal carotid artery, MR CLEAN = Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in The Netherlands, mRS = modified Rankin Scale, NIHSS = National Institutes of Health Stroke Scale, OR = odds ratio

From the Departments of Neurology (R.-J.B.G., N.D., R.J.v.O.) and Radiology (W.H.v.Z.), Maastricht University Medical Center and Cardiovascular Research Institute Maastricht, Room 4.R1.032, P. Debyelaan 25, 6229 HX Maastricht, The Netherlands; Departments of Radiology and Nuclear Medicine (C.B.L.M.M.) and Neurology (Y.B.W.E.M.R.), Amsterdam University Medical Center, Amsterdam, The Netherlands; Departments of Neurology (D.W.J.D.) and Radiology (A.C.G.M.v.E.), Erasmus University Medical Center, University Medical Center, Rotterdam, The Netherlands; Department of Radiology (J.A.V.), Sint Antonius Hospital, Nieuwegein, The Netherlands; and Department of Neurology (J.B.), Haaglanden Medical Center, The Hague, The Netherlands. Received February 27, 2019; final revision received May 27, 2019; accepted May 31, 2019. **Address correspondence to** R.B.G.; E-mail: robertjan.goldhoorn@mumc.nl

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Figures E1–E3 and Tables E1–E7 can be found by accessing the online version of this article on *www.jvir.org* and clicking on the Supplemental Material tab.

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EDITORS' RESEARCH HIGHLIGHTS

- This study used the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in The Netherlands (MR CLEAN) Registry data to determine if use of a balloon guide catheter (BGC) improved patient outcomes.
- Thrombectomy was performed though a BGC in 528 patients and without a BGC in 359. Use of a BGC did not significantly improve patient outcomes based on the modified Rankin scale at 90 days (primary outcome measure), but did significantly improve postprocedure perfusion and early neurologic status based on the National Institutes of Health Stroke Scale (secondary outcome measures).
- Issues with the study included its nonrandomized registry data. In some instances, it was unclear if the balloon was in fact inflated, although, understandably, it was not inflated if concurrent internal carotid artery occlusion was present.
- Based on the findings here, there does not appear to be a greater risk when using a BGC for stroke thrombectomy. There was, in fact, a significantly lower rate of symptomatic intracranial hemorrhage. However, BGC use was not beneficial in terms of improvement in 90-day neurologic outcomes.

A balloon guide catheter (BGC) can be used in endovascular treatment (EVT) for acute ischemic stroke to enable flow arrest during clot removal to prevent distal emboli. A recent meta-analysis of 5 observational studies (1) suggested that the use of a BGC improves reperfusion grade and clinical outcome in patients who were treated with stent retrievers as the first modality. Despite these results, a BGC is not always used in clinical practice. Evidence of the effect of a BGC during direct aspiration thrombectomy is limited. The aim of the present study is to compare outcomes after EVT for acute ischemic stroke with and without the use of a BGC in clinical practice. A secondary aim was to separately analyze the effect of BGC use in stent retriever thrombectomy and direct aspiration.

MATERIALS AND METHODS

Patients

Between March 2014 and June 2016, patients who underwent EVT for ischemic stroke in The Netherlands were enrolled in the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in The Netherlands (MR CLEAN) Registry. The main goal was to gain nationwide coverage of endovascular procedures performed and assess if similar results could be achieved in routine clinical practice as were achieved in MR CLEAN. We used data of the MR CLEAN Registry for the present substudy to assess the association of BGC use with technical and clinical outcomes. Detailed methods of the MR CLEAN Registry have been described previously (2). The

Table 1. Baseline Characteristics of Patients Who Underwent EVT for Ischemic Stroke with a BGC versus without

Characteristic	BGC (n = 528)	Non-BGC (n = 359)	*P* Value	Missing
Age (y)			.26	0
Median	69	70		
IQR	59–78	60–80		
Male sex	297 (56)	182 (51)	.10	0
NIHSS score			.76	20
Median	16	16		
Range; IQR	12–20	12–20		
Clinical localization in left hemisphere	278 (53)	190 (53)	.42	0
Systolic blood pressure (mm Hg)	148 ± 24	150 ± 25	.31	21
Intravenous alteplase treatment	403 (76)	273 (76)	.96	2
Medical history				
Atrial fibrillation	133 (25)	72 (20)	.08	11
Hypertension	254 (49)	189 (53)	.25	11
Diabetes mellitus	87 (17)	67 (19)	.42	5
Hypercholesterolemia	147 (29)	116 (33)	.22	26
Current smoking	132 (25)	80 (22)	.10	202
Ischemic stroke	97 (18)	58 (16)	.39	5
Prestroke mRS score			< .01	17
0	366 (69)	218 (61)		
1	71 (13)	45 (13)		
2	24 (5)	41 (11)		
> 2	57 (11)	48 (13)		
Use of coumarine	81 (15)	41 (11)	.08	8
Use of direct oral anticoagulants	15 (3)	5 (1)	.15	15
Use of antiplatelet medication	175 (33)	133 (37)	.26	11
Level of occlusion on noninvasive vessel imaging			.43	41
Intracranial ICA	31 (6)	22 (6)		
ICA terminus	121 (23)	71 (20)		
MCA M1 segment	305 (58)	201 (56)		
MCA M2 segment	45 (9)	41 (11)		
Other (MCA M3 segment and ACA)	4 (1)	5 (1)		
ASPECTS subgroups			.05	35
0–4	38 (7)	14 (4)		
5–7	121 (23)	100 (28)		
8–10	349 (66)	230 (64)		
Collateral grade			.34	57
0	40 (8)	21 (6)		
1	150 (28)	108 (30)		
2	192 (36)	144 (40)		
3	112 (21)	63 (18)		
Proximal ICA (symptomatic side)			.53	144
No abnormalities	123 (23)	66 (18)		
Atherosclerotic stenosis < 50%	196 (37)	140 (39)		

continued

Table 1. Baseline Characteristics of Patients Who Underwent EVT for Ischemic Stroke with a BGC versus without *(continued)*

Characteristic	BGC (n = 528)	Non-BGC (n = 359)	*P* Value	Missing
Atherosclerotic stenosis > 50%	45 (9)	31 (9)		
Occlusion	34 (6)	28 (8)		
Other	47 (9)	33 (9)		
Transfer from primary stroke center	302 (57)	199 (55)	.60	0
Onset to start of EVT (min)			< .01	0
Median	200	217		
IQR	155–256	170–270		

Note–Values presented as mean ± standard deviation where applicable. Values in parentheses are percentages.
ACA = anterior cerebral artery; ASPECTS = Alberta Stroke Program Early CT Score; BGC = balloon guide catheter; EVT = endovascular treatment; ICA = internal carotid artery; IQR = interquartile range; MCA = middle cerebral artery; mRS = modified Rankin scale; NIHSS = National Institutes of Health Stroke Scale.

MR CLEAN Registry was approved by the ethics committee of the Erasmus University MC, Rotterdam, The Netherlands (MEC-2014-235).

For the present study, we used the following criteria: groin puncture within 6.5 hours after symptom onset; age > 18 y; anterior circulation occlusion of intracranial carotid (internal carotid artery [ICA] or terminus of ICA), middle (M1/M2 segment), or anterior (A1/A2 segment) cerebral artery demonstrated by baseline computed tomographic (CT) angiography; and thrombectomy attempt with a stent retriever or direct aspiration as the first treatment modality employed. Patients were included only when at least 2 planes (2-directional view) were available on final digital subtraction angiography. All images were assessed by an independent core laboratory.

The use of a BGC for EVT was reported by local investigators on the case report forms from the MR CLEAN Registry. Patients in whom the type of guiding catheter was not reported were excluded from the present analyses. A 6-F guiding catheter was categorized as a non-BGC. The balloon was inflated during the procedure to achieve flow arrest whenever possible, except when flow arrest was already achieved without inflation of the balloon as a result of preexisting significant stenosis of the ICA (significant stenoocclusive pathologic process was present in 16% of patients); however, even if the balloon was inflation was unnecessary, aspiration through the BGC was performed in all.

During the study period, 1,627 patients were enrolled in the MR CLEAN Registry. After exclusion of patients primarily on the basis of posterior circulation occlusion, interval from symptom onset to start of EVT longer than 390 minutes, thrombectomy attempt without a stent retriever or direct aspiration first, missing information about BGC use, and missing 2-directional view on digital subtraction angiography, we included 887 patients in the present study (**Fig E1** [available online on the article's Supplemental Material page at *www.jvir.org*]). A BGC was used in 528 patients (60%), and a non-BGC was used in 359 (40%). Age and median National Institutes of Health Stroke Scale (NIHSS) score were similar between groups (**Table 1**). Prestroke functional status was better in the BGC group even though reported medical history, such as previous ischemic stroke, atrial fibrillation, and diabetes mellitus, was not different between groups. Intracranial occlusion site, collateral vessel status, and steno-occlusive pathologic process proximal in the ICA on the symptomatic side were similar between groups. Time from symptom onset to EVT was longer in the non-BGC group (median, 217 vs 200 min; $P < .01$), whereas the percentages of patients who were transferred from a primary stroke center to an intervention center were similar between groups.

Outcome Measures

The primary outcome measure was the modified Rankin scale (mRS) score at 90 days (3). Secondary outcome measures included reperfusion grade, early neurologic outcome (ie, NIHSS score improvement of ≥ 4 points 24–48 h after intervention) (4), and safety outcomes.

Reperfusion was assessed with the extended Thrombolysis In Cerebral Infarction (eTICI) grade (5), which ranges from 0 (no reperfusion) to 3 (complete reperfusion). Successful reperfusion was defined by an eTICI grade of 2B or higher.

Safety outcomes were the occurrence of symptomatic intracranial hemorrhage (sICH), ischemic stroke progression, and mortality at 90 days. Intracranial hemorrhage was considered symptomatic if the patient had died or showed neurologic deterioration (NIHSS score decrease of ≥ 4 points) and the hemorrhage was related to the clinical deterioration (according to Heidelberg criteria) (6). sICH was assessed by the adverse events committee after evaluation of medical reports and imaging assessment. Ischemic stroke progression was defined as neurologic deterioration of at least 4 points on the NIHSS in cases in which an intracranial hemorrhage was excluded as the cause of the deterioration on CT. The adverse events committee made the final decision to report a progression of ischemic stroke on the basis of medical reports.

Missing Data

Missing NIHSS scores were retrospectively scored with a standardized score chart based on information from the reported neurologic examination. Any mRS score of 0–5 assessed within 30 days was considered not valid and treated as missing. These values were therefore replaced by mRS scores derived from multiple imputation (7). Multiple imputation was performed with Stata/SE 14.1 (StataCorp, College Station, Texas) with the following variables: age, sex, baseline NIHSS score, diabetes mellitus, previous

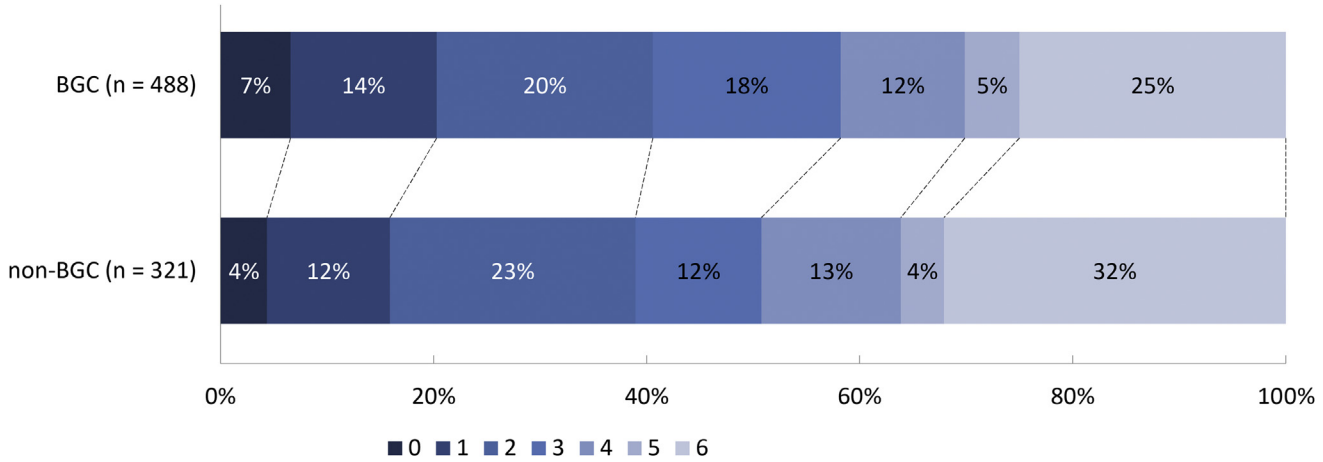

Figure. Functional outcome on the mRS for patients treated with a BGC versus a non-BGC (n = 809; mRS score was missing for 78 patients).

myocardial infarction, previous stroke, prestroke mRS score, atrial fibrillation, intravenous thrombolysis before EVT, systolic blood pressure, baseline Alberta Stroke Program Early CT Score, occlusion segment, CT angiographic collateral vessel status, time from symptom onset to start of EVT, time from symptom onset to successful reperfusion, eTICI score at the end of the intervention, and NIHSS score after 24–48 hours. All descriptive analyses include patients with original data as reported by the investigators, whereas all regression models include all patients, including those with imputed data.

Statistical Analysis

Baseline characteristics were analyzed by using standard statistics. Unadjusted and adjusted (for age, sex, prestroke mRS score, baseline NIHSS score, collateral vessels, and time from onset to EVT) logistic regression analyses were used to determine the association between use of a BGC and outcomes. To compare functional outcome between use of a BGC versus use of a non-BGC, we analyzed the shift on the mRS with ordinal logistic regression. We performed subgroup analyses for BGC use in patients treated with a stent retriever first and with direct aspiration first.

RESULTS

Use of a BGC was not significantly associated with improved functional outcome, measured as a shift on the mRS toward a better outcome (adjusted common odds ratio [acOR], 1.17; 95% confidence interval [CI], 0.91–1.52; **Fig**, **Table 2**). Results were essentially unchanged after exclusion of patients with proximal ICA steno-occlusive pathologic conditions (**Tables E1**, **E2** [available online on the article's Supplemental Material page at *www.jvir.org*]). After correction for anesthetic management and intervention center in a multilevel analysis, regression analysis showed a nonsignificant trend in the same direction (acOR, 1.36; 95% CI, 0.91–2.02). The percentage of patients who were functionally independent (ie, mRS score 0–2) at 90 days was similar between groups (41% vs 39%; $P = .64$; **Table 3**). Use of a BGC was associated with significantly improved

Table 2. Associations between Treatment Outcomes and Use of Balloon Guide Catheter

Outcome	OR (95% CI)	
	Unadjusted	Adjusted
mRS score*		
At 90 d†	1.25 (0.98–1.59)	1.17 (0.91–1.52)
0–1 at 90 d	1.27 (0.88–1.82)	1.10 (0.74–1.64)
0–2 at 90 d	1.05 (0.79–1.40)	0.87 (0.63–1.21)
0–3 at 90 d	1.32 (1.01–1.74)	1.18 (0.86–1.63)
Reperfusion		
Successful (eTICI score ≥ 2B)	1.42 (1.06–1.90)	1.41 (1.04–1.90)
Excellent (eTICI score ≥ 2C)	1.17 (0.89–1.53)	1.14 (0.87–1.50)
Complete (eTICI score 3)	1.31 (0.99–1.73)	1.30 (0.97–1.72)
Symptomatic ICH	0.53 (0.30–0.95)	0.55 (0.31–1.00)
Ischemic stroke progression	1.22 (0.76–1.96)	1.29 (0.79–2.11)
Pneumonia	1.59 (1.01–2.51)	1.74 (1.09–2.77)
Mortality at 90 d	0.71 (0.52–0.96)	0.72 (0.51–1.03)
NIHSS score after intervention (24 h)	−0.98 (−2.25 to 0.29)	−0.70 (−1.81 to 0.41)
NIHSS improvement ≥ 4 points	1.49 (1.13–1.96)	1.40 (1.04–1.88)

Note–Adjustments were made for age, sex, baseline NIHSS score, collateral vessels, prestroke mRS score, and time from onset to EVT (arterial puncture).
CI = confidence interval; EVT = endovascular treatment; eTICI = extended Thrombolysis in Cerebral Infarction score; ICH = intracranial hemorrhage; mRS = modified Rankin Scale; NIHSS = National Institutes of Health Stroke Scale; OR = odds ratio.
*mRS score was available for 809 patients.
†Common OR for improved outcome.

Table 3. Primary and Secondary Outcomes for Patients Who Underwent Endovascular Treatment for Ischemic Stroke with a BGC versus without

Outcome	BGC (n = 528)	Non-BGC (n = 359)	*P* Value
mRS score at 90 d*			.07
Median	3	3	
IQR	2–6	2–6	
0–1	99 (20)	51 (16)	.12
0–2	198 (41)	125 (39)	.64
0–3	284 (58)	163 (51)	.04
Reperfusion			
Successful (eTICI score ≥ 2B)	394 (75)	243 (68)	.02
Excellent (eTICI score ≥ 2C)	272 (52)	172 (48)	.29
Complete (eTICI score 3)	217 (41)	126 (35)	.07
Symptomatic ICH	22 (4)	27 (8)	.03
Ischemic stroke progression	51 (10)	29 (8)	.42
Pneumonia	67 (13)	30 (8)	.04
Mortality at 90 d	122 (23)	103 (29)	.03
NIHSS score after intervention (24 h)†			.06
Median	9	11	
IQR	3–17	4–19	
NIHSS improvement ≥ 4 points†	306 (62)	159 (52)	< .01

Note–Values in parentheses are percentages.
eTICI = extended Thrombolysis In Cerebral Infarction; ICH = intracranial hemorrhage; IQR = interquartile range; mRS = modified Rankin Scale; NIHSS = National Institutes of Health Stroke Scale.
*n = 809; mRS score at 90 d was missing for 78 patients.
†n = 800; baseline NIHSS score, postintervention NIHSS score, or both were missing for 87 patients.

outcome in terms of eTICI score (acOR, 1.33; 95% CI, 1.04-1.70; **Table 2**). Successful reperfusion (ie, eTICI grade ≥ 2B) was achieved more frequently in the BGC group (75% vs 68%; $P = .02$; **Table 3**).

In patients treated with the use of a BGC, NIHSS score 24–48 hours after intervention was lower (median, 9 vs 11; $P = .06$), and improvement of 4 points or more on the NIHSS occurred more frequently (62% vs 52%; $P < .01$; **Table 3**). After adjustment for potential confounders, use of a BGC was associated with a significant improvement of 4 points or more on the NIHSS (adjusted odds ratio [aOR], 1.40; 95% CI, 1.04–1.88; **Table 2**). sICH (4% vs 8%; $P = .03$) and death (23% vs 29%; $P = .03$) occurred less often in the BGC group than in the non-BGC group. Pneumonia occurred more frequently in the BGC group (13% vs 8%; $P = .04$; **Table 3**).

Anesthetic management was significantly different between groups ($P < .01$; **Table E3** [available online on the article's Supplemental Material page at *www.jvir.org*]). In the BGC group, local anesthesia only was used more frequently (69% vs 32%), and, in the non-BGC group, general anesthesia was used more often (15% vs 59%). Procedure duration and number of attempts were not significantly different (**Table E3** [available online on the article's Supplemental Material page at *www.jvir.org*]).

Stent retriever thrombectomy. Of 887 patients included in the present study, 724 underwent the first attempt with a stent retriever (82%). A BGC was used in 505 of these 724 patients (70%). Functional outcome on the mRS at 90 days was not significantly different with the use of a BGC versus a non-BGC (acOR, 1.12; 95% CI, 0.81–1.55; **Fig E2**, **Table E4** [available online on the article's Supplemental Material page at *www.jvir.org*]). However, reperfusion per eTICI (acOR, 1.70; 95% CI, 1.26–2.27) and early clinical outcome on the NIHSS (improvement of ≥ 4 points, aOR, 1.45; 95% CI, 1.01–2.10) were better with the use of a BGC (**Table E4** [available online on the article's Supplemental Material page at *www.jvir.org*]). Death occurred less frequently with the use of a BGC (23% vs 30%; $P = .03$; adjusted OR, 0.65; 95% CI, 0.43–1.00; **Tables E4**, **E5** [available online on the article's Supplemental Material page at *www.jvir.org*]).

Direct aspiration. Of 887 patients included in the present study, 163 underwent the first attempt with direct aspiration (18%), among whom a BGC was used in 23 (14%). Functional outcome on the mRS at 90 days was not significantly different with the use of a BGC versus a non-BGC (adjusted cOR, 1.49; 95% CI, 0.60–3.71; **Fig E3** and **Table E6** [available online on the article's Supplemental Material page at *www.jvir.org*]). The results were also neutral concerning reperfusion grade (acOR, 1.00; 95% CI, 0.44–2.26), early clinical outcome (improvement of ≥ 4 points on NIHSS, aOR, 0.92; 95% CI, 0.35–2.40), and occurrence of death (aOR, 0.98; 95% CI, 0.30–3.26; **Tables E6**, **E7** [available online on the article's Supplemental Material page at *www.jvir.org*]).

DISCUSSION

In this nationwide registry in The Netherlands, a BGC was used in more than half of patients undergoing EVT for acute ischemic stroke. Even though the use of a BGC improved reperfusion grade and neurologic deficits and lowered mortality and sICH rates, this was not reflected in better functional outcome at 90 days in clinical practice. The positive association with reperfusion grade and early improvement of neurologic deficits was predominantly present in the stent retriever thrombectomy subgroup.

Several previous studies (8–13) have shown significant improvement of the rate of functional independence at

follow-up with the use of a BGC versus a non-BGC during stent retriever thrombectomy. In the present study, there was no significant difference in reaching independence at 90 days, even though a positive nonsignificant trend was shown toward better functional outcome as a shift on the whole mRS (**Fig**).

In concordance with the present study, in past studies (8,10–15), successful reperfusion (ie, TICI grade 2B-3) was more frequently achieved with the use of a BGC compared with a non-BGC technique. Successful reperfusion rates with the use of a BGC ranged from 76% to 100% on postintervention angiography. The rate in the present study was at the lower limit (75%), which could partially be explained by the blinded core laboratory imaging evaluation. Core laboratory evaluation is thought to be more restrictive than evaluation by the interventionist who performed the procedure.

In studies in which the choice whether to use a BGC with stent retriever thrombectomy was left to the treating interventionist (8–12), the frequency of BGC use was generally lower than in the present study (39%–56% vs 70% in the present stent retriever subgroup). Even though local preferences could have caused this difference, previous studies also included patients treated between 2011 and 2014, the time during which EVT was still an experimental treatment, and BGC use could have been early in the process of implementation.

Evidence of the effect of BGC use during direct aspiration thrombectomy is limited. One recent, large observational study in Korea (14) that included 429 patients who underwent direct aspiration thrombectomy showed positive effects for successful reperfusion and functional outcome, whereas we found neutral results in the direct aspiration subgroup analysis. The frequency of BGC use was 45% (14) as a result of local protocol instead of the treating physician's preference as in the present study (14%). One retrospective study (15) reported on patients who received simultaneous distal aspiration and stent retriever thrombectomy combined with the use of a BGC, which showed positive effects on reperfusion and early clinical outcome (ie, NIHSS score) (15). Unfortunately, long-term functional outcome was not reported.

The present study has several limitations. First, we report observational, nonrandomized data. Use of a BGC was left to the preference of the treating physician, which introduced possible selection bias. Pathologic conditions of the common carotid artery or ICA could also have influenced the choice whether to use a BGC. However, we found no significant differences between groups concerning steno-occlusive pathologic conditions at baseline. Second, whether the balloon was actually inflated during the procedure to achieve flow arrest was not prospectively registered. Nevertheless, the procedures were performed by trained interventionists who reported that the balloon was inflated during the procedure whenever possible. The balloon was not inflated in cases in which flow arrest was already achieved as a result of preexisting significant proximal stenosis or occlusion of the ICA. Outcomes were similar when patients with stenosis of the extracranial carotid artery were excluded (**Tables E2, E3** [available online on the article's Supplemental Material page at *www.jvir.org*]). Third, only a small number of patients underwent thrombectomy with the combination of a BGC and direct aspiration, and we were unable to identify patients who underwent simultaneous direct aspiration and stent retriever thrombectomy combined with the use of a BGC. Nevertheless, our results add to the limited evidence that exists for this subgroup.

In clinical practice, use of a BGC was associated with higher reperfusion grade and early improvement of neurologic deficits, but had no positive effect on long-term functional outcome. In all patients in whom a BGC was used, the positive effect of a BGC was prominently present in the stent retriever group, whereas the effect in the aspiration group was neutral.

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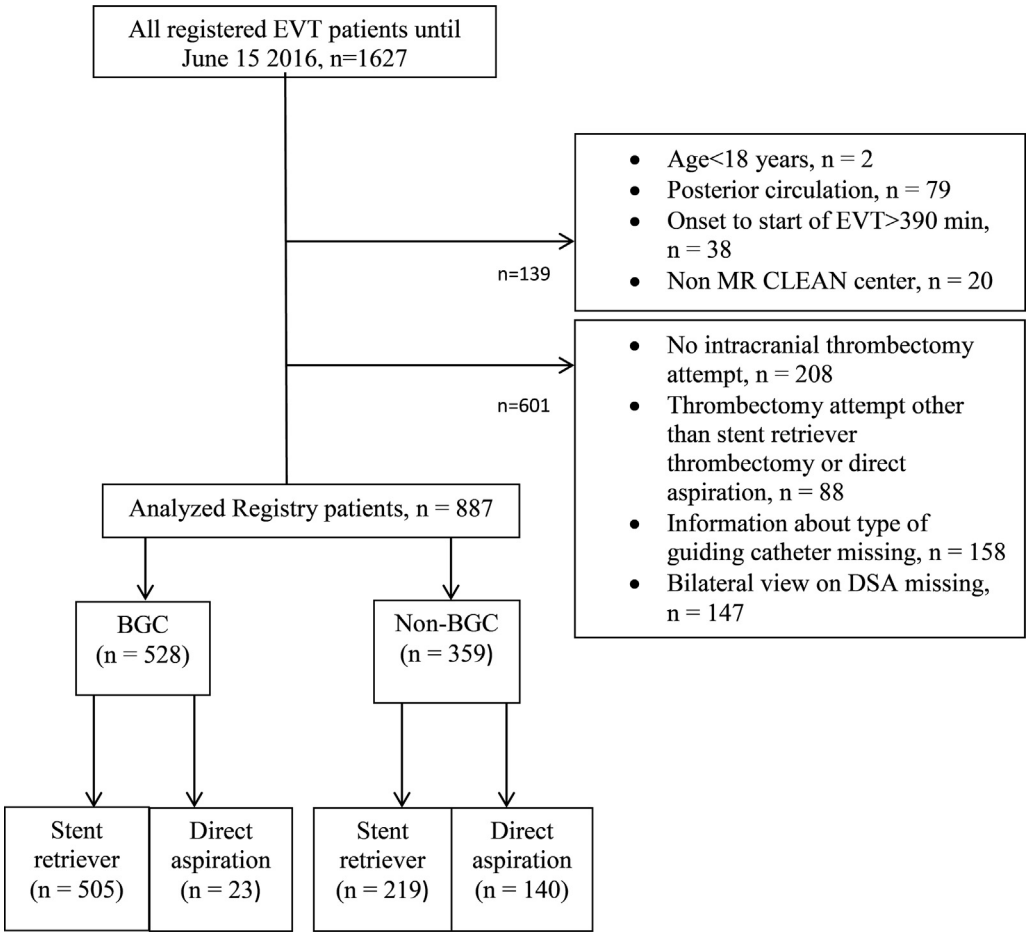

Figure E1. Flowchart of Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in The Netherlands Registry patients included in the present study.

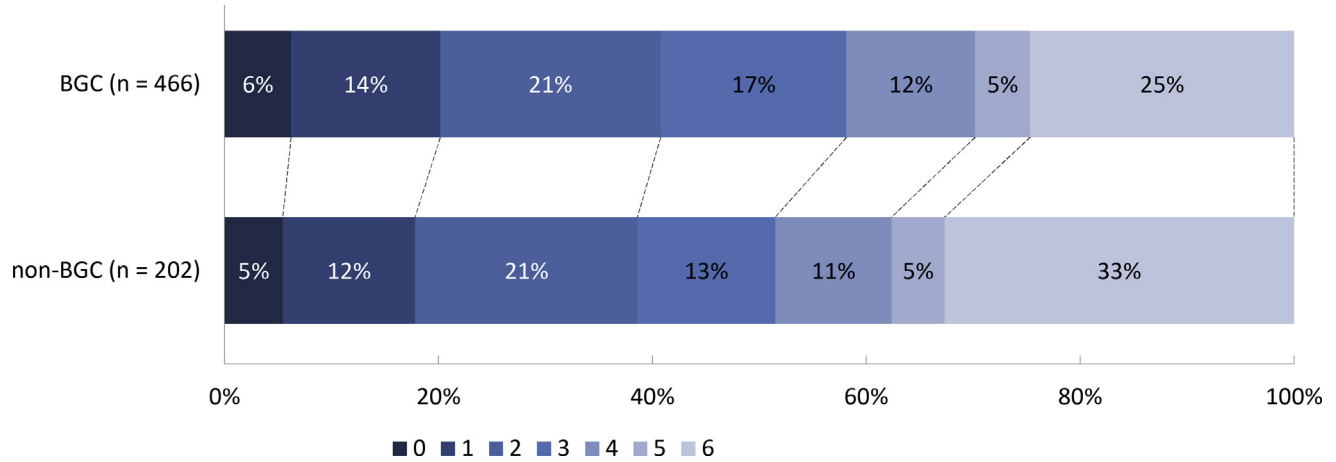

Figure E2. Functional outcome on the modified Rankin scale (mRS) for patients treated with a stent retriever as first-line modality: balloon guide catheter (BGC) versus non-BGC (n = 668; mRS score at 90 d was missing for 56 patients).

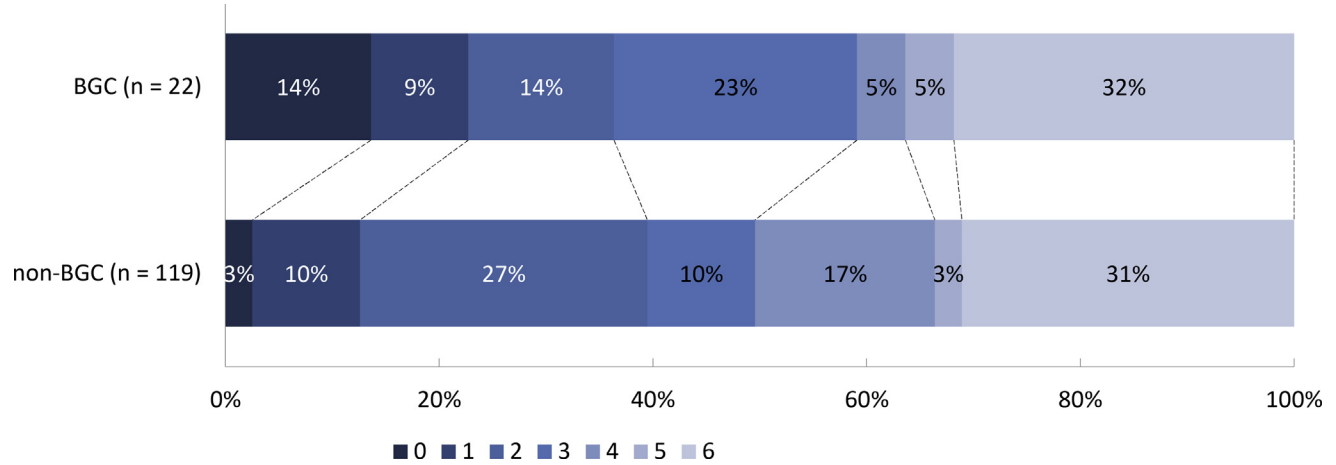

Figure E3. Functional outcome on the mRS for patients treated with direct aspiration as first-line modality: BGC versus non-BGC (n = 141; mRS score at 90 d was missing for 22 patients).

Table E1. Associations between Use of Balloon Guide Catheter and Outcomes

Outcome	OR (95% CI)	
	Unadjusted	Adjusted
mRS score*		
At 90 d†	1.22 (0.93–1.59)	1.12 (0.84–1.50)
0–1 at 90 d	1.20 (0.79–1.81)	1.04 (0.65–1.67)
0–2 at 90 d	0.99 (0.72–1.37)	0.80 (0.55–1.18)
0–3 at 90 d	1.34 (0.99–1.81)	1.18 (0.83–1.68)
Reperfusion		
Successful (eTICI ≥ 2B)	1.50 (1.09–2.07)	1.47 (1.06–2.04)
Excellent (eTICI ≥ 2C)	1.21 (0.90–1.63)	1.17 (0.87–1.58)
Complete (eTICI 3)	1.35 (0.99–1.83)	1.33 (0.97–1.82)
sICH	0.59 (0.31–1.11)	0.59 (0.31–1.14)
Ischemic stroke progression	1.14 (0.69–1.90)	1.23 (0.72–2.08)
Pneumonia	1.66 (1.02–2.72)	1.83 (1.10–3.06)
Mortality at 90 d	0.73 (0.53–0.1.02)	0.76 (0.52–1.12)
Postinterventional NIHSS score (24 h)	−0.73 (−2.11 to 0.66)	−0.50 (−1.71 to 0.72)
NIHSS score improvement ≥ 4 points†	1.55 (1.15–2.09)	1.40 (1.02–1.94)

Note–After exclusion of patients with a cervical ICA stenosis of > 50% or proximal ICA occlusion in (n = 749; 138 patients excluded). Adjustments were made for age, sex, baseline NIHSS score, collateral vessels, prestroke mRS score, and time from onset to endovascular treatment (arterial puncture).
CI = confidence interval; eTICI = extended Thrombolysis In Cerebral Infarction; mRS = modified Rankin scale; NIHSS = National Institutes of Health Stroke Scale; OR = odds ratio; sICH = symptomatic intracranial hemorrhage.
*n = 680; mRS score at 90 d was missing for 69 patients.
†n = 672; baseline NIHSS score, postinterventional NIHSS score, or both were missing for 77 patients.

Table E2. Primary and Secondary Outcomes for Patients Who Underwent Endovascular Treatment for Ischemic Stroke with a BGC versus without

Outcome	BGC (n = 449)	Non-BGC (n = 300)	*P* Value
mRS score at 90 d*			.07
Median	3	4	
IQR	2–6	2–6	
mRS score 0–1 at 90 d*	77 (19)	41 (15)	.28
mRS score 0–2 at 90 d*	163 (39)	105 (39)	.98
mRS score 0–3 at 90 d*	237 (57)	132 (50)	.05
Reperfusion			
Successful (eTICI ≥ 2B)	336 (75)	200 (67)	.02
Excellent (eTICI ≥ 2C)	234 (52)	143 (48)	.23
Complete (eTICI 3)	190 (42)	106 (35)	.06
sICH	19 (4)	21 (7)	.10
Ischemic stroke progression	44 (10)	26 (9)	.60
Pneumonia	59 (13)	25 (8)	.04
Mortality at 90 d	106 (26)	85 (32)	.07
Postintervention (24 h) NIHSS score†			.12
Median	9	11	
IQR	4–17	4–19	
NIHSS score improvement ≥ 4 points†	291 (65)	177 (59)	.11

Note–A total of 749 patients are included in the table after exclusion of patients with a cervical ICA stenosis of > 50% or proximal ICA occlusion in (138 patients excluded). Values in parentheses are percentages.
BGC = balloon guide catheter; eTICI = extended Thrombolysis In Cerebral Infarction; mRS = modified Rankin scale; NIHSS = National Institutes of Health Stroke Scale; sICH = symptomatic intracranial hemorrhage.
*n = 680; mRS score at 90 d was missing for 69 patients.
†n = 672; baseline NIHSS score, postinterventional NIHSS score, or both were missing for 77 patients.

Table E3. Intervention Characteristics for Patients Who Underwent EVT for Ischemic Stroke with a BGC versus without

Characteristic	BGC (n = 528)	Non-BGC (n = 359)	*P* Value
Total thrombectomy attempts (all devices used)			.08
Median	2	2	
IQR	1–3	1–3	
EVT start (arterial puncture) to reperfusion/last contrast bolus (min)			.30
Median	56	55	
IQR	35–80	33–77	
Interventional procedure duration (min)			.53
Median	65	64	
IQR	41–87	43–85	
Anesthetic management			< .01
General anesthesia	77 (15)	210 (59)	
Conscious sedation	74 (14)	27 (8)	
Local anesthesia	366 (69)	114 (32)	
Unknown	11 (2)	8 (2)	

Note–Values in parentheses are percentages.
BGC = balloon guide catheter; EVT = endovascular treatment; IQR = interquartile range.

Table E4. Associations of BGC Use with Primary and Secondary Outcomes in Patients Treated with a Stent Retriever First

Outcome	OR (95% CI)	
	Unadjusted	Adjusted
mRS score*		
At 90 d†	1.22 (0.91–1.64)	1.12 (0.81–1.55)
0–1 at 90 d	1.19 (0.77–1.83)	1.00 (0.61–1.62)
0–2 at 90 d	1.12 (0.80–1.57)	0.92 (0.62–1.36)
0–3 at 90 d	1.35 (0.97–1.87)	1.20 (0.81–1.77)
Reperfusion		
Successful (eTICI ≥ 2B)	1.81 (1.29–2.53)	1.81 (1.28–2.55)
Excellent (eTICI ≥ 2C)	1.44 (1.04–1.99)	1.44 (1.03–2.00)
Complete (eTICI 3)	1.61 (1.14–2.27)	1.61 (1.13–2.28)
sICH	0.56 (0.28–1.12)	0.59 (0.29–1.19)
Ischemic stroke progression	1.09 (0.63–1.89)	1.15 (0.65–2.02)
Pneumonia	1.56 (0.90–2.71)	1.70 (0.96–2.98)
Mortality at 90 d	0.66 (0.46–0.94)	0.65 (0.43–1.00)
Postintervention (24 h) NIHSS score	−1.48 (−3.00 to 0.05)	−1.05 (−2.42 to 0.32)
NIHSS score improvement ≥ 4 points†	1.53 (1.08–2.16)	1.45 (1.01–2.10)

Note–Adjustments were made for age, sex, baseline NIHSS score, collateral vessel, prestroke mRS score, and time from onset to endovascular treatment (arterial puncture).
BGC = balloon guide catheter; eTICI = extended Thrombolysis In Cerebral Infarction score; mRS = modified Rankin scale; NIHSS = National Institutes of Health Stroke Scale; OR = odds ratio; sICH = symptomatic intracranial hemorrhage.
*mRS score was available for 668 patients.
†Common OR for improved outcome.

Table E5. Primary and Secondary Outcomes for Patients Who Underwent EVT with a Stent Retriever First for Ischemic Stroke with a BGC versus without

Outcome	BGC (n = 505)	Non-BGC (n = 219)	*P* Value
mRS score at 90 d*			.46
Median	3	3	
IQR	2–5	2–6	
mRS score 0–1 at 90 d*	94 (20)	36 (18)	.48
mRS score 0–2 at 90 d*	190 (41)	78 (39)	.60
mRS score 0–3 at 90 d*	271 (58)	104 (51)	.11
Reperfusion			
Successful (eTICI ≥ 2B)	376 (74)	135 (62)	< .01
Excellent (eTICI ≥ 2C)	259 (51)	92 (42)	.02
Complete (eTICI 3)	208 (41)	66 (30)	< .01
sICH	20 (4)	15 (7)	.10
Ischemic stroke progression	50 (10)	20 9)	.75
Pneumonia	62 (12)	18 (8)	.11
Mortality at 90 d	115 (23)	66 (30)	.03
Postintervention (24 h) NIHSS score†			.01
Median	9	12	
IQR	3–17	5–19	
NIHSS score improvement ≥ 4 points†	295 (62)	100 (51)	.01

Note–Values in parentheses are percentages.
BGC = balloon guide catheter; eTICI = extended Thrombolysis In Cerebral Infarction; EVT = endovascular treatment; mRS = modified Rankin Scale; NIHSS = National Institutes of Health Stroke Scale; sICH = symptomatic intracranial hemorrhage.
*n = 668; mRS score at 90 d was missing for 56 patients.
†n = 670; baseline NIHSS score, postintervention NIHSS score, or both were missing for 54 patients.

Table E6. Associations of BGC Use with Primary and Secondary Outcomes in Patients Treated with Direct Aspiration First

Outcome	OR (95% CI)	
	Unadjusted	Adjusted
mRS score*		
At 90 d†	1.03 (0.45–2.37)	1.49 (0.60–3.71)
0–1 at 90 d	1.51 (0.50–4.51)	1.49 (0.44–5.05)
0–2 at 90 d	0.79 (0.31–2.01)	0.88 (0.29–2.64)
0–3 at 90 d	1.25 (0.50–3.13)	1.62 (0.50–5.19)
Reperfusion		
Successful (eTICI ≥ 2B)	1.13 (0.39–3.27)	1.25 (0.42–3.73)
Excellent (eTICI ≥ 2C)	1.03 (0.42–2.50)	1.02 (0.41–2.55)
Complete (eTICI 3)	0.91 (0.37–2.26)	0.94 (0.37–2.37)
sICH	1.02 (0.21–4.87)	0.83 (0.16–4.45)
Ischemic stroke progression	0.66 (0.08–5.48)	0.62 (0.07–5.46)
Pneumonia	2.96 (0.93–9.40)	2.92 (0.83–10.31)
Mortality at 90 d	1.19 (0.45–3.16)	0.98 (0.30–3.26)
Postintervention (24 h) NIHSS score	2.39 (−1.79 to 6.58)	0.61 (−3.08 to 4.29)
NIHSS score improvement ≥ 4 points	0.92 (0.37–2.31)	0.92 (0.35–2.40)

Note–Adjustments were made for age, sex, baseline NIHSS score, collateral vessels, prestroke mRS score, and time from onset to endovascular treatment (arterial puncture).
BGC = balloon guide catheter; CI = confidence interval; eTICI = extended Thrombolysis In Cerebral Infarction; mRS = modified Rankin scale; NIHSS = National Institutes of Health Stroke Scale; OR = odds ratio; sICH = symptomatic intracranial hemorrhage.
*mRS score was available for 141 patients.
†Common OR for improved outcome.

Table E7. Primary and Secondary Outcomes for Patients Who Underwent Endovascular Treatment with Direct Aspiration First for Ischemic Stroke with a BGC versus a non-BGC

	BGC n = 23	Non-BGC n = 140	*p*
mRS at 90 days - median (IQR)*	3 (2-6)	4 (2-6)	.08
mRS 0-1 at 90 days – n. (%)*	5 (23)	15 (13)	.21
mRS 0-2 at 90 days – n. (%)*	8 (36)	47 (40)	.78
mRS 0-3 at 90 days – n. (%)*	13 (59)	104 (50)	.41
Successful reperfusion (eTICI 2B or higher) – n. (%)	18 (78)	108 (77)	.91
Excellent reperfusion (eTICI 2C or higher) – n. (%)	13 (57)	80 (57)	.96
Complete reperfusion (eTICI 3) – n. (%)	9 (39)	60 (43)	.74
sICH – n. (%)	2 (9)	12 (9)	.98
Ischemic stroke progression – n. (%)	1 (4)	9 (6)	.70
Pneumonia – n. (%)	5 (22)	12 (9)	.06
Mortality at 90 days – n. (%)	7 (30)	37 (26)	.95
NIHSS post intervention (24h) – median (IQR)†	14 (7-21)	10 (3-17)	.13
Improvement on the NIHSS of $\geq$ 4 points – n. (%)†	11 (50)	59 (55)	.69

BGC = balloon guide catheter; NIHSS = National Institutes of Health Stroke Scale; mRS = modified Rankin Scale; EVT = endovascular treatment; eTICI = extended Thrombolysis in Cerebral Infarction score; sICH = symptomatic intracranial hemorrhage.

*n = 141; mRS score at 90 days was missing for 22 patients.

†n = 130; baseline NIHSS score, post intervention NIHSS score, or both were missing for 33 patients.