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ABSTRACT

BACKGROUND: Balloon guide catheters are increasingly used to improve clot retrieval by temporarily stopping proximal blood flow during endovascular thrombectomy.

PURPOSE: Our aim was to provide a summary of the literature comparing the procedural and clinical outcomes of endovascular thrombectomy with or without balloon guide catheters, depending on the first-line technique used.

DATA SOURCES: We used PubMed/MEDLINE, EMBASE, and the Cochrane Database of Systematic Reviews.

STUDY SELECTION: We chose studies that compared using balloon guide catheters with not using them.

DATA ANALYSIS: Random effects meta-analysis was performed to compare the procedural outcomes measured as the first-pass effect, successful reperfusion, number of passes, procedural duration, arterial puncture to reperfusion time, distal emboli, and clinical outcomes.

DATA SYNTHESIS: Overall, a meta-analysis of 16 studies (5507 patients, 50.8% treated with balloon guide catheters and 49.2% without them) shows that the use of balloon guide catheters increases the odds of achieving a first-pass effect (OR = 1.92; 95% CI, 1.34–2.76; $P < .001$), successful reperfusion (OR = 1.85; 95% CI, 1.42–2.40; $P < .001$), and good functional outcome (OR = 1.48; 95% CI, 1.27–1.73; $P < .001$). Balloon guide catheters reduce the number of passes (mean difference = −0.35; 95% CI, −0.65 to −0.04; $P = .02$), procedural time (mean difference = −19.73; 95% CI, −34.63 to −4.83; $P = .009$), incidence of distal or new territory emboli (OR = 0.5; 95% CI, 0.26–0.98; $P = .04$), and mortality (OR = 0.72; 95% CI, 0.62–0.85; $P < .001$). Similar benefits of balloon guide catheters are observed when the first-line technique was a stent retriever or contact aspiration, but not for a combined approach.

LIMITATIONS: The analysis was based on nonrandomized trials with a moderate risk of bias.

CONCLUSIONS: Current literature suggests improved clinical and procedural outcomes associated with the use of balloon guide catheters during endovascular thrombectomy, especially when using the first-line stent retriever.

ABBREVIATIONS: eTICI = extended TICI score; sICH = symptomatic intracranial hemorrhage

Acute stroke management changed drastically after 2015, when endovascular thrombectomy became the standard-of-care treatment for large-vessel occlusion.[1-3] Shorter procedural time and successful recanalization were the independent procedural predictors of favorable clinical outcome after endovascular thrombectomy.[4-6] Currently, there is no consensus on the optimal procedural techniques or devices to achieve fast and complete endovascular reperfusion. Stand-alone strategies of stent retriever and contact aspiration have emerged as the most popular approaches for endovascular thrombectomy[7] without definite differences in clinical and procedural outcomes.[8-12]

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Combined techniques of stent retriever and contact aspiration have also been shown to result in high rates of successful reperfusion and good functional outcomes and are now increasingly used.[13,14]

During endovascular thrombectomy, using a balloon guide catheter has been associated with higher recanalization rates and better functional outcomes in early clinical studies.[15,16] Balloon guide catheters offer transient proximal flow arrest and decrease the forward pressure impacting the clot, which has been shown to prevent distal thrombus migration or embolization to new vascular territories during retrieval.[17,18] Despite level 2A evidence suggesting benefits of stent retrievers in conjunction with proximal balloon guide catheters,[2] there is continued debate over their use in everyday clinical practice, especially when used in conjunction with contact aspiration.

Two previous meta-analyses suggested that the use of balloon guide catheters during endovascular thrombectomy is associated with improved clinical and angiographic outcomes.[19,20] However, a few larger registries have since been published in addition to many endovascular thrombectomy procedural modifications. Thus, we conducted this updated systematic review to investigate the effects of balloon guide catheters on the clinical and procedural outcomes following endovascular thrombectomy and considering the first-line endovascular thrombectomy technique: stent retriever, contact aspiration, or a combination (stent retriever + contact aspiration).

MATERIALS AND METHODS

Search Strategy, Study Selection, and Eligibility Criteria

The study was performed per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[21] We systematically searched electronic data bases up to December 2020, including PubMed/MEDLINE, EMBASE, and the Cochrane Database of Systematic Reviews. The following keywords were used in combination or individually using the Boolean operators "OR" and "AND": "thrombectomy," "endovascular procedures," "stroke," "retrievable stent," "stent retriever," "stentriever," "aspiration," "suction," and "balloon guided catheter." The articles were selected in 2 stages. First, the titles and abstracts were screened for relevant studies. Second, the full texts were downloaded and assessed for eligibility. The reference lists of included publications were then hand-searched for additional relevant studies. This process was performed by 4 assessors independently (A.P., G.J., A.S., P.S.D.). Any differences were resolved by consensus.

Studies evaluating ≥1 procedural and clinical outcome of endovascular thrombectomy were included. Randomized and nonrandomized controlled (retrospective and prospective) trials, observational studies, or post hoc analyses of observational data in trials were included when a control group was reported. Exclusion criteria included studies published before 2009, review articles and meta-analyses, guidelines, technical notes, studies on animals, and studies in languages other than English.

In the case of an overlapping patient population, only the series with the largest number of patients or the most detailed data were included.

Data Extraction

The variables were, if available, the following: use of balloon guide catheters, the first-line endovascular thrombectomy technique used, study type (retrospective, prospective), study period, anatomic region (anterior/posterior circulation), sample size, mean age, number of women, presence of comorbidities (atrial fibrillation, hypertension, diabetes, coronary artery disease, dyslipidemia, smoking), tandem occlusion, clot location, baseline NIHSS score, IV-tPA, use of general anesthesia, use of a distal-access catheter, use of intra-arterial thrombolysis, onset to arterial puncture time, arterial puncture to reperfusion time, total procedural time (the time from the sheath insertion until the sheath is out), number of passes, successful reperfusion rate (defined as extended TICI [eTICI] 2b[22] or higher), first-pass effect defined as eTICI 2b or higher[16,18,23-25] or eTICI 2c or higher[25-27] or eTICI 3[28-30] or complete reperfusion[18,28] after the first pass, good functional outcome defined as functional independence described as mRS ≤2 at 90 days, symptomatic intracranial hemorrhage (sICH) defined as any ICH with an increase of the NIHSS score of ≥4 within 24 hours or death, and mortality at 90 days.

Outcome Measures

Study characteristics and extracted variables were summarized using standard descriptive statistics. Continuous variables were expressed as means (SD), and categoric variables were expressed as frequencies or percentages. The primary outcomes were procedural (the first-pass effect, successful recanalization, procedural time, arterial puncture to reperfusion time, number of passes, distal embolization, or embolization in the new territory) and clinical (good functional outcome [mRS ≤2] at 90 days, sICH, mortality at 90 days).

Statistical Analysis

Binary outcomes are reported as ORs with 95% confidence intervals. Continuous outcomes are analyzed as mean difference with a 95% CI. Tests of heterogeneity were conducted with the Q-statistic distributed as a χ^2 variate (assumption of homogeneity of effect sizes). The extent of between-study heterogeneity was assessed with the I^2 statistic.[31,32] A random effects model was used. The ROBINS-I[33,34] tool was used to evaluate and visualize the individual risk of bias of each study. *P* values were 2-tailed with values < .05 considered statistically significant. All analyses were conducted in Statistica 13.1 (StatSoft Poland), online calculators, and Review Manager 5.4.1 software (https://www.advanceduninstaller.com/Review-Manager-5_4_1-509a434684edfe58c850c849ab795eca-application.htm).[35]

Ethics

This study is a systematic review and meta-analysis, and no human-participant procedure was involved. Informed consent and ethics approval were not essential for this study.

RESULTS

Literature Search Results

We screened 8930 titles and abstracts and 877 full-text articles (Online Supplemental Data). Of those, data were extracted from

Table 1: Baseline characteristics of the included studies

Feature	BGC (No.) (%)	Non-BGC (No.) (%)	*P*
Baseline characteristics			
Mean age (yr)	68.2 (SD, 14.2)/2796	69.7 (SD, 14.0)/2711	<.001
Sex (female)	1318/2748 (48.0)	1314/2672 (49.2)	.37
IV t-PA	1598/2748 (58.2)	1487/2672 (55.7)	.06
Baseline NIHSS (mean)	16.3 (SD, 8.1)/2646	16.2 (SD, 8.8)/2591	.67
Comorbidities			
Atrial fibrillation	1064/2369 (44.9)	755/1972 (38.3)	<.001
Hypertension	1600/2516 (63.6)	1533/2346 (65.3)	.20
Diabetes	561/2516 (22.3)	544/2346 (23.2)	.46
Coronary artery disease	407/1891 (21.5)	388/1883 (20.6)	.49
Dyslipidemia	909/2516 (36.1)	798/2346 (34.0)	.12
Smoking	770/2492 (30.9)	673/2308 (29.2)	.19
Localization			
Tandem occlusions	136/1305 (10.4)	136/1423 (9.6)	.45
Distal ICA	716/2621 (27.3)	581/2604 (22.3)	<.001
M1 segment	1169/1976 (59.1)	1026/1776 (57.7)	.39
M2 segment	255/1918 (13.3)	256/1703 (15.0)	.13
Unspecified MCA segment	492/740 (66.5)	384/884 (43.4)	<.001
Periprocedural			
Onset to arterial puncture (min)	278.1 (SD, 171.7)/2563	280.3 (SD, 162.4)/2279	.65
General anesthesia	432/1705 (25.3)	391/1677 (23.3)	.17
Distal access catheter use	35/827 (4.2)	124/763 (16.3)	<.001
Intra-arterial thrombolysis	149/1389 (10.7)	191/1185 (16.1)	<.001

Note:—BGC indicates balloon guide catheter.

Table 2: Summary of balloon guide catheter effects on procedural and clinical outcomes of endovascular thrombectomy

Impact of BGC on/during	Overall	SR	Combined (SR + CA)	CA
Procedural outcomes				
First-pass effect	↑	↑	–	NA
Successful reperfusion	↑	↑	–	↑
Procedural time	↓	↓	NA	NA
Arterial puncture to reperfusion	–	–	–	–
No. of passes	↓	–	–	NA
Distal or new territory emboli	↓	–	–	–
Clinical outcomes				
Good functional outcome	↑	↑	–	↑
sICH	–	–	–	–
Mortality	↓	↓	NA	–

Note:—NA indicates not available; SR, stent retriever; CA, contact aspiration; ↑, increase; ↓, decrease; –, no difference.

16 studies that met inclusion criteria.[15,16,18,23-28,30,36-41] Eight hundred sixty-one studies were excluded due to not reporting balloon guide catheter versus non-balloon guide catheter, not reporting the desired variables, or lack of full text.

Characteristics of Included Studies

The 16 studies published between 2010 and 2020 described 5507 patients (2796 with balloon guide catheters and 2711 patients without balloon guide catheters) undergoing endovascular thrombectomy due to occlusion in the anterior circulation (5472 patients)[16,18,23-30,36-38,40,41] or posterior circulation (35 patients).[1] Nine studies of 3213 patients (1875 balloon guide catheters versus 1338 non-balloon guide catheters) reported on outcomes with a stent retriever–first approach,[15,16,18,25,30,37-40] four studies of 1107 patients (464 balloon guide catheters versus 643 non-balloon guide catheters) with a contact aspiration-first approach,[18,23,37,41] and 4 studies of 1023 patients (377 balloon guide cathethers versus 646 non-balloon guide catheters) with a combined first approach.[24,26,28,36] The studies are summarized in the Online Supplemental Data, and the baseline characteristics are presented in Table 1.

Procedural Outcomes

Eleven studies of 4000 patients reported the first-pass effect (Table 2).[16,18,23-28,30,39,40] It was achieved among 829/1962 (42.3%) patients undergoing endovascular thrombectomy using balloon guide catheters and 572/2038 (28.1%) patients undergoing endovascular thrombectomy without balloon guide catheters (OR = 1.92; 95% CI, 1.34–2.76; $P < .001$) (Online Supplemental Data). Final successful reperfusion (eTICI 2b or more) was reported in 15 studies (5207 patients).[15,16,18,23-28,36-41] This was higher in patients undergoing endovascular thrombectomy using balloon guide catheters (2258/2676, 84.8%) versus without balloon guide catheters (2007/2617, 76.7%) (OR = 1.85; 95% CI, 1.42–2.40; $P < .001$) (Online Supplemental Data).

Total procedural time was reported in 6 studies (1345 patients).[15,16,30,38-40] Procedures using balloon guide catheters were shorter (mean, 73.7 [SD, 47.9] minutes) than those that did not use balloon guide catheters (98.7 [SD 61.9] minutes), corresponding to a mean difference of −19.73 minutes (95% CI, −34.63 to −4.83 minutes; $P = .009$) (Online Supplemental Data). In 7 studies (2602 patients) that reported arterial puncture–reperfusion time,[18,23-25,28,36,41] this was also shorter using balloon guide catheters with a mean of 51.2 (SD, 28.6) versus 57.8 (SD, 38.6) minutes without balloon guide catheters (mean difference = −7.57 minutes; 95% CI, −17.50 to 2.37 minutes; $P = .14$) (Online Supplemental Data). Similarly, the number of passes needed to achieve successful reperfusion was lower in procedures using balloon guide catheters by a mean difference of −0.35 (95% CI, −0.65 to −0.04; $P = .02$). This was reported in 13 studies (3927 patients) (Online Supplemental Data).

Distal embolization or emboli in a new territory were reported in 9 studies (2063 patients).[15,23-25,28,36,38,40,41] They complicated 77/1028 (7.5%) procedures using balloon guide catheters and 119/1035 (11.5%) without balloon guide catheters (OR = 0.5; 95% CI, 0.26−0.98; P = .04) (Online Supplemental Data). Symptomatic ICH was reported in 10 studies (4469 patients).[15,18,25,28,37-41,42] It occurred in 119/2345 (5.1%) patients undergoing endovascular thrombectomy using balloon guide catheters and 155/2124 without (7.3%) (OR = 0.76; 95% CI, 0.55–1.05; P = .09) (Online Supplemental Data).

Clinical Outcomes

Twelve studies of 4718 patients reported 90-day functional outcomes (Table 2).[15,18,23,25-27,30,36,37,39-41] Favorable outcome (mRS 0–2) was higher in patients undergoing endovascular thrombectomy using balloon guide catheters (1253/2426, 51.6%) versus those without balloon guide catheters (971/2292, 42.4%) (OR = 1.48; 95% CI, 1.27–1.73; P < .001) (Online Supplemental Data). On the other hand, mortality occurred in 364/2470 (14.7%) patients undergoing endovascular thrombectomy using balloon guide catheter versus 454/2335 (19.4%) patients undergoing endovascular thrombectomy without balloon guide catheters (OR = 0.72; 95% CI, 0.62–0.85; P < .001) (Online Supplemental Data). This was reported in 12 studies (4805 patients).[15,18,23,25-27,30,36-40]

Procedural Outcomes in Subgroup Analysis Based on the First-line Endovascular Thrombectomy Technique

A balloon guide catheter increases the odds of first-pass effect when the stent retriever is used as a first approach (OR = 2.18; 95% CI, 1.56–3.06; P < .001) (Table 2),[16,18,25,30,39,40] but not when a combined approach of stent retriever + contact aspiration was used (OR = 1.03; 95% CI, 0.72–1.46; P = .87).[24,26,28] The contact aspiration subgroup was not included because only 1 study population reported this subgroup outcome (Online Supplemental Data).[18,23]

The use of balloon guide catheters increased the odds of successful reperfusion when a stent retriever–first approach was used (OR = 1.7; 95% CI, 1.27–2.27; P < .001)[15,16,18,25,37-40] or when a contact aspiration–first approach was used (OR = 2.47; 95% CI, 1.35–4.52; P = .003).[18,23,41] It had no influence when the combined approach was used (OR = 1.69; 95% CI, 0.76–3.77; P = .2) (Online Supplemental Data).[24,26,28,36]

The use of balloon guide catheters was not associated with a change in arterial puncture to reperfusion time in any of the first-approach subgroups (OR for stent retriever = −9.63; 95% CI, −28.35–9.08; P = 0.31;[18,43] OR for combined = 2.82; 95% CI, −15.13–20.77; P = 0.76;[24,28,36] and OR for contact aspiration = −23; 95% CI, −52.69–6.69; P = .13) (Online Supplemental Data).[18,41]

While overall balloon guide catheter use reduced the number of passes required to achieve reperfusion, this effect did reached statistical significance, neither in the stent retriever–first approach (OR = −0.26; 95% CI, −0.59–0.06; P = .11)[15,16,18,25,30,38-40] nor in the combined approach (OR = −0.36; 95% CI, −0.99–0.27; P = .26).[28,36] The contact aspiration subgroup was not included because only 1 study reported these outcomes (Online Supplemental Data).[18,23] Similarly, while overall the balloon guide catheter reduced the incidence of distal embolization or new-territory emboli, this effect was not significant in the first-approach subgroups (OR for stent retriever = 0.51; 95% CI, 0.17–1.5; P = 0.22;[15,25,38,40] OR for combined = 0.59; 95% CI, 0.11–3.1; P = 0.53;[24,28,35] OR for contact aspiration = 0.4; 95% CI, 0.11–1.38; P = .15) (Online Supplemental Data).[23,41]

There was no difference in the incidence of sICH with regard to the use of balloon guide catheters in any of the subgroups (OR for stent retriever = 0.73; 95% CI, 0.4–1.33; P = 0.30;[15,37-40] OR for combined = 0.77; 95% CI, 0.42–1.42; P = 0.41;[26,28] OR for contact aspiration = 0.8; 95% CI, 0.25–2.54; P = .71) (Fig 1*B*).[37,41]

Clinical Outcomes in Subgroup Analysis Based on the First-line Endovascular Thrombectomy Technique

Use of a balloon guide catheter improves the odds of good functional outcome in the stent retriever–first approach (OR = 1.6; 95% CI, 1.23–2.09; P < .001) (Table 2)[15,25,30,37,39,40] and contact aspiration–first approach (OR = 1.75; 95% CI, 1.26–2.44; P < .001),[23,37,41] while there was no statistically significant difference in the combined approach (OR = 1.26; 95% CI, 0.91–1.75; P = .16) (Fig 1*A*).[26,36]

A balloon guide catheter is associated with decreased odds of death in the stent retriever–first approach (OR = 0.72; 95% CI, 0.59–0.89; P < .001)[15,25,30,37-40] but not in the contact aspiration–first approach (OR = 0.75; 95% CI, 0.41–1.38; P = .36).[23,37,41] The combined-approach subgroup was not included because only 1 study reported these outcomes (Fig 1*C*).[26]

Risk of Bias

The risk of bias was moderate in 13 studies and low in 3 studies (Online Supplemental Data).

DISCUSSION

Our systematic review and meta-analysis of 5507 patients suggests that the use of a balloon guide catheter increases the odds of achieving the first-pass effect and successful reperfusion and reduces the procedural time, the number of passes, and distal embolization or emboli in a new vascular territory. Furthermore, the use of a balloon guide catheter increases the odds of achieving good functional outcome and reduces the risk of death, without influencing the risk of sICH. This updated review, which includes recent large patient cohort registries, is among the largest meta-analysis on this topic to date.[18,25,26,37,39] Our findings validate the results of previous meta-analyses[20,44] and expand to report the procedural and clinical outcomes according to the first-line endovascular thrombectomy technique.

A longer procedural time is associated with a lower likelihood of a good functional outcome and a higher probability of sICH. Some observed a transition point at 30 minutes when the cumulative rate of good functional outcome drops by 40%.[45] Similar to the results of endovascular thrombectomy workflow analysis studies,[46] our findings show that the use of a balloon guide catheter is associated with a shorter total procedural time. This likely corresponds to fewer passes required and an increased first-pass effect. In accordance with the Trevo Acute Ischemic Stroke (TRACK) Multicenter Registry analysis, high-volume centers use balloon guide catheters most often.[47]

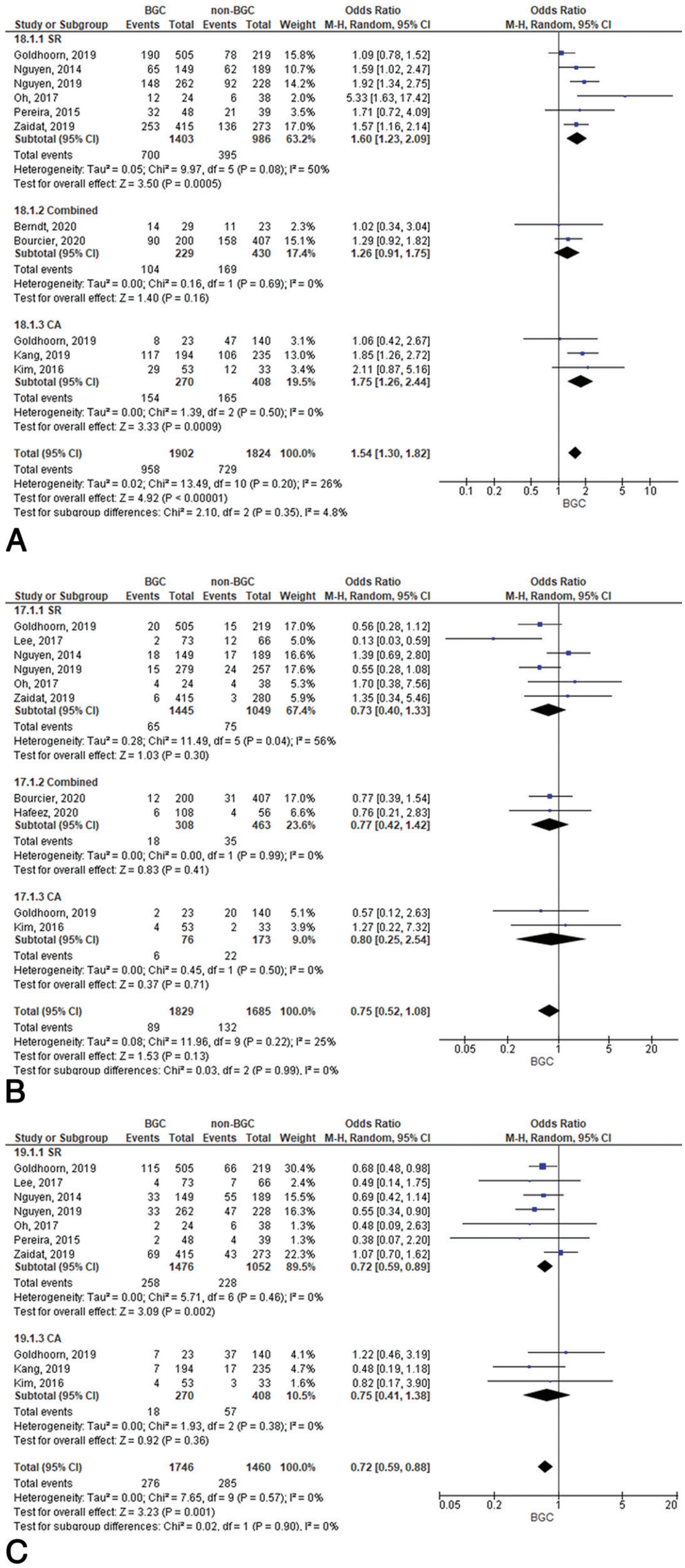

FIGURE. Clinical outcomes. This figure is a summary of random effects forest plots showing studies divided into the 3 groups depending on the first-line endovascular thrombectomy technique. *A*, Good functional outcome at 90 days. *B*, sICH. *C*, Mortality at 90 days. SR indicates stent retriever versus combined versus contact aspiration (CA).

Our findings confirmed a reduction in distal clot embolizations, including those to new vascular territories. Previous studies have also demonstrated that the balloon guide catheter reduces clot fragmentation and distal embolic shower and provides more effective revascularization,[48] but this was not reported in previous meta-analyses.[19,20] In vitro studies have also reported that the use of proximal flow control by a balloon guide catheter significantly reduced the formation of large distal emboli with a diameter of >1 mm.[49]

There remains ambiguity over the best first-line endovascular thrombectomy technique (stent retriever, contact aspiration, or combined) when used in conjunction with a balloon guide catheter. For instance, Baek et al[18] analyzed 955 participants and reported that the positive influence of a balloon guide catheter on procedural and clinical outcomes is independent of the first-line treatment technique, whereas Goldhoorn et al[37] reported no difference in the clinical outcome in each stent-retriever and contact-aspiration group, with or without a balloon guide catheter. Bourcier et al[26] also observed no difference between balloon guide catheters and conventional guide catheters when the stent-retriever technique was combined with contact aspiration. The recent Contact Aspiration vs Stent Retriever for Successful Revascularization (ASTER2) trial compared the use of the combined approach versus stent retriever only; both used balloon guide catheters. The authors demonstrated no significant differences in the procedural and functional outcomes, though there was a tendency toward the combined technique.[50,51] Our subgroup analysis suggests that the most significant benefit of a balloon guide catheter is in conjunction with the first-line stent-retriever approach. Balloon guide catheters also improve successful reperfusion rates and good clinical outcomes when used during contact aspiration. However, there is currently insufficient evidence regarding their use during a combined-approach technique.

Balloon guide catheters have limitations related to their construction: 1) a larger outer diameter requiring larger introductory sheaths, 2) larger aspiration catheters not compatible with most balloon guide catheters, and 3) a relatively more rigid construct rendering endovascular navigation with balloon guide catheter more challenging. However, new balloon guide catheters with larger internal diameters of up to 0.087 inches are able to accommodate large-bore aspiration catheters and can still be used through an 8F sheath.[52,53] Concerns have also been raised about potential groin complications, especially among patients on anticoagulants or IV-tPA.[17] However, a recent study of 472 patients reported only a 0.4%–0.8% risk of sheath-related groin complications for balloon guide catheters.[54]

Limitations and Further Directions

None of the included studies were randomized, and most of them were weighted with a moderate risk of bias. Furthermore, the included studies had a high heterogeneity level except for the overall clinical outcomes (I^2 was 30% for good clinical outcome, 28% for sICH, and 0% for mortality).

There were differences in the baseline characteristics of the population. Atrial fibrillation and ICA occlusions were more frequently identified in the balloon guide catheter group. Most interesting, data from the ASTER2 trial suggest better efficacy in a subset of patients with distal ICA occlusions when balloon guide catheters with the combined technique were used.[50,51] Periprocedurally, distal access catheter use and intra-arterial thrombolysis administration were less frequently observed in the balloon guide catheter group (Table 2.) While we extracted the baseline characteristics of the clot location, the studies did not report the outcome measures in these subgroups, precluding direct comparison.

A small number of posterior circulation strokes ($n = 35$) from a single study were included in our meta-analysis.[15] However, it was not possible to extract the outcome measures for this cohort of patients or exclude this cohort from the analysis because the relevant outcomes were not separately reported.

Additional factors that may influence the outcome of endovascular thrombectomy with balloon guide catheter use are its position and the adequacy of the balloon inflation. The latter could not be reliably assessed in the included studies. Jeong et al[55] compared proximal and distal positions of balloon guide catheters in the carotid artery among 102 patients. They reported that a shorter procedural time and higher recanalization rates were associated with a more distal balloon guide catheter position. Another factor is the size and positioning of the stent retriever. The Systematic Evaluation of Patients Treated with Neurothrombectomy Devices for Acute Ischemic Stroke (STRATIS) registry showed that the size of the stent retriever may have a positive influence on successful recanalization rates, regardless of the use of a balloon guide catheter.[56] However, information concerning the size of the stent retriever used was not provided by all studies.

A uniform assessment of emboli in new territories was lacking in most studies, mainly due to the lack of subsequent MR imaging after the procedure. For example, Schönfeld et al[27] studied 37 patients with successful reperfusion (TICI 2b or higher) following endovascular thrombectomy (with or without a balloon guide catheter) who had subsequent MR imaging with a DWI sequence within 24 hours. They reported that the use of a balloon guide catheter led to a significant reduction in the number and volume of peripheral emboli, with a median number/volume of peripheral emboli of 4.5/287 versus 12/938 µL.[27] However, the assessment of embolic showers in new territories is generally difficult because its definition often varies among studies.

Further randomized trials[57] are needed to evaluate our findings while taking into account other factors such as clot localization and composition and the first-line endovascular thrombectomy technique. While a large proportion of the included studies investigated and highlighted the benefits of balloon guide catheters with stent retrievers, the use of stent retrievers only in modern day endovascular thrombectomy is diminishing. Instead, the combined approach or contact aspiration–only first-line techniques are increasingly adopted in many centers. However, there is a lack of data on the efficacy of balloon guide catheter use in both groups, which are under-represented in our study.

CONCLUSIONS

Current literature and our meta-analysis confirm the benefits of balloon guide catheters in achieving shorter total procedural times. The balloon guide catheter improves the successful reperfusion rate and good clinical outcomes when used during first-line contact aspiration or stent retrieval but not with a combined approach.

Disclosures: Mayank Goyal—*UNRELATED*: *Consultancy*: Stryker, Medtronic, MicroVention, Mentice.

REFERENCES

1. Goyal M, Menon BK, van Zwam WH, et al. **Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials.** *Lancet* 2016;387:1723–31 CrossRef Medline
2. Powers WJ, Rabinstein AA, Ackerson T, et al. **Guidelines for the Early Management of Patients with Acute Ischemic Stroke: 2019 update to the 2018 Guidelines for the Early Management of Acute Ischemic Stroke—a guideline for healthcare professionals from the American Heart Association/American Stroke Association.** *Stroke* 2019;50:E344–418 CrossRef Medline
3. Turc G, Bhogal P, Fischer U, et al. **European Stroke Organisation (ESO) – European Society for Minimally Invasive Neurological Therapy (ESMINT) Guidelines on Mechanical Thrombectomy in Acute Ischaemic Stroke Endorsed by Stroke Alliance for Europe (SAFE).** *Eur Stroke J* 2019;4:6–12 CrossRef Medline
4. Deb-Chatterji M, Pinnschmidt H, Flottmann F, et al. **Stroke patients treated by thrombectomy in real life differ from cohorts of the clinical trials: a prospective observational study.** *BMC Neurol* 2020;20:81 CrossRef Medline
5. Ozdemir O, Giray S, Arlier Z, et al. **Predictors of a good outcome after endovascular stroke treatment with stent retrievers.** *Scientific World Journal* 2015;2015:403726 CrossRef Medline
6. Yoon W, Kim SK, Park MS, et al. **Predictive factors for good outcome and mortality after stent-retriever thrombectomy in patients with acute anterior circulation stroke.** *J Stroke* 2017;19:97–103 CrossRef Medline

7. Munich SA, Vakharia K, Levy EI. **Overview of mechanical thrombectomy techniques.** *Clin Neurosurg* 2019;85:S60–67 CrossRef Medline
8. Phan K, Maingard J, Kok HK, et al. **Contact aspiration versus stent-retriever thrombectomy for distal middle cerebral artery occlusions in acute ischemic stroke: meta-analysis.** *Neurointervention* 2018;13:100–09 CrossRef Medline
9. Primiani CT, Vicente AC, Brannick MT, et al. **Direct aspiration versus stent retriever thrombectomy for acute stroke: a systematic review and meta-analysis in 9127 patients.** *J Stroke Cerebrovasc Dis* 2019;28:1329–37 CrossRef Medline
10. Qin C, Shang K, Xu S-B, et al. **Efficacy and safety of direct aspiration versus stent-retriever for recanalization in acute cerebral infarction.** *Medicine (Baltimore)* 2018;97:e12770 CrossRef Medline
11. Ye G, Lu J, Qi P, et al. **Firstline a direct aspiration first pass technique versus first-line stent retriever for acute basilar artery occlusion: a systematic review and meta-analysis.** *J Neurointerv Surg* 2019;11:740–46 CrossRef Medline
12. Zafar M, Mussa M, Memon RS, et al. **Aspiration thrombectomy versus stent retriever thrombectomy alone for acute ischemic stroke: a systematic review and meta-analysis.** *Cureus* 2020;12:1–15 CrossRef Medline
13. Maus V, Behme D, Kabbasch C, et al. **Maximizing first-pass complete reperfusion with SAVE.** *Clin Neuroradiol* 2018;28:327–38 CrossRef Medline
14. McTaggart RA, Tung EL, Yaghi S, et al. **Continuous aspiration prior to intracranial vascular embolectomy (CAPTIVE): a technique which improves outcomes.** *J Neurointerv Surg* 2017;9:1154–59 CrossRef Medline
15. Nguyen TN, Malisch T, Castonguay AC, et al. **Balloon guide catheter improves revascularization and clinical outcomes with the Solitaire device: analysis of the North American Solitaire Acute Stroke Registry.** *Stroke* 2014;45:141–45 CrossRef Medline
16. Velasco A, Buerke B, Stracke CP, et al. **Comparison of a balloon guide catheter and a non-balloon guide catheter for mechanical thrombectomy.** *Radiology* 2016;280:169–76 CrossRef Medline
17. Chueh JY, Kang DH, Kim BM, et al. **Role of balloon guide catheter in modern endovascular thrombectomy.** *J Korean Neurosurg Soc* 2020;63:14–25 CrossRef Medline
18. Baek JH, Kim BM, Kang DH, et al. **Balloon guide catheter is beneficial in endovascular treatment regardless of mechanical recanalization modality.** *Stroke* 2019;50:1490–96 CrossRef Medline
19. Brinjikji W, Murad H, Fiorella D, et al. **Impact of balloon guide catheter on technical and clinical outcomes: a systematic review and meta-analysis.** *J Neurontery Surg* 2018;10:335–39 CrossRef Medline
20. Ahn JH, Cho SS, Kim SE, et al. **The effects of balloon-guide catheters on outcomes after mechanical thrombectomy in acute ischemic strokes: a meta-analysis.** *J Korean Neurosurg Soc* 2019;62:389–97 CrossRef Medline
21. Hutton B, Salanti G, Caldwell DM, et al. **The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations.** *Ann Intern Med* 2015;162:777 CrossRef Medline
22. Liebeskind DS, Bracard S, Guillemin F, et al. **ETICI reperfusion: defining success in endovascular stroke therapy.** *J Neurointerv Surg* 2019;11:433–38 CrossRef Medline
23. Kang DH, Kim BM, Heo JH, et al. **Effect of balloon guide catheter utilization on contact aspiration thrombectomy.** *J Neurosurg* 2019;131:1494–500 CrossRef Medline
24. Maegerlein C, Mönch S, Boeckh-Behrens T, et al. **PROTECT: PRoximal balloon Occlusion TogEther with direCt Thrombus aspiration during stent retriever thrombectomy–evaluation of a double embolic protection approach in endovascular stroke treatment.** *J Neurointerv Surg* 2018;10:751–55 CrossRef Medline
25. Zaidat OO, Mueller-Kronast NH, Hassan AE, et al. **Impact of balloon guide catheter use on clinical and angiographic outcomes in the STRATIS stroke thrombectomy registry.** *Stroke* 2019;50:697–704 CrossRef Medline
26. Bourcier R, Marnat G, Labreuche J, et al. **Balloon guide catheter is not superior to conventional guide catheter when stent retriever and contact aspiration are combined for stroke treatment.** *Neurosurgery* 2020;88:E88–90 CrossRef Medline
27. Schönfeld MH, Kabiri R, Kniep HC, et al. **Effect of balloon guide catheter utilization on the incidence of sub-angiographic peripheral emboli on high-resolution DWI after thrombectomy: a prospective observational study.** *Front Neurol* 2020;11:1–8 CrossRef Medline
28. Hafeez MU, Kan P, Srivatsan A, et al. **Comparison of first-pass efficacy among four mechanical thrombectomy techniques: a single-center experience.** *World Neurosurg* 2020;144:e533–40 CrossRef Medline
29. Johnson CO, Nguyen M, Roth GA, et al. **Global, regional, and national burden of stroke, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016.** *Lancet Neurol* 2019;18:439–58 CrossRef Medline
30. Pereira V, Siddiqui A, Jovin T, et al. **Role of balloon guiding catheter in Mechanical Thrombectomy Using Stent Retrievers subgroup analysis of SWIFT-PRIME.** *J Neuronterv Surg* 2015;7:A30 CrossRef
31. Higgins JP, Thompson SG, Deeks JJ, et al. **Measuring inconsistency in meta-analyses Testing for heterogeneity.** *BMJ* 2003;327:557–60 CrossRef Medline
32. Higgins JPT, Thompson SG. **Quantifying heterogeneity in a meta-analysis.** *Stat Med* 2002;21:1539–58 [Database] CrossRef Medline
33. Sterne JA, Hernán MA, Reeves BC, et al. **ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions.** *BMJ* 2016;355:4919 CrossRef Medline
34. McGuinness LA, Higgins JP. Risk-of-bias VISualization (ROBVIS): an R package and Shiny web app for visualizing risk-of-bias assessments. *Res Synth Methods* 2021;12:55–61 CrossRef Medline
35. Cochrane. **Revman.** https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman. Accessed December 15, 2020
36. Berndt MT, Goyal M, Psychogios M, et al. **Endovascular stroke treatment using balloon guide catheters may reduce penumbral tissue damage and improve long-term outcome.** *Eur Radiol* 2021;31:2191–98 CrossRef Medline
37. Goldhoorn RJ, Duijsters N, Majoie CB, et al. MR CLEAN Registry Investigators. **Balloon guide catheter in endovascular treatment for acute ischemic stroke: results from the MR CLEAN Registry.** *J Vasc Interv Radiol* 2019;30:1759–64 CrossRef Medline
38. Lee DH, Sung JH, Kim SU, et al. **Effective use of balloon guide catheters in reducing incidence of mechanical thrombectomy related distal embolization.** *Acta Neurochir (Wien)* 2017;159:1671–77 CrossRef Medline
39. Nguyen TN, Castonguay AC, Nogueira RG, et al. **Effect of balloon guide catheter on clinical outcomes and reperfusion in Trevo thrombectomy.** *J Neurointerv Surg* 2019;11:861–65 CrossRef Medline
40. Oh JS, Yoon SM, Shim JJ, et al. **Efficacy of balloon-guiding catheter for mechanical thrombectomy in patients with anterior circulation ischemic stroke.** *J Korean Neurosurg Soc* 2017;60:155–56 CrossRef Medline
41. Kim YS, Kang DH, Hwang YH, et al. **Efficacy of proximal aspiration thrombectomy for using balloon-tipped guide catheter in acute intracranial internal carotid artery occlusion.** *J Korean Neurosurg Soc* 2016;59:379–84 CrossRef Medline
42. Di Maria F, Kyheng M, Consoli A, et al. ETIS Investigators. **Identifying the predictors of first-pass effect and its influence on clinical outcome in the setting of endovascular thrombectomy for acute ischemic stroke: results from a multicentric prospective registry.** *Int J Stroke* 2021;16:20–28 CrossRef Medline
43. Zaidat OO, Castonguay AC, Linfante I, et al. **First pass effect: a new measure for stroke thrombectomy devices.** *Stroke* 2018;49:660–66 CrossRef Medline
44. Brinjikji W, Starke RM, Murad MH, et al. **Impact of balloon guide catheter on technical and clinical outcomes: a systematic review and meta-analysis.** *J Neurointerv Surg* 2018;10:335–39 CrossRef Medline

45. Alawieh A, Vargas J, Fargen KM, et al. **Impact of procedure time on outcomes of thrombectomy for stroke.** *J Am Coll Cardiol* 2019;73:879–90 CrossRef Medline
46. Goyal M, Jadhav AP, Bonafe A, et al. SWIFT PRIME investigators. **Analysis of workflow and time to treatment and the effects on outcome in endovascular treatment of acute ischemic stroke: results from the SWIFT PRIME randomized controlled trial.** *Radiology* 2016;279:888–97 CrossRef Medline
47. Nogueira RG, Haussen DC, Castonguay A, et al. **Site experience and outcomes in the Trevo Acute Ischemic Stroke (TRACK) multicenter registry: higher volumes translate in better outcomes.** *Stroke* 2019;50:2455–60 CrossRef Medline
48. Blanc R, Escalard S, Baharvadhat H, et al. **Recent advances in devices for mechanical thrombectomy.** *Expert Rev Med Devices* 2020;17:697–706 CrossRef Medline
49. Chueh JY, Kühn AL, Puri AS, et al. **Reduction in distal emboli with proximal flow control during mechanical thrombectomy: a quantitative in vitro study.** *Stroke* 2013;44:1396–401 CrossRef Medline
50. Lapergue B, Blanc R, Labreuche J. **Combined use of contact aspiration and stent retriever technique versus stent retriever alone for recanalisation in acute cerebral infarction: ASTER 2 combined**. *J Neurointerv Surg* 2020;12:471–76 CrossRef Medline
51. Lapergue B, Fischer UR, . **Looking at the ASTER 2 Trial Results at ESOC 2019. YouTube.** 2019. https://www.youtube.com/watch?v=h5B9nZ_wePw. Accessed January 03, 2021
52. FDA. **BOBBY Balloon Guide Catheter. Premarket Notification Results. 2020.** https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K193607. Accessed January 03, 2021
53. Fiorella. **Walrus 087 Balloon Guide Catheter System; Premarket Notification Results. 2019.** https://www.youtube.com/watch?v=fZOtqwVGsEw. Accessed January 03, 2021
54. Shah VA, Martin CO, Hawkins AM, et al. **Groin complications in endovascular mechanical thrombectomy for acute ischemic stroke: a 10-year single center experience.** *J Neurointerv Surg* 2016;8:568–70 CrossRef Medline
55. Jeong DE, Kim JW, Kim BM, et al. **Impact of balloon-guiding catheter location on recanalization in patients with acute stroke treated by mechanical thrombectomy.** *AJNR Am J Neuroradiol* 2019;40:840–44 CrossRef Medline
56. Zaidat OO, Haussen DC, Hassan AE, et al. **Impact of stent retriever size on clinical and angiographic outcomes in the STRATIS stroke thrombectomy registry.** *Stroke* 2019;50:441–47 CrossRef Medline
57. **Efficacy and Safety of Balloon Guide Catheter in Mechanical Thrombectomy Patients. ESCAPE**. https://clinicaltrials.gov/ct2/show/NCT03754738. Accessed January 03, 2021