Patient Outcomes with Stent-Retriever Thrombectomy for Anterior Circulation Stroke: A Meta-Analysis and Review of the Literature

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ABSTRACT: Mechanical thrombectomy with stent retrievers is now the reference therapy for acute ischemic stroke (AIS) in the anterior circulation in association with thrombolysis. We conducted an extensive systematic review and meta-analysis to evaluate the clinical and angiographic outcomes of stent-retriever thrombectomy in patients with acute anterior circulation stroke. Available literature published to date on observational studies and three randomized trials (MR CLEAN, ESCAPE, and EXTEND-IA) involving the stent-retriever device were reviewed. Successful recanalization and favorable clinical outcome were defined by a TICI ≥ 2b and modified Rankin Scale score of ≤ 2 at 90 days following AIS, respectively. A total of 2067 patients harboring an anterior circulation stroke were treated with a stent retriever: 433 patients from 3 randomized trials involving the device and 1634 patients from observational studies. Mean NIH Stroke Scale score on admission was 16.6, and mean time from onset to recanalization was 300 minutes. Successful recanalization was achieved in 82% (95%CI 77–86, 31 studies). The 90 day favorable outcome was achieved in 47% (95%CI 42–5.2, 34 studies) with an overall mortality rate of 17% (95%CI 13–20, 31 studies). Symptomatic intracerebral hemorrhage was identified in 6% (95%CI 4–8, 32 studies). In patients with AIS caused by a proximal intracranial occlusion of the anterior circulation, stent-retriever thrombectomy is safe and restores brain reperfusion in four of five treated patients, allowing favorable clinical outcome in one of two AIS patients with large vessel occlusion.

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For 20 years intravenous (IV) thrombolysis with tissue plasminogen activator (t-PA) was the only approved first-line treatment for acute ischemic stroke (AIS) since publication of the NINDS (National Institute of Neurological Disorders and Stroke) trial [1]. In 2013, three randomized controlled trials (IMS 3, SYNTHESIS, and MR RESCUE) were prematurely halted owing to the futility of endovascular therapy with mechanical thrombectomy compared to medical management alone (IV t-PA) [2-4]. The concept of endovascular therapy has changed dramatically with the stent-retriever device. In 2010, Castano et al. [5] reported promising results of the stent retriever in a prospective single-center study of 20 patients with acute ischemic stroke attributable to large artery occlusion of the anterior circulation. Stent retrievers can rapidly, safely and effectively retrieve clots from the middle cerebral artery and distal internal carotid artery. Stent-retriever mechanical thrombectomy (SRT) has become the new reference therapy, in association with IV t-PA, for anterior AIS with proximal arterial occlusion since publication of the MR CLEAN, ESCAPE, EXTEND-IA and, later on, the SWIFT PRIME and REVASCAT trials [6-10]. In fact, results from the MR CLEAN trial, consistently followed by the ESCAPE, EXTED-IA, SWIFT PRIME and REVASCAT trials, has proved the superiority of SRT and IV t-PA over IV t-PA alone in clinical outcome 90 days after AIS due to proximal intracranial occlusion. However, 90 day favorable outcomes are variable, ranging from 33% in MR CLEAN to 71% in EXTEND-IA. A similar disparity was found in mortality, ranging from 21% in MR CLEAN to 9% in EXTEND-IA and SWIFT PRIME.

Our main objective was to determine whether these percentages reflect the actual results as reported by a wider range of authors in different settings, and to determine accurately the

*The first two authors contributed equally to this work safety and efficacy profile of SRT in patients with acute anterior circulation stroke. We therefore conducted an extensive systematic review and meta-analysis of all previous studies using SRT, including MR CLEAN, ESCAPE, and EXTEND-IA trials.

SEARCH TERMS

We conducted a search in the Pubmed database using the terms "ischemic stroke," "stent retriever," "anterior circulation occlusion," "mechanical thrombectomy," "Revive," "Solitaire" and "Trevo" in both "AND" and "OR" combinations, that appeared between 1 January 2010 and 28 February 2015. Only studies with at least 10 cases of anterior circulation occlusion were included in our analysis to minimize the chance of anecdotal outcomes. Since many articles reported data for both anterior and posterior circulation together, we contacted the corresponding authors by email. Only studies from which we could extract the anterior circulation data from the text or that provided us with the specific data for the anterior circulation cases were included in the final analysis.

The abstracts were reviewed by two authors (R.S.H. and D.N.G.) and the full text was revised again by two authors (R.S.H. and F.G.). A second revision was undertaken by a different author (B.G.). Different interpretations of reported data were discussed and resolved in collaboration with the two main authors.

INCLUSION CRITERIA

Each study had to report the National Institute of Health Stroke Scale (NIHSS) score at baseline, the recanalization rate, symptomatic intracerebral hemorrhage (sICH) rate, functional neurological outcomes, and mortality rates at 90 days. Successful recanalization rate was based on the Thrombolysis in Cerebral Infarction scale (TICI) as TICI ≥ 2b. One study reported thrombolysis in myocardial infarction (TIMI) 3 only, and two others used TIMI ≥ 2 as the standard for good outcome. These three articles were included in the analysis. Functional neurological outcomes were based on the modified Rankin Scale (mRS) score, with a favorable outcome defined as mRS ≤ 2 at 3 months. Publications that did not report mRS at 90 days or provide us with the information were excluded. According to the European Cooperative Acute Stroke Study II (ECASS-II) [11], sICH was defined as any parenchymal hematoma, subarachnoid hemorrhage, or intraventricular hemorrhage associated with worsening of the NIHSS score by ≥ 4 within 24 hours. Most studies reported the rate of sICH separately from that of all intracerebral hemorrhages. When the authors did not specifically note whether hemorrhages were symptomatic, we considered hemorrhages associated with any decline in neurological status as symptomatic. In studies that did not provide any clinical details but described a radiographic type of hemorrhage, cases of parenchymal hematomas were classified as sICH. We also collected data on the distal embolization rates as the result of the procedure. Those data were not always reported by authors, and how authors determined whether or not there was distal embolization was not clarified by any of them. Since this was not an exclusion criterion for published studies, it was analyzed when possible.

STATISTICAL ANALYSIS

The percentage of patients presenting the outcome was estimated for each study included in the systematic review and for each outcome. The 95% confidence intervals (95%CI) of the estimates were calculated using the Wilson method. The estimate and the 95% confidence interval of the mean percentage of all the studies were obtained for each outcome using a logistic mixed model with a random effect on the intercept in order to take into account heterogeneity among the studies. All the analyses were performed using the statistical software R, version 3.1.0. We prepared this report with reference to MOOSE (meta-analyses of observational studies) guidelines.

SEARCH STRATEGY

We identified 517 studies published between 1 January 2010 and 28 February 2015. Excluding by title, we identified 123 studies of patients with AIS who had received treatment with stent-retriever devices and 51 were judged eligible for inclusion [Figure 1]. In 34 studies, we could extract the data regarding anterior circulation stroke [Table 1], and in 17 studies outcome was reported for anterior and posterior circulation stroke [Table 2]. In these 34 articles regarding anterior circulation stroke patients, we had a total of 2067 patients (mean sample size 47, range 10–233). Studies used for analysis of each group, including methodological and baseline characteristics of the included studies, as well as treatment outcomes, are listed in Table 1. Seventeen studies were prospective and 17 were retrospective, and 6 were multicenter. Three randomized controlled trials (MR CLEAN, ESCAPE and EXTEND-IA) were included in

Figure 1. PRISMA flow diagram showing screening and selection of studies for systematic review

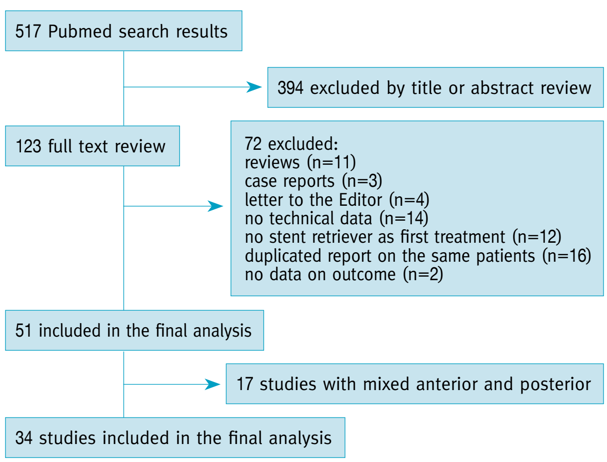


Table 1. Demographics, efficacy, and safety outcome associated with the use of stent-retrievers in anterior circulation

Author	Year	Design	Patients	ICA	MCA	Tandem occlusion	IV t-PA, %	Mean age	Baseline NIHSS	Time to recanalization, minutes	NIHSS post-SRT#	Recanalization, %	sICH[β], %	mRS ≤ 2 at 90 days, %	Mortality at 90 days, %
Castano et al.	2010	Prospective	15	5	8	2	53	65.5	16.1	371	6.3[b]	100	10.0	53.3	20
Roth et al.	2010	Prospective	14	2	12		0	64.8	19	277	7.9[c]	93.0	7.1	50	7.1
Miteff et al.	2011	Retrospective	16	8	5	3	0	68	18.3	395	3.1[c]	94	6.3	56.2	12.5
Mendonca et al.	2013	Prospective	13	5	8		54	74	19	330	13.2[a]	38.0	0.0	38.5	30.8
Costalat et al.	2011	Prospective	34	14	20		88	67.6	14.7	294	6.5[c]		0.0	58.8	5.8
Fesl et al.	2012	Retrospective	14	5	9		100	67.1	16.5	267		93.0	29.0	41.7	0
Castro-Alfonso et al.	2012	Prospective	19	3	13	3	37	65.7	18		18[c]	89.0	15.8	57.9	31.6
Kim et al.	2012	Retrospective	18	6	9	3	56	66.8	13.5	354	1.7[b]	94.0		66.7	22.2
Raoult et al.	2013	Retrospective	32	2	30		53	59	15.7	299	5.5[c]	90.0	6.3	56.25	15.6
Mpotsaris et al.	2013	Prospective	41	8	16	17	83	62	15.8		8.5[c]	85.3	7.3	36.6	14.6
Lee et al.	2013	Retrospective	17	4	13			65	17.1			88.0	0.0	41.2	
Apetse et al.	2013	Prospective	10	0	4	6	50	66.8	20.4	249	6.6[c]	60	10.0	40	3
McCabe et al.	2013	Retrospective	16	2	8	6	56	65.8	15.4	255		69	0.0	43.75	6.25
Tasal et al.	2013	Retrospective	19	0	12	7		63.2	19.5	234	8.4[c]	74.0	0.0	63.2	15.8
Vendrell et al.	2013	Retrospective	17	0	17		100	69	15.2	297		88	0.0	66.7	6.7
Cohen et al.	2013	Prospective	31	0	31		19	63	19.5	287		94	3.2	77.4	9.7
Yoon et al.	2013	Retrospective	26	26	0		65	73	13	277	7.2[c]	77	0.0	39	8
Kurre et al.	2013	Retrospective +Prospective	109*	35	81		7	83	15	284	14.6[c]	87.9	9.2	17.4	47.7
Pereira et al.	2013	Prospective	202*	36	160		59	68.4	17	271		88.1	1.5	57.9	6.9
Song et al.	2014	Retrospective	50	28	22		60	68.1	17	346		82	8.0	54	18
Mendonca et al.	2014	Prospective	20	9	11		50	70	17	371	11[a]	45	15.0	40	25
Ribo et al.	2014	Retrospective	69*	23			58	72	18	281	7[c]	67.2	10.8	50.9	
Gratz et al.	2014	Retrospective	227	44	158	25	35	68.2	16	314		70.9	9.7	39.8	25.7
Lockau et al.	2015	Retrospective	37	37			54	63	17			73	10.0	46	18.9
Lescher et al.	2015	Retrospective	39	0		39	74	68	14	280		64	10.0	35.8	7.7
Parrilla et al.	2015	Retrospective	99	29	55	15	48[β]	65	16.5	394	6.4[c]	94.0	2.0	52.5	15.1
Parrilla et al.	2015	Retrospective	28	12	13	3	32[β]	82	16.8	435	9.5[c]	86.0	7.1	10.7	39.3
Soize et al.	2014	Prospective	31	2	29		68	65	16.5	287	8.8[c]		0.0	67.7	12.9
Soize et al.	2014	Prospective	11	0		11	55	68.7	18.8	302	20[c]		30	18.2	45.5
Kuntze Söderqvist et al.	2014	Retrospective	136				34		16		6[a]	80.0	5.1	52.9	13.2
Berkhemer et al.	2015	Prospective	233	1	173	59	87	65	17		8[b]		2.6	33	21
Sztajzel et al.	2015	Prospective	63	11	52		100	68.3	15.7			77	6.3	56	14
Nikoubashman et al.	2014	Prospective	113	27	77	9	79	71	15	320		81.4	2.6	27	
Schwaiger et al.	2014	Retrospective	48	0	48			71	15	299	7[c]	81.3	0	37.5	16.6
Goyal et al.	2015	Prospective	165*	0	117	45		71	16	241			3.6	53	10.3
Campbell et al.	2015	Prospective	35	11	24		100	68	17	248			0	71.4	8.6

[β]Decline of ≥ 4 points in NIHSS score within 24 hours with any blood products (petechial bleeding, hematoma, or subarachnoid hemorrhage) evident on head CT at 24 hours

#NIHSS was given at [a]24 hours, [b]1 week, or at [c]discharge

*The number of patients according to location does not add to the total number of patients reported by the authors

CA = internal carotid artery, MCA = middle cerebral artery, t-PA = tissue plasminogen activator, NIHSS = NIH Stroke Scale score, sICH = symptomatic intracerebral hemorrhage, mRS = modified Rankin Scale score

Table 2. Demographics, efficacy, and safety outcome associated with the use of stent retrievers in anterior and posterior circulation

Author	Year	Design	Patients	ICA	MCA	IV t-PA, %	Baseline NIHSS	Time to recanalization, minutes	NIHSS post-SRT#	Recanalization, %	sICH$^{\beta}$, %	mRS ≤ 2 at 90 days, %	Mortality at 90 days, %
Brekenfeld et al.	2011	Prospective	17	5	9	6.0	19		14 a	94 (TIMI ≥ 2)	0	43	
Stampfl et al.	2011	Retrospective	18	0	13	13	21	289		66.7	14.3	33.3 (at discharge)	27.8
Davalos et al.	2012	Retrospective	141	39	85	74	18	346	8 a	85	4.0	55	20
Bae et al.	2012	Prospective	40	11	27	17	12.5	300	8.8 c	90 (TICI ≥ 2a)	0	42.5	5
Saver et al.	2012	Prospective	89	19	67	42	17.4	332.3			1.1	59.8	18
San Roman et al.	2012	Prospective	60	13	41	33	18	302		86.7	12	45	28
Nogueira et al.	2012	Prospective	88	14	67	51	18.3	293	12 a	92.0	4.5	40	33
Roth et al.	2013	Prospective	40	10	28	28	16.4	208		95	2.5	60	12.5
Šaňák et al.	2013	Prospective	50	2	43	43	18	244		94	6.0	60	14
Broussalis et al.	2013	Prospective	62	18	36	43	17		10 c	82.3	9.7	58.1	1.8
Mokin et al.	2013	Retrospective	101	34	70	39	17.6	325		88	15.0	47	26
Zaidat et al.	2014	Retrospective	354	82	197		18.1	413		72.5	9.9	42	30.2
Deshaies et al.	2014	Retrospective	31	11	27	6	16	360		81	7.0	32	42
Cheang et al.	2014	Prospective	60	21	27	27	18	361		73.3	6.7	43.3	31.7
Binning et al.	2014	Prospective	52	15	23	19	17		9 a	74	3.7	48	15
Turk et al.	2015	Retrospective	222			16	17			83.3		43	
Humphries et al.	2015	Retrospective	105	29	66	47	17	405.3	5 c	87.6	4.6	44.1	28.4

Demographics, efficacy, and safety outcome associated with the use of stent retrievers in anterior and posterior circulation

$^{\beta}$Decline of ≥ 4 points in NIHSS score within 24 hours with any blood products (petechial bleeding, hematoma, or subarachnoid hemorrhage) evident on head CT at 24 hours

#NIHSS was given at ^{a}24 hours, ^{b}1 week, or at ^{c}discharge

ICA = internal carotid artery, MCA = middle cerebral artery, t-PA = tissue plasminogen activator, NIHSS = NIH Stroke Scale score, sICH = symptomatic intracerebral hemorrhage, mRS = modified Rankin Scale score

the meta-analysis. In two studies, the authors compared two groups with complete separation of the results, and we included each of those groups as different data.

DATA ANALYSIS

The admission mean NIHSS score was 16.6 (range 13–20), and median time from onset to recanalization was 300 minutes (range 234–435, 29 series). Mean IV thrombolysis rate was 58.5% (range 0–100, 31 studies). The procedural time ranged from 20 to 120 minutes (mean 72 minutes, 21 studies).

The rate of successful recanalization was found to be 82% (95%CI 77–86, heterogeneity $P < 0.001$, 31 studies), and 90 day favorable outcome was achieved in 47% (95%CI 42–52, heterogeneity $P < 0.001$, 34 studies). Mortality was 17% (95%CI 13–20, heterogeneity $P < 0.001$, 31 studies) either at discharge or after 3 months follow-up, and the sICH was 6% (95%CI 4–8, heterogeneity $P = 0.03$, 32 studies). Distal embolization was 4% (95%CI 2–7, heterogeneity $P = 0.1$, 13 studies.

FINDINGS AND SYSTEMATIC REVIEW

Our meta-analysis, including MR CLEAN, ESCAPE, and EXTEND-IA trials, demonstrated high rates of successful recanalization for large vessel occlusion treated with SRT. In fact, we showed a pooled estimate of 82% (95%CI 77–86, 31 studies) for successful arterial recanalization defined as final angiographic TICI ≥ 2b. However, we observed a significant heterogeneity between series included in our meta-analysis ($P < 0.001$). There was a wide range of recanalization rates in our systematic review (38% to 100%); a similar finding was also reported since the frequency of modified TICI ≥ 2b was 59% in MR CLEAN and 88% in EXTEND-IA [6,7]. Few data are available to date for clarifying these results; however, the design of the stent retriever as well as the technique of the stent placement could provide an explanation. Unfortunately, there are insufficient technical data in most articles to help us thoroughly understand these results. In fact, it was reported recently that the push and fluff technique for closed-cell stent retrievers leads to a higher rate of mTICI 3 (58% versus 40%, $P = 0.03$) when compared with the standard unsheathing technique [12]. Stent retrievers clearly achieve a better rate of recanalization compared to the previous mechanical devices such as the Merci retriever system (Concentric Medical, Mountain View, CA, USA). In a literature review of the Merci retriever trial, successful revascularization (TIMI score 2–3) was observed in 63.6% of the 1226 patients [13]. Previously, stent retrievers were compared head-to-head with the Merci device in the SWIFT and TREVO 2 randomized trials [14,15]. Both trials found that stent retrievers achieve a higher incidence of recanalization compared with the Merci retriever system (61% vs. 24% in SWIFT and 86% vs. 60% in TREVO 2) [14,15].

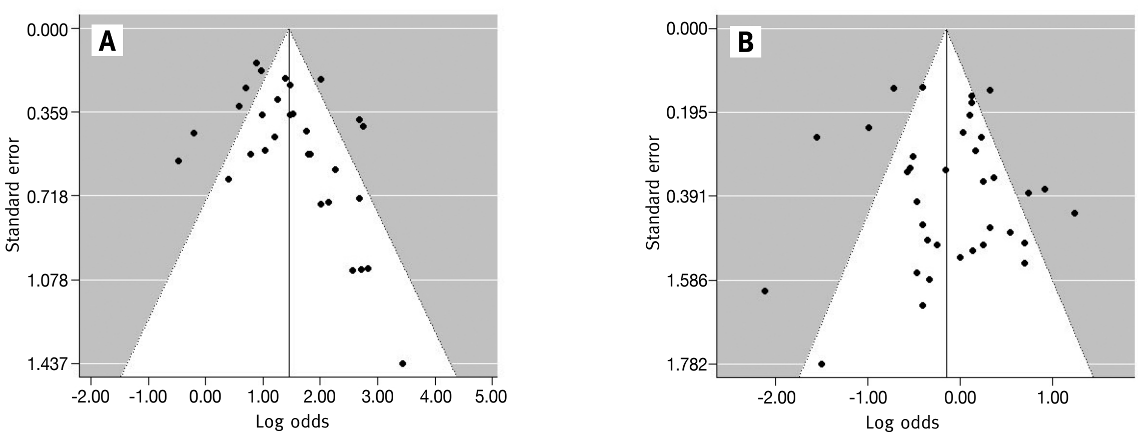
Complete arterial recanalization represents the major objective to be achieved in the acute reperfusion therapy of AIS, since a strong correlation between recanalization rates and improved functional outcomes has been demonstrated in stroke patients treated with either IV t-PA or endovascular therapy [16-18]. The SWIFT PRIME trial confirmed this finding as patients who achieved reperfusion had substantially more favorable clinical outcomes in both the intervention and the control groups [19]. However, time to recanalization is also a crucial objective to achieve in the management of these patients, and a strong relationship between time of symptoms onset and reperfusion was previously reported [18-21]. Faster time from symptom onset to reperfusion (modified TICI ≥ 2b) was significantly associated with functional independence in the intervention group ($P < 0.01$) in the SWIFT PRIME trials [19]. In the combined databases of the SWIFT and STAR trials, for every 5 minutes delay in endovascular reperfusion using stent retrievers 1 of 100 patients had a worse disability outcome [21]. In this large meta-analysis that included 2067 patients, time from onset of symptoms to reperfusion was 300 minutes, almost 40 minutes later than in MR CLEAN and REVASCAT. In ESCAPE, dramatic improvements in workflow were attained, with a median of 51 minutes from imaging to groin puncture and 84 minutes from imaging to first reperfusion [8].

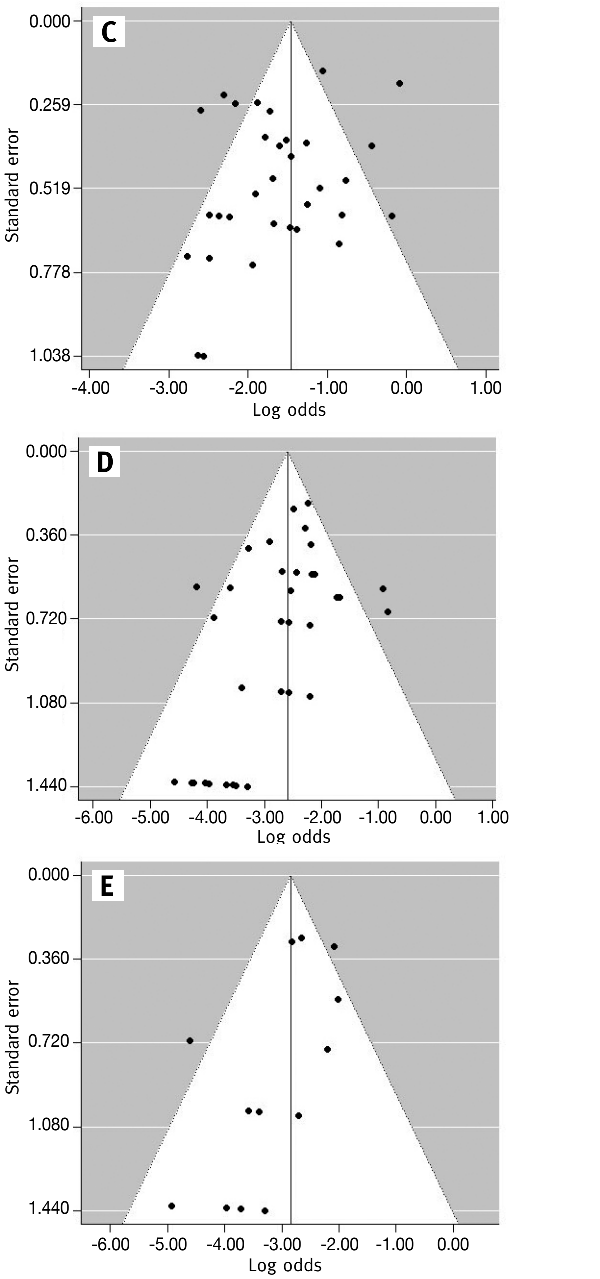
Our meta-analysis provides more representative data on functional outcome and mortality although a significant heterogeneity was also observed. We demonstrated a 47% rate (95%CI 42–52, 34 studies) of 90 day mRS of ≤ 2 and 17% rate (95%CI 13–20, 31 studies) of mortality among SRT anterior circulation stroke patients. Compared with the Merci retriever, the stent retriever is clearly more efficient since the 90 day mRS of ≤ 2 was achieved in 32% of the patient group, with an overall mortality rate of 35.2% according to the results of a review including the Merci trial and Multi-Merci trial studies [13]. These positive results are explained in part by faster and more complete brain reperfusion. In the recent trials, the percentage of patients achieving good outcome is strikingly proportionate to the percentage of patients achieving modified TICI ≥ 2b, and the same correlation was found with mortality [22,23]. However, we observed a wide variability of outcomes with a significant heterogeneity, mostly explained by differences of baseline imaging characteristics.

Initial infarct size is a potent prognostic factor after endovascular therapy with stent retrievers [24], and the purpose of imaging has been to exclude patients with a large area of irreversibly injured ischemic core [25]. However, we did not have access to the individual data of the studies and could not separate patients with small and large infarct core at baseline. To date, there is no consensus on the best imaging modality for the initial selection of AIS patients. According to the recent results of SWIFT PRIME, patients with the target mismatch profile exert a highly favorable response to endovascular therapy in both clinical and imaging outcomes, and substantially more favorable clinical and imaging outcomes [19]. In the EXTEND-IA and SWIFT PRIME, a higher proportion of good outcomes was reported (71% and 60%), probably due to the systematic use of perfusion imaging to exclude patients with a large infarct core and no or small hypoperfusion salvageable brain area [7,10]. However, Olivot et al. [24] reported that large lesions might still benefit from recanalization in a retrospective analysis of 139 AIS patients treated with endovascular therapy.

Symptomatic intracerebral hemorrhage rates were 5.6%, demonstrating that SRT is safe. A similar sICH rate was reported in the NINDS trial after IV thrombolysis [1]. The safety of endovascular therapy was also proved in the IMS 3 trial, as the proportion of patients with sICH within 30 hours after initiation of IV t-PA was 6.2% in the endovascular therapy and 5.9% in intravenous t-PA groups ($P = 0.83$) [2]. In MR CLEAN and EXTEND-IA, similar results were observed, 7.7% and 6% respectively, without significance between intervention and control groups.

Figure 2. Funnel plots for **[A]** recanalization, **[B]** favorable outcome, **[C]** mortality, **[D]** symptomatic intracranial hemorrhage, and **[E]** distal embolization. Effect size indicates the Freeman-Tukey transformed proportion expressed in degrees





The main limitations of this meta-analysis are the major publication and selection bias by examining the funnel plots of Freeman-Tukey transformed proportions against their SE [Figure 2].

CONCLUSIONS

According to our large meta-analysis, including the MR CLEAN, ESCAPE, and EXTEND-IA trials, mechanical thrombectomy using stent retrievers is safe and restores perfusion to the brain in four of five treated patients, allowing favorable clinical outcome in one of two AIS patients with large vessel occlusion.

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References

1. The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. Tissue plasminogen activator for acute ischemic stroke. *N Engl J Med* 1995; 333: 1581-7.
2. Broderick JP, Palesch YY, Demchuk AM, et al. Endovascular therapy after intravenous t-PA versus t-PA alone for stroke. *N Engl J Med* 2013; 368 (10): 893-903.
3. Ciccone A, Valvassori L, Nichelatti M, et al. Endovascular treatment for acute ischemic stroke. *N Engl J Med* 2013; 368 (10): 904-13.
4. Kidwell CS, Jahan R, Gornbein J, et al. A trial of imaging selection and endovascular treatment for ischemic stroke. *N Engl J Med* 2013; 368: 914-23.
5. Castaño C, Dorado L, Guerrero C, et al. Mechanical thrombectomy with the Solitaire AB device in large artery occlusions of the anterior circulation: a pilot study. *Stroke* 2010; 41: 1836-40.
6. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med* 2015; 372: 11-20.
7. Campbell BC, Mitchell PJ, Kleinig TJ, at al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med* 2015; 372 (11): 1009-18.
8. Goyal M, Demchuk AM, Menon BK, at al. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med* 2015; 372 (11): 1019-30.
9. Jovin TG, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med* 2015; 372 (24): 2296-306.
10. Saver JL, Goyal M, Bonafe A, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med* 2015; 372 (24): 2285-95.
11. Hacke W, Kaste M, Fieschi C, et al. Randomised double-blind placebo-controlled trial of thrombolytic therapy with intravenous alteplase in acute ischaemic stroke (ECASS II). *Lancet* 1998; 352: 1245-51.
12. Haussen DC, Rebello LC, Nogueira RG. Optimizating clot retrieval in acute stroke: the push and fluff technique for closed-cell stentrievers. *Stroke* 2015; 46 (10): 2838-42.
13. Alshekhlee A, Pandya DJ, English J, et al. Merci mechanical thrombectomy retriever for acute ischemic stroke therapy: literature review. *Neurology* 2012; 79 (13 Suppl 1): S126-34.
14. Saver JL, Jahan R, Levy EI, et al. Solitaire flow restoration device versus the Merci Retriever in patients with acute ischaemic stroke (SWIFT): a randomised, parallel-group, non-inferiority trial. *Lancet* 2012; 380: 1241-9.
15. Nogueira RG, Lutsep HL, Gupta R, et al. Trevo versus Merci retrievers for thrombectomy revascularisation of large vessel occlusions in acute ischaemic stroke (TREVO 2): a randomised trial. *Lancet* 2012; 380: 1231-40.
16. Rha JH, Saver JL. The impact of recanalization on ischemic stroke outcome: a meta-analysis. *Stroke* 2007; 38: 967-73.
17. Kharitonova TV, Melo TP, Andersen G, et al. Importance of cerebral artery recanalization in patients with stroke with and without neurological improvement after intravenous thrombolysis. *Stroke* 2013; 44: 2513-18.
18. Emberson J, Lees KR, Lyden P, et al. Effect of treatment delay, age, and stroke severity on the effects of intravenous thrombolysis with alteplase for acute ischaemic stroke: a meta-analysis of individual patient data from randomised trials. *Lancet* 2014; 384: 1929-35.
19. Albers GW, Goyal M, Jahan R, et al. Relationships between imaging assessments and outcomes in Solitaire with the intention for thrombectomy as primary endovascular treatment for acute ischemic stroke. *Stroke* 2015; 46 (10): 2786-94.
20. Khatri P, Abruzzo T, Yeatts SD, et al. Good clinical outcome after ischemic stroke with successful revascularization is time-dependent. *Neurology* 2009; 73: 1066-72.
21. Sheth SA, Jahan R, Gralla J, et al. Time to endovascular reperfusion and degree of disability in acute stroke. *Ann Neurol* 2015; 78 (4): 584-93.
22. Grotta JC, Hacke W. Stroke neurologist's perspective on the new endovascular trials. *Stroke* 2015; 46: 1447-52.
23. Mazighi M, Chaudhry SA, Ribo M, et al. Impact of onset-to-reperfusion time on stroke mortality: a collaborative pooled analysis. *Circulation* 2013; 127: 1980-5.
24. Olivot JM, Mosimann PJ, Labreuche J, et al. Impact of diffusion-weighted imaging lesion volume on the success of endovascular reperfusion therapy. *Stroke* 2013; 44: 2205-11.
25. Menon BK, Campbell BC, Levi C, Goyal M. Role of imaging in current acute ischemic stroke workflow for endovascular therapy. *Stroke* 2015; 46: 1453-61.