Should the direct aspiration first pass technique be advocated over the stent-retriever technique for acute ischemic stroke? A systematic review and meta-analysis of 7692 patients

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INTRODUCTION

Acute ischaemic stroke (AIS) is considered to be one of the leading causes of the mortality worldwide.¹ Moreover, stroke is associated with a high rate of disability among the survivors.²
There are two major methods to treat AIS; mechanical thrombectomy and standard medical therapy, which can be considered if patients present to a thrombectomy-capable facility in a timely manner. Over the last decade, several randomized controlled trials (RCTs) showed the superiority of mechanical thrombectomy techniques over medical management in thrombectomy-eligible patients. These RCTs have drawn more attention to mechanical thrombectomy, which is now considered one of the main lines of treatment for AIS.

The reference mechanical thrombectomy technique is the stent-retriever (SR) for selected patients, especially those with AIS due to vascular occlusion in the anterior circulation, according to the results of a recently published meta-analysis by Sivan-Hoffmann et al., which showed that the SR is a safe method with favorable clinical outcomes. The SR technique is the gold standard technique for mechanical thrombectomy in patients with AIS.

Recently, a direct aspiration first pass technique (ADAPT) was proposed by Turk et al. and started to gain acceptance due to the lower costs of the procedure, increased rates of successful recanalization, and the better clinical outcomes reported by some studies when used either alone or as an adjunctive technique to the SR. However, data from the literature are controversial regarding the comparative outcomes of the ADAPT technique compared with the conventional thrombectomy technique of the SR.

Therefore, the present meta-analysis aimed to synthesize evidence from all published studies with head-to-head data on the outcomes of ADAPT and SR in AIS patients.

**MATERIALS AND METHODS**

We followed the most recent version of the preferred reporting items for systematic reviews and meta-analysis (PRISMA statement 2020) guidelines during this systematic review and meta-analysis.

**Eligibility criteria**

Studies satisfying the following criteria were included in this meta-analysis:

1. Population: studies on patients with AIS undergoing thrombectomy
2. Intervention: studies where the exposed group received ADAPT
3. Comparator: studies where the control group received SR
4. Outcome: studies reporting recanalization outcomes, National Institutes of Health Stroke Scale (NIHSS) score at baseline, 24 h and/or 7 days after the stroke event, mRS at 90 days, complications of the procedure and/or procedure time
5. Study design: studies with comparative designs, whether RCTs or observational studies comparing the outcomes of ADAPT and SR.

We excluded studies that were not in English language and studies on either ADAPT or SR without direct comparison between the two techniques.

**Information sources**

We performed a comprehensive search of four electronic databases (PubMed, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials) from inception to March 1, 2021.

**Search strategy**

We used the following search query ([aspiration OR ADAPT] AND [SR OR Solitaire OR Trevo OR Merci] AND [stroke OR Large vessel occlusion OR LVO]) in the four databases with no filters or limitations.

**Selection process**

Retrieved records from the literature search were screened in two steps. In the first step, the title and abstracts of all articles were screened for eligibility. Then, the full-text articles of the eligible abstracts were retrieved and further screened for eligibility.

**Data collection process and data items**

Data were extracted to a uniform data extraction sheet. The extracted data included (1) Characteristics of the included studies, (2) Characteristics of the population of included studies, (3) Risk of bias domains, and (4) Outcome measures.

**Study risk of bias assessment**

For RCTs, we used the Cochrane Risk of Bias assessment tool (ROB 2.0) while for observational studies; we used the Newcastle Ottawa Scale (NOS scale).

**Effect measures**

In this meta-analysis, we considered the following outcome measures:

- Successful recanalization (%): defined angiographically, according to the modified thrombolysis in cerebral infarction (mTICI) scale, as mTICI2b/3 at the end of the procedure
- Complete recanalization (%): defined angiographically, according to the mTICI scale, as mTICI-3 at the end of the procedure
- Favorable neurological outcome (%): defined as the number of patients with an mRS score of 0-2 at 90 days after the stroke event
• Complications (%): defined as any complication reported in the included studies with a frequency of more than 5%. This includes intracranial hemorrhage (ICH), symptomatic ICH (sICH), Subarachnoid haemorrhage (SAH), parenchymal hematoma, hemorrhagic infarction, and embolization to a new territory (ENT)
• Procedural time (%): defined as the time interval from groin puncture to reperfusion time.

Synthesis methods
For outcomes that constitute continuous data, the mean difference (MD) between the two groups from the baseline to the endpoint, with its confidence interval (CI), was pooled in the DerSimonian-Laird random-effect model. In the case of studies reporting data in multiple time points, we considered the last endpoint for the primary analysis. For outcomes that constitute dichotomous data, the frequency of events and the total number of patients in each group were pooled as relative risk between the two groups in the DerSimonian-Laird random-effect model.

Subgroup analysis
We conducted subgroup analysis according to the study design (RCTs only vs. observational studies) and according to the site of stroke (anterior circulation vs. posterior circulation).

Assessing the heterogeneity
Heterogeneity (non-combinability) of the included studies and subgroups was examined by visual inspection of the forest plot and assessed by the Cochrane Q and I-square tests using RevMan version 5.3 for windows. For heterogeneity testing, a $P < 0.1$ and I-square $>50\%$ were considered for significant heterogeneity.

Calculating the missing data
When the MD from baseline to endpoint was not provided, we calculated it from the pre- and post-treatment means (MD = Posttreatment-pretreatment). Then, we calculated the MD between the ADAPT and SR groups as follows: (MD = MD experimental-MD placebo).

When the standard error (SE) of MD was not provided, we calculated it from the standard deviation $[SE=SD(\sqrt{n})]$, 95% CI $([\text{upper limit}-\text{lower limit}]/3.92)$, or 90% CI $([\text{upper limit}-\text{lower limit}]/3.29)$.

For studies and groups with a sample size of <60 patients, the numbers (3.92 and 3.29) were substituted by a value from the table of $t$ distributions with degrees of freedom equal to the group sample size minus 1.

Reporting bias assessment
To explore the publication bias across studies, we constructed funnel plots to present the relationship between effect size and SE. Two methods assessed evidence of publication bias; (1) Egger's regression test and (2) Begg and Mazumdar rank correlation test (Kendall's tau).

Certainty assessment
To test the robustness of the evidence, we conducted a certainty assessment through sensitivity analysis (also called, leave-one-out meta-analysis). For every outcome in the meta-analysis, we run sensitivity analysis in multiple scenarios excluding one study in each scenario to make sure the overall effect size was not dependent on any single studies.

RESULTS
Study selection
Our literature search process retrieved 2,832 records. Following titles and abstract screening, 351 articles were eligible for full-text screening. From these 351 studies, 30 studies were included in the meta-analysis. The references of the included studies were manually searched, and no further articles were included. The flow chart of the study selection process is shown in the PRISMA flow diagram in [Figure 1].

Study characteristics
The population of the studies was homogenous; all studies enrolled 7868 patients with AIS. Two studies were RCTs while 28 studies were observational studies. The characteristics of the included studies are summarized in [Table 1], while summary and baseline characteristics of populations of these studies are shown in [Table 2].

Risk of bias within studies
The quality of included studies ranged from moderate to high quality according to the Cochrane Risk of Bias assessment tool for RCTs and the NOS for the observational studies.

Improvement in NIHSS score
The overall standardized MD (SMD) of improvement in the NIHSS from baseline did not favor either of the two techniques (SMD 0.01, 95% CI [–0.11 to 0.13]). Subgroup analysis did not show any difference between the two techniques after 24 h (SMD 0.01, 95% CI [–0.14 to 0.15]), after 7 days (SMD –0.04, 95% CI [–0.26 to 0.18]) or at discharge (SMD 0.08, 95% CI [–0.25 to –0.41]), [Figure 2] and [Supplementary File 1]. Subgroup analysis of the
improvement in NIHSS according to the study design did not show the superiority of either of the two techniques in the subgroup of the RCTs (SMD –0.01, 95% CI [–0.16 to 0.15]) or in the subgroup of the observational studies (SMD 0.05, 95% CI [–0.16 to 0.25]) [Figure 2] and [Supplementary File 1].

Similarly, subgroup analysis of the improvement in the NIHSS according to the site of vascular occlusion did not show superiority of either of the two techniques for the 4 studies conducted on patients with AIS in the anterior circulation occlusion (SMD –0.03, 95% CI [–0.16 to 0.09]), the two studies conducted on patients with basilar artery occlusion (SMD –0.11, 95% CI [–0.45 to 0.24]) or the two studies with (unspecified) intracranial arterial occlusion (SMD 0.36, 95% CI [0.04 to 0.68]). The pooled effect estimates on all subgroups were homogenous (Chi-square $P > 0.1$) [Figure 2] and [Supplementary File 1].

**Time to groin puncture**

The pooled analysis of the time to groin puncture reported by 18 studies ($n = 5729$ patients) did not favor either of the two techniques (SMD 0.81, 95% CI [–11.78 to 13.40]). The difference was not statistically significant in the subgroups of the RCTs or the observational studies [Supplementary File 2].

**Successful recanalization (TICI 2b-3)**

Twenty-nine studies ($n = 7560$ patients) reported the frequency of achieving successful recanalization (TICI 2b-3) by both techniques. The pooled risk ratio (RR) of successful recanalization (TICI 2b-3) favored aspiration thrombectomy technique (RR 1.06, 95% CI [1.02 to 1.10]) [Figure 3] and [Supplementary File 3].

Subgroup analysis of the rates of successful recanalization (TICI 2b-3) according to the study design showed that...
Table 1: Characteristics of the included studies.

| Study ID          | Design                      | Setting                        | From            | To              | N   | Occluded Vessel                                      | Time frame               |
|-------------------|-----------------------------|--------------------------------|-----------------|------------------|-----|------------------------------------------------------|--------------------------|
| Gerber et al. 2017[9] | Retrospective              | Single center, Germany         | January 2013    | April 2016       | 33  | Basilar Artery                                      | NR                       |
| Gory et al. 2018[10] | Retrospective              | 3 stroke centers, France       | March 2010      | October 2016     | 100 | Basilar Artery                                      | NR                       |
| Kang et al. 2018[11] | Retrospective              | 3 stroke centers, Korea        | January 2011    | August 2017      | 212 | Basilar Artery                                      | NR                       |
| Lapergue et al. 2016[12] | Prospective clinical registry | France                        | November 2012   | June 2014        | 243 | Anterior circulation large vessel occlusion         | Within 6 h               |
| Lapergue et al. 2017[13] | Retrospective              | 8 stroke centers, France       | October 2015    | October 2016     | 381 | Intracranial internal carotid artery M1 or M2 branches of the middle cerebral artery | Within 6 h               |
| Maegerlein et al. 2017[14] | Retrospective              | Germany                        | June 2014       | March 2016       | 97  | Distal internal carotid artery (ICA), Carotid-T, Middle cerebral artery (MCA), Anterior cerebral artery (ACA), Basilar artery (BA) occlusion | NR                       |
| Mokin et al. 2016[15] | Retrospective              | Multiple centers, USA          | March 2012      | March 2015       | 102 | Posterior circulation                               | NR                       |
| Procházka et al. 2018[16] | Retrospective              | Multiple centers, USA          | March 2012      | March 2016       | 113 | MCA M2                                               | Within 24 h              |
| Nishi et al. 2018[17] | Retrospective              | Single center, Japan           | December 2013   | February 2016    | 89  | Large intracranial arteries                         | Within 8 h               |
| Procházka et al. 2018[18] | Retrospective              | Single center, Korea           | March 2011      | December 2011    | 31  | Basilar Artery                                      | Within 8 h               |
| Stapleton et al. 2018[19] | Retrospective              | Single center, USA             | June 2012       | October 2015     | 117 | Anterior circulation large vessel occlusion         | Within 8 h               |
| Turk et al. 2014[20]   | Retrospective              | Single center, USA             | January 2009     | December 2013    | 222 | Middle cerebral artery (76.6%), Internal carotid artery (13.5%), Basilar artery (8.2%) occlusion | NR                       |
| Turk et al. 2019[21]   | RCT                         | 14 centers in the USA and one hospital in Canada | June 1, 2015    | July 5, 2017     | 270 | Anterior circulation large vessel occlusion         | Within 6 h               |
| O’Neill et al. 2019[22] | Retrospective study        | Single center, Ireland         | September 2017   | September 2018   | 254 | Internal carotid artery (28%), Middle cerebral artery (72%) occlusion | NR                       |

(Contd...)
| Study ID               | Design          | Setting                              | From          | To             | N    | Occluded Vessel                          | Time frame       |
|-----------------------|-----------------|--------------------------------------|---------------|----------------|------|------------------------------------------|------------------|
| Alawieh et al. 2019   | Retrospective   | Seven stroke centers in USA          | June 2013     | February 2018  | 1380 | Internal carotid artery, Middle cerebral artery, M1/M2 | NR               |
| Jeon et al. 2019      | Retrospective   | Single center, Korea                 | January 2013  | October 2019   | 62   | Middle cerebral artery M1 (53.2%) | Within 24 h      |
| Nabil et al. 2020     | Retrospective   | Single Center, Switzerland           | September 2014| March 2017     | 70   | Middle cerebral artery, M1/M2 | NR               |
| Lee et al. 2020       | Retrospective   | Single center, USA                   | March 2010    | December 2017  | 40   | vertebrobasilar occlusion | Within 24 h      |
| Atchaneeyasakul et al.2019 | Retrospective study | Three centers, USA               | October 1999  | June 2016       | 197  | Middle Cerebral Artery M2 Occlusion | NR               |
| Bernsen et al. 2019   | Retrospective   | Multi centers, Netherlands           | March 2014    | March 2014     | 1175 | Anterior circulation large-vessel occlusion | NR               |
| Kang et al. 2019      | Retrospective   | 17 stroke centers, South Korea       | January 2011  | December 2015  | 955  | Anterior circulation large-vessel occlusion | NR               |
| Haussen et al. 2020   | Retrospective   | Single center, USA                   | January 2014  | July 2018      | 144  | Distal arterial occlusions (DAO) involving the MCA (mid or distal M2 segment, M3 segment), ACA (A1, A2, A3), or PCA (P1, P2) | NR               |
| Xing et al. 2020      | Retrospective   | Single center, China                 | September 2013| November 2018  | 109  | Terminal internal carotid artery       | Within 16 h      |
| Brehm et al. 2019     | Retrospective   | Single center, Germany               | January 2014  | September 2017 | 171  | Anterior circulation large-vessel occlusion | NR               |
| Consoli et al. 2018   | Retrospective   | Two stroke centers, France           | January 2016  | April 2016     | 84   | M1-middle cerebral artery occlusion | NR               |
| Kaiser et al. 2020    | Retrospective   | Single centre, Germany               | January 2016  | December 2018  | 203  | M1-middle cerebral artery              | NR               |
| Kaneko et al. 2019    | Retrospective   | 12 stroke centers, Japan              | January 2015  | December 2017  | 48   | Basilar artery                        | NR               |

NR: Not reported

the observational studies (1.06, 95% CI [1.02 to 1.11]) but not the RCTs (1.05, 95% CI [0.97 to 1.15]) had statistically significant pooled RR in favor of the ADAPT group.

**Complete recanalization (TICI 3)**

Seventeen studies (n=3824 patients) reported the frequency of achieving complete perfusion (mTICI 3) by
Table 2: The characteristics of the included studies’ populations.

| Study ID | Group | N | Age | Males | NIHSS (Pre) | Prior thrombolysis | General Anesthesia |
|----------|-------|---|-----|-------|-------------|--------------------|-------------------|
| Xing et al. 2020 | ADAPT | 40 | 68.3 (14.0) | 21 | 21 (15–23) | 12 | NR |
| Brehm et al. 2019 | ADAPT | 72 | 72.6 (14.1) | 30 | 16 (9–20) | 50 | NR |
| Kaiser et al. 2020 | ADAPT | 155 | 75.3 (65.5–81.2) | 73 | 16 (11–20) | 118 | NR |
| Bernsen et al. 2019 | ADAPT | 207 | 68.50 (54–77) | 112 | 16 (12–19) | 156 | 110 |
| Kaiser et al. 2019 | ADAPT | 155 | 75.3 (65.5–81.2) | 73 | 16 (11–20) | 118 | NR |
| Alawieh et al. 2019 | ADAPT | 868 | 67.5 (15.0) | 420 | 16.2 (7) | 372 | NR |
| Hesse et al. 2018 | ADAPT | 164 | 72 (60–79) | 75 | 15.3 (6.1) | NR | NR |
| Procházka et al. 2018 | ADAPT | 100 | 69 (61–75) | 53 | NR | 52 | 53 |
| Martini et al. 2019 | ADAPT | 121 | 68.9 (15.8) | 56 | 15.7 (6.7) | 65 | 66 |
| Kang et al. 2018 | ADAPT | 107 | 69.8 (15.1) | 49 | 16.4 (6.9) | 59 | NR |
| Turk 2019 (COMPASS trial) | ADAPT | 134 | 71.8 (13.1) | 58 | 7.5 (9) | 92 | 39 |
| Stapleton et al. 2018 | ADAPT | 47 | 63.5 | 26 | 16.5 | 34 | 7 |
| Gory et al. 2018 | ADAPT | 46 | 61 (53–71) | 27 | 14 (9–25) | 23 | 38 |
| Lapergue et al. 2017 (ASTER trial) | ADAPT | 189 | 68.1 | 104 | 16.1 (6.5) | 124 | 25 |
| Nishi et al. 2018 | ADAPT | 54 | 67 (53–78) | 34 | 20 (11–30) | 22 | 46 |
| Mokin et al. 2017 | ADAPT | 45 | 77.8 | 26 | 19 (15–26) | 21 | 2 |
| Mokin et al. 2016 | ADAPT | 51 | 67.0 (14.5) | 67 | 15 (median) | 52 | 31 |
| Maegerlein et al. 2017 | ADAPT | 36 | 72.4 (15.7) | 22 | NR | 21 | NR |
| Lapergue et al. 2016 | ADAPT | 124 | 64.3 (15.7) | 61 | 15.9 (6.5) | 82 | NR |

(Contd...)
both techniques, the pooled RR of complete perfusion (mTICI 3) favored the ADAPT technique (RR 1.20, 95% CI [1.01 to 1.43]) [Figure 3] and [Supplementary File 4].

Subgroup analysis of the complete perfusion (mTICI 3) according to the study design showed that the pooled RR did not favor any of both techniques either in the RCTs (RR 1.10, 95% CI [0.83 to 1.46]) or in the observational studies (RR 1.22, 95% CI [1.0 to 1.49]).

**Mortality**

Five studies (n = 729 patients) reported the in-hospital mortality while ten studies (n = 2901 patients) reported the 90-day mortality. Neither the pooled RR of the in-hospital mortality nor the 90-day mortality favored either of the two groups (RR 0.89 and RR 0.92; both P > 0.05) [Figure 3] and [Supplementary Files 5 and 6].

**Favorable outcome (mRS of 0-2)**

The frequency of patients with favorable outcome according to the mRS score (ranging from 0 to 2) was reported by 22 studies (n = 6244 patients), the pooled RR of favorable outcome (mRS 0-2) did not favor either of the two techniques (RR 0.99, 95% CI [0.93 to 1.05]) [Figure 3] and [Supplementary File 7].

**Rescue therapy**

The frequency of the patients who required rescue therapy was reported by 15 studies (n = 3079 patients), the pooled RR of rescue therapy showed that more patients in the ADAPT group required rescue therapy compared with the SR group (RR 1.81, 95% CI [1.29 to 2.54]) [Figure 3] and [Supplementary File 8].

**Prior thrombolysis**

The frequency of patients with prior thrombolysis was reported by 23 studies (n = 6763 patients), the pooled RR of prior thrombolysis did not favor either of the two techniques (RR 1.00, 95% CI [0.93 to 1.07]) [Figure 3] and [Supplementary File 9].

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**Table 2: (Continued).**

| Study ID     | Design | Setting | From | To    | N    | Occluded Vessel | Time frame |
|--------------|--------|---------|------|-------|------|-----------------|------------|
| Gerber et al. 2017 | ADAPT | 20      | 62.8 | 14    | 18 (28)* | 12               | NR         |
|              | SR     | 13      | 63.2 | 8     | 25 (19)* | 11               |            |
| Son et al. 2016   | ADAPT | 18      | 66.4 (11.4) | 14 | 21.3 (9.7) | 9               | NR         |
|              | SR     | 13      | 68.9 (10.4) | 7  | 27.3 (11)  | 5               |            |
|              | SR     | 55      | 69.6 | 23    | 16.8  | 33               |            |

NR: Not reported, ADAPT: A direct aspiration first pass technique, SR: Stent-retriever
General anesthesia

The frequency of patients who underwent general anesthesia was reported by 7 studies (n = 3561 patients), the pooled RR of the frequency of general anesthesia did not favor either of the two techniques (RR 0.81, 95% CI [0.48 to 1.36]) [Figure 3] and [Supplementary File 10].

Intracerebral haemorrhage

The frequency of patients with ICH was reported by 8 studies (n = 2063 patients), the pooled RR of intracranial haemorrhage did not favor either of the two techniques (RR 1.22, 95% CI [0.90 to 1.66]) [Figure 3] and [Supplementary File 10].

Occurrence of embolus in a new territory

The frequency of patients with ENT was reported by 11 studies (n = 1876 patients), the pooled RR of occurrence of an embolus in a new territory did not favor either of the two techniques (RR 1.13, 95% CI [0.73 to 1.73]) [Figure 3] and [Supplementary File 11].

Symptomatic intracerebral haemorrhage

The frequency of patients with sICH was reported by 14 studies (n = 4504 patients), the pooled RR of symptomatic intracranial haemorrhage did not favor either of the two techniques (RR 0.91, 95% CI [0.54 to 1.54]) [Figure 3] and [Supplementary File 12].

Haemorrhagic infarction

The frequency of the patients with haemorrhagic infarction was reported by 3 studies (n = 626 patients), the pooled RR of haemorrhagic infarction did not favor either of the two techniques (RR 1.04, 95% CI [0.63 to 1.72]) [Figure 3] and [Supplementary File 14].

Parenchymal hematoma

The frequency of patients with parenchymal hematoma was reported by 9 studies (n = 1389 patients), the pooled RR of parenchymal hematoma did not favor either of the two techniques (RR 0.83, 95% CI [0.58 to 1.19]) [Figure 3] and [Supplementary File 15].

SAH

The frequency of SAH in the two groups was reported by 9 studies (n = 1289 patients), the pooled RR of SAH did not favor either of the two techniques (RR 0.78, 95% CI [0.45 to 1.37]) [Figure 3] and [Supplementary File 16].

Procedural complications

The frequency of patients with procedural complications was reported by 9 studies (n = 3916 patients), the pooled RR of procedural complications did not favor either of the two techniques (RR 0.93, 95% CI [0.80 to 1.08]) [Figure 3] and [Supplementary File 17].

Subgroup analysis

We conducted subgroup analysis for the main outcomes according to the study design (RCTs only vs. observational studies vs. all studies). Data showed consistent results in both RCTs and observational studies except for the outcome of successful recanalization (TICI 2b-3) where RCTs showed no difference between the ADAPT, and the SR while observational studies reported significantly higher

| Outcome                                      | RCTs only                        | Observational studies only                     | All studies                         |
|-----------------------------------------------|----------------------------------|-----------------------------------------------|-------------------------------------|
| Improvement in NIHSS score                    | No difference -0.01 (-0.16, 0.15)| No difference 0.05 (-0.16, 0.25)              | No difference 0.01 (-0.11, 0.13)    |
| Onset to groin time                           | No difference -6.67 (-23.17, 9.83)| No difference 3.19 (-12.77, 19.15)            | No difference 0.81 (-11.78, 13.40) |
| Successful recanalization (TICI 2b-3)        | No difference 1.05 (0.97, 1.15)  | Favours ADAPT technique 1.06 (1.02, 1.11)    | Favours ADAPT technique 1.06 (1.02, 1.10) |
| Complete perfusion (TICI 3)                  | No difference 1.10 (0.83, 1.46)  | No difference 1.22 (1.00, 1.49)               | No difference 1.20 (1.01, 1.43)     |
| Prior thrombolysis                            | No difference 0.99 (0.89, 1.10)  | No difference 1.00 (0.92, 1.09)               | No difference 1.00 (0.93, 1.07)     |
| General anesthesia                            | No difference 0.92 (0.68, 1.25)  | No difference 0.77 (0.40, 1.49)               | No difference 0.81 (0.48, 1.36)     |
| Parenchymal hematoma                          | No difference 0.74 (0.47, 1.18)  | No difference 0.99 (0.55, 1.79)               | No difference 0.83 (0.58, 1.19)     |
| 90-day mortality                              | No difference 1.00 (0.73, 1.36)  | No difference 0.91 (0.78, 1.05)               | No difference 0.92 (0.81, 1.06)     |
| 90-day favorable outcome (mRS 0-2)            | No difference 0.97 (0.82, 1.13)  | No difference 0.99 (0.93, 1.06)               | No difference 0.99 (0.93, 1.05)     |
| Occurrence of ENT                             | No difference 1.55 (0.61, 3.97)  | No difference 1.06 (0.64, 1.75)               | No difference 1.13 (0.73, 1.73)     |
| Procedural complications                      | No difference 0.98 (0.68, 1.41)  | No difference 0.88 (0.67, 1.15)               | No difference 0.93 (0.80, 1.08)     |

RCT: Randomized controlled trials, NIHSS: National Institutes of Health Stroke Scale, ADAPT: A direct aspiration first pass technique
successful recanalization rates in ADAPT compared with the SR [Table 3].

Further, we conducted subgroup analysis for the main outcomes according to the site of stroke (anterior circulation vs. posterior circulation). Data were consistent in the subgroups of anterior circulation and posterior circulation except that the risks of emboli in a new territory was significantly lower in the ADAPT compared with the SR in the subgroup of posterior circulation [Table 4].

**DISCUSSION**

The development of mechanical thrombectomy technology has revolutionized the treatment of patients with AIS. The SR technique is the current gold-standard mechanical thrombectomy technique used in patients with AIS. However, despite the results of RCTs showing favorable outcomes of this technique, the rate of successful revascularization is still considered suboptimal. Therefore, using large-bore aspiration catheters during routine clinical practice has been widely debated in medical literature.

The ADAPT method was developed by Turk et al.\[13\] to achieve a higher recanalization rate in a shorter period of time. The method was initially described as fast, safe, simple, and effective.\[39\] However, the major limitation of the ADAPT method was the unavailability of the catheter technology needed to perform such a procedure. This technique started to gain acceptance recently after solving the catheter availability problem by developing the latest generation of tractable large-bore aspiration catheter, which provides sufficient aspiration force and easy manoeuvrability to navigate through the cerebral vasculature. However, it is still debatable whether the ADAPT technique should be preferred over the conventional SR technique for AIS owing to the inconsistent data reported in the literature. Therefore, we conducted this meta-analysis to synthesize evidence from published studies on ADAPT outcomes compared with SR using data from head-to-head comparative studies.

Our meta-analysis provides evidence that the ADAPT technique achieves slightly higher rates of successful recanalization and complete recanalization than the conventional SR technique. However, the subgroup analysis showed that this significant effect size in successful recanalization was mainly driven by observational studies but not RCTs. On the contrary, the ADAPT method was associated with higher need for rescue therapy (defined as the use of another endovascular strategy after failure of the initially used technique [mTICI 0-2a]) as compared with the SR. There were no significant differences between the two techniques in terms of mortality at discharge, mortality after 90 days, change in NIHSS score, the favorable outcome (mRS of 0-2), time to the groin puncture, or frequency of complications as ICH, sICH, the occurrence of an embolus in a new territory, hemorrhagic infarction, parenchymal hematoma, SAH, and procedural complications.

The main finding of our meta-analysis that ADAPT provides higher successful recanalization rates compared with the conventional SR is concordant with the findings of Phan et al.\[31\] and Ye et al.\[42\]. The meta-analysis of Phan et al.\[31\] provided an indirect comparison between the two techniques, pooling single-arm data into two subgroups. Our findings are consistent with Phan et al.\[31\] that ADAPT provides a higher successful recanalization rate, but we found a superiority of ADAPT in the rate of complete perfusion, which was not significant in their meta-analysis. A limitation of their meta-analysis methods was the indirect comparison between the two arms, limiting the generalizability of their findings. Our meta-analysis provides more robust evidence by including comparative data from a head-to-head comparison between the two techniques.

Our finding that the ADAPT provides a higher successful recanalization rate and a higher complete recanalization rate (mTICI 3) is reasonable and is supported by the previous

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**Table 4: Summary of the subgroup analysis results, data are stratified according to the site of stroke into anterior circulation, posterior circulation, and all studies.**

| Outcome                                      | Anterior circulation | Posterior circulation | All studies       |
|----------------------------------------------|----------------------|-----------------------|-------------------|
| Improvement in NIHSS score                   | No difference –0.03 (–0.16, 0.09) | No difference –0.11 (−0.45, 0.24) | No difference –0.04 (–0.16, 0.08) |
| Onset to groin time                          | No difference 0.04 (−0.18, 0.11) | No difference 0.06 (−0.08, 0.20) | No difference –0.01 (–0.11, 0.11) |
| Successful recanalization (TICI 2b-3)        | No difference 1.05 (0.99, 1.12) | No difference 1.10 (0.98, 1.25) | No difference 1.06 (1.00, 1.12) |
| Complete perfusion (TICI 3)                  | No difference 1.09 (0.89, 1.33) | No difference 1.22 (0.92, 1.62) | No difference 1.13 (0.97, 1.32) |
| Prior thrombolysis                           | No difference 1.01 (0.93, 1.10) | No difference 0.89 (0.58, 1.37) | No difference 1.00 (0.93, 1.09) |
| Parenchymal hematoma                         | No difference 0.82 (0.54, 1.24) | No difference 1.06 (0.37, 2.99) | No difference 0.85 (0.57, 1.25) |
| 90-day mortality                             | No difference 1.06 (0.77, 1.46) | No difference 1.03 (0.63, 1.67) | No difference 1.05 (0.81, 1.37) |
| Occurrence of emboli in new territory        | No difference 1.18 (0.82, 1.71) | Favors ADAPT 0.25 (0.07, 0.96) | No difference 1.06 (0.66, 1.70) |
| 90-day favorable outcome (mRS 0-2)           | No difference 0.97 (0.90, 1.04) | No difference 0.93 (0.74, 1.18) | No difference 0.96 (0.90, 1.03) |

NIHSS: National Institutes of Health Stroke Scale, ADAPT: A direct aspiration first pass technique.
literature. Phan et al.\textsuperscript{[31]} reported from an indirect meta-analysis that ADAPT patients tended to have more excellent neurologic outcomes ($P = 0.11$), although the difference was not statistically significant. There is now a general understanding that patients with mTICI 3 are more likely to have the excellent neurologic outcome (mRS 0-1) after a stroke event. Therefore, our findings that ADAPT provides a higher complete recanalization rate corroborates the trend analysis of excellent neurologic outcome (mRS 0-1) reported by Phan et al.\textsuperscript{[31]} previously. While this difference in complete recanalization rate was not statistically significant in previous individual studies, our meta-analysis provides a larger sample size and higher statistical power to allow small effect estimates to be detectable. However, the clinical significance of this slight difference remains questionable.

In terms of the need for rescue therapy, Gory et al.\textsuperscript{[30]} Lapergue et al.\textsuperscript{[21]} and Nishi et al.\textsuperscript{[29]} reported that more patients in the ADAPT group required rescue therapy which is in line with our findings. Ye et al.\textsuperscript{[42]} did not find any differences between the ADAPT and the SR groups in terms of the need for rescue therapy. However, our meta-analysis showed that patients who underwent the ADAPT required more rescue therapy than those who underwent the SR technique. This discrepancy could be justified by our meta-analysis pooling data from a larger set of studies (30 studies) and a larger sample size (7868 patients), which provides the high statistical power to detect small differences between the thrombectomy techniques.

In Table 5, we provide a summary of findings from 3 previous meta-analyses that directly and indirectly provided partial evidence on the comparison between ADAPT and SR for AIS. However, it is noteworthy that these studies have major limitations, including (1) dropping significant portions of the literature at the screening process, or (2) the authors selected a particular type of stroke patients to study; Ye et al.\textsuperscript{[42]} compared the ADAPT and SR for acute basilar artery occlusion, or (3) providing indirect rather than a direct head-to-head comparison between the two arms, which is an unreliable method to establish the superiority of a technique as long as direct evidence exists in the literature.

We conducted subgroup analysis according to the study design and site of stroke. These results were consistent across the strata except that the difference in the successful recanalization was significant in observational studies but not in the RCTs suggesting that this difference was mainly driven by observational studies which have less internal validity and higher risk of confounders compared with well-designed RCTs. Besides, in the subgroup of posterior circulation occlusion, the occurrence of ENT was significantly lower in the ADAPT group compared with the SR. These results are consistent with the findings of Ye et al.\textsuperscript{[42]} who meta-analyzed data from 5 studies to compare both ADAPT and SR in basilar artery occlusion. The authors explained this difference by the fact that ADAPT does not require passing through the thrombus and therefore carries a lower risk of thrombus fragmentation, in addition to the lower risks of endothelial injury with ADAPT as reported in studies on experimental animal models. However, this difference in emboli occurrence was not observed in the case of anterior circulation. This variation in the risk of ENT in anterior and posterior circulations remains open for discussion.

The strengths of our meta-analysis are the following: (1) we ran an extensive search on multiple medical electronic databases; (2) we included all observational studies and clinical trials comparing the two techniques; (3) we followed the guidelines of the Cochrane Handbook for Systematic Reviews of Interventions when conducting this systematic review and we reported this manuscript according to the PRISMA statement. The major limitation of our meta-analysis is that most of the

| Table 5: A summary of the findings of previous meta-analyses. |
|---------------------------------------------------------------|
| **Phan et al.\textsuperscript{[31]}** | **Qin et al.\textsuperscript{[33]}** | **Ye et al.\textsuperscript{[42]}** | **Our study** |
| Number of studies | 23 studies | 9 studies | 5 studies (basilar artery stroke only) | 30 studies |
| Number of patients | 1915 patients | 1273 patients | 476 patients | 7868 patients |
| Complete reperfusion | NR | No difference | No difference | ADAPT (higher) |
| Successful recanalization (partial perfusion) | ADAPT (higher) | No difference | ADAPT (higher) | ADAPT (higher) |
| Favorable outcome | No difference | ADAPT (higher) | No difference | No difference |
| Mortality | No difference | NR | No difference | No difference |
| sICH | No difference | ADAPT (less) | NR | No difference |
| ICH | NR | No difference | NR | No difference |
| ENT | NR | ADAPT (less) | ADAPT (less) | No difference |
| Rescue therapy | NR | NR | No difference | SR (less) |
| General anesthesia | NR | NR | NR | No difference |
| Time to groin | No difference | NR | NR | No difference |
| Procedure time | No difference | ADAPT (less) | ADAPT (less) | No difference |

NR: Not reported; ICH: Intracranial hemorrhage. ADAPT: A direct aspiration first pass technique.
included studies are observational; it is known that observational studies might suffer from confounding bias and are not reliable in establishing a causal relationship between the intervention and the clinical outcome. Only two studies were described as well-designed RCTs, and 28 studies were observational studies, which invites future research to compare both techniques in RCT design to confirm and update our findings.

CONCLUSION

Current evidence supports the use of the ADAPT technique to achieve successful and complete recanalization while considering the higher need for rescue therapy in some patients.

Availability of data, code, and other materials

Data of this study and the Review Manager file (.rm file) are available upon request.

Declaration of patient consent

Patient’s consent not required as there are no patients in this study.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Adams HP, Davis PH, Leira EC, Chang KC, Bendixen BH, Clarke WR, et al. Baseline NIH stroke scale score strongly predicts outcome after stroke: A report of the trial of org 10172 in acute stroke treatment (TOAST). Neurology 1999;53:126–31.
2. Alawieh A, Chatterjee AR, Vargas J, Chaudry MI, Lena J, Turner R, et al. Lessons learned over more than 500 stroke thrombectomies using ADAPT with increasing aspiration catheter size. Neurosurgery 2020;86:61–70.
3. Atchaneyyasakul K, Malik AM, Yavagal DR, Haussen DC, Jadhav AP, Bouslama M, et al. Thrombectomy outcomes in acute ischemic stroke due to middle cerebral artery M2 occlusion with stent retriever versus aspiration: A multicenter experience. Interv Neur 2020;8:180–6.
4. Bernsen ML, Goldhoorn RJ, van Oostenbrugge RJ, van Zwam WH, Uyttenboogaart M, Roos YB, et al. Equal performance of aspiration and stent retriever thrombectomy in daily stroke treatment. J Neurointerv Surg 2019;11:631–6.
5. Brehm A, Maus V, Tsogkas I, Colla R, Hesse AC, Gera RG, et al. Stent-retriever assisted vacuum-locked extraction (SAVE) versus a direct aspiration first pass technique (ADAPT) for acute stroke: Data from the real-world. BMC Neurol 2019;19:65.
6. Campbell BC, Mitchell PJ, Kleining TJ, Dewey HM, Churilov L, Yassi N, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med 2015;372:1009–18.
7. Consoli A, Rosi A, Coskun O, Nappini S, Di Maria F, Renieri L, et al. Thrombectomy for M1-middle cerebral artery occlusion: Angiographic aspect of the arterial occlusion and recanalization: A preliminary observation. Stroke 2018;49:1286–9.
8. Donkor ES. Stroke in the 21st century: A snapshot of the burden, epidemiology, and quality of life. Stroke Res Treat 2018;2018:3238165.
9. Gerber JC, Daubner D, Kaiser D, Engellandt K, Haedrich K, Mueller A, et al. Efficacy and safety of direct aspiration first pass technique versus stent-retriever thrombectomy in acute basilar artery occlusion—a retrospective single center experience. Neuroradiology 2017;59:297–304.
10. Gory B, Mazighi M, Blanc R, Labreuche J, Piotin M, Turjman F, et al. Mechanical thrombectomy in basilar artery occlusion: Influence of reperfusion on clinical outcome and impact of the first-line strategy (ADAPT vs stent retriever). J Neurosurg 2018;129:1482–91.
11. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 2015;372:1019–30.
12. Haussen DC, Eby B, Al-Bayati AR, Grossberg JA, Rodrigues GM, Frankel MR, et al. A comparative analysis of 3MAX aspiration versus 3 mm Trevo Retrieval for distal occlusion thrombectomy in acute stroke. J Neurinterv Surg 2020;12:279–82.
13. Hemkens LG, Ewald H, Gloy VL, Olu KK, Niderf M, et al. Colchicine for prevention of cardiovascular events. Cochrane Database Syst Rev 2016;2016:CD011047.
14. Hesse AC, Behme D, Kemmling A, Zapf A, Hokamp NG, Frischmuth I, et al. Comparing different thrombectomy techniques in five large-volume centers: A “real world” observational study. J Neurointerv Surg 2018;10:525–9.
15. Jeon Y, Baik SH, Jung C, Kim JY, Kim BJ, Kang J, et al. Mechanical thrombectomy in patients with acute cancer-related stroke: Is the stent retriever alone effective? J Neurointerv Surg 2021;13:318–23.
16. Kaiser D, Laske K, Winzer R, Haedrich K, Wahl H, Krukowsk W, et al. Impact of thrombus surface on first pass reperfusion in contact aspiration and stent retriever thrombectomy. J Neurointerv Surg 2021;13:221–5.
17. Kaneko J, Ota T, Tagami T, Unemoto K, Shigeta K, Amano T, et al. Endovascular treatment of acute basilar artery occlusion: Tama-Registry of acute thrombectomy (TREAT) study. J Neurol Sci 2019;401:29–33.
18. Kang DH, Jung C, Yoon W, Kim SK, Baek BH, Kim JT, et al. Endovascular thrombectomy for acute basilar artery occlusion: A multicenter retrospective observational study. J Am Heart Assoc 2018;7:e009419.
19. Kang DH, Kim JW, Kim BM, Heo JH, Nam HS, Kim YD, et al. Need for rescue treatment and its implication: Stent retriever versus contact aspiration thrombectomy. J Neurointerv Surg 2019;11:979–83.
20. Lapergue B, Blanc R, Gory B, Labreuche J, Duhamel A, Marnat G, et al. Effect of endovascular contact aspiration vs stent retriever on revascularization in patients with acute
ischemic stroke and large vessel occlusion: The ASTER randomized clinical trial. JAMA 2017;318:443-52.
21. Lapergue B, Blanc R, Guedin P, Decroix JP, Labreuche J, Preda C, et al. A direct aspiration, first pass technique (ADAPT) versus stent retrievers for acute stroke therapy: An observational comparative study. AJNR Am J Neuroradiol 2016;37:1860-5.
22. Lee DH, Kim SH, Lee H, Kim S Bin, Lee D, et al. Thrombectomy in acute vertebrobasilar occlusion: A single-centre experience. Neuroradiology 2020;62:723-31.
23. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. PLoS Med 2009;6:e1000100.
24. Maegerlein C, Prothmann S, Lucia KE, Zimmer C, Friedrich B, Kaesmacher J. Intraprocedural thrombus fragmentation during interventional stroke treatment: A comparison of direct thrombus aspiration and stent retriever thrombectomy. Cardiovasc Intervent Radiol 2017;40:987-93.
25. Martini M, Mocco J, Turk A, Siddiqui AH, Fiorella D, Hanel RA, et al. "Real-world” comparison of first-line direct aspiration and stent retriever mechanical thrombectomy for the treatment of acute ischemic stroke in the anterior circulation: A multicenter international retrospective study. J Neurointerv Surg 2019;11:957-63.
26. Mokin M, Primiani CT, Ren Z, Kan P, Duckworth E, Turner RD 4th, et al. Endovascular treatment of middle cerebral artery M2 occlusion strokes: Clinical and procedural predictors of outcomes. Neurosurgery 2017;81:795-802.
27. Mokin M, Sonig A, Sivakanthan S, Ren Z, Elijovich I, Arthur A, et al. Clinical and procedural predictors of outcomes from the endovascular treatment of posterior circulation strokes. Stroke 2016;47:782-8.
28. Nabil M, Chater G, Correia P, Wegener S, Baltasvias G. Thrombectomy-related emboli: Direct aspiration versus stent retriever thrombectomy for acute ischemic stroke: Our experience and literature review. World Neurosurg 2020;135:e588-97.
29. Nishi H, Ishii A, Nakahara I, Matsumoto S, Sadamasa N, Kai Y, et al. Different learning curves between stent retrieval and a direct aspiration first-pass technique for acute ischemic stroke. J Neurosurg 2018;129:1456-63.
30. O’Neill D, Griffin E, Doyle KM, Power S, Brennan P, Sheehan M, et al. A standardized aspiration-first approach for thrombectomy to increase speed and improve recanalization rates. AJNR Am J Neuroradiol 2019;40:1335-41.
31. Phan K, Dmytriw AA, Teng I, Moore JM, Griessenauer C, Ogilvy C, et al. A direct aspiration first pass technique vs standard endovascular therapy for acute stroke: A systematic review and meta-analysis. Clin Neurosurg 2018;83:19-27.
32. Procházka V, Jonszta T, Czerny D, Krajač J, Roubec M, Hurtikova E, et al. Comparison of mechanical thrombectomy with contact aspiration, stent retriever, and combined procedures in patients with large-vessel occlusion in acute ischemic stroke. Med Sci Monit Int Med J Exp Clin Res 2018;24:9342-53.
33. Qin C, Shang K, Xu SB, Wang W, Zhang Q, Tian DS. Efficacy and safety of direct aspiration versus stent-retriever for recanalization in acute cerebral infarction. Medicine (Baltimore) 2018;97:e12770.
34. Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015;372:2285-95.
35. Sivan-Hoffmann R, Gory B, Rabiloud M, Gherasim DN, Armoiry X, Riva R, et al. Patient A meta-analysis and review of the literature. Isr Med Assoc J 2016;18:561-6.
36. Son S, Choi DS, Oh MK, Hong J, Kim SK, Kang H, et al. Comparison of Solitaire thrombectomy and Penumbra suction thrombectomy in patients with acute ischemic stroke caused by basilar artery occlusion. J Neurointerv Surg 2016;8:13-8.
37. Stapleton C, Leslie-Mazwi TM, Torok CM, Hakimelahi R, Hirsch JA, Yoo AJ, et al. A direct aspiration first-pass technique vs stent retriever thrombectomy in emergent large vessel intracranial occlusions. J Neurosurg 2018;128:567-74.
38. Turk AS 3rd, Siddiqui A, Fifi JT, De Leacy RA, Fiorella DI, Gu E, et al. Aspiration thrombectomy versus stent retriever thrombectomy as first-line approach for large vessel occlusion (COMPASS): A multicentre, randomised, open label, blinded outcome, non-inferiority trial. Lancet (London, England) 2019;393:998-1008.
39. Turk AS, Frei D, Fiorella D, Mocco J, Baxter B, Siddiqui A, et al. ADAPT FAST study: A direct aspiration first pass technique for acute stroke thrombectomy. J Neurointerv Surg 2014;6:260-4.
40. Turk AS, Spiotta A, Frei D, Mocco J, Baxter B, Fiorella D, et al. Initial clinical experience with the ADAPT technique: A direct aspiration first pass technique for stroke thrombectomy. J Neurointerv Surg 2018;10:ii20-5.
41. Xing PF, Yang PF, Li ZF, Zhang L, Shen HJ, Zhang YX, et al. Comparison of aspiration versus stent retriever thrombectomy as the preferred strategy for patients with acute terminal internal carotid artery occlusion: A propensity score matching analysis. AJNR Am J Neuroradiol 2020;41:469-76.
42. Ye G, Lu J, Qi P, Yin X, Wang L, Wang D. Firstline a direct aspiration first pass technique versus firstline stent retriever for acute basilar artery occlusion: A systematic review and meta-analysis. J Neurointerv Surg 2019;11:740-6.

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