Endovascular thrombectomy with or without intravenous alteplase for acute ischemic stroke due to large vessel occlusion: a systematic review and meta-analysis of randomized trials

Xin Wang, Zhikang Ye, Jason W Busse, Michael D Hill, Eric E Smith, Gordon H Guyatt, Kameshwar Prasad, M Patrice Lindsay, Hui Yang, Yi Zhang, Rachel J Couban, Zhuoling An

ABSTRACT

Background Among patients who had an ischaemic stroke presenting directly to a stroke centre where endovascular thrombectomy (EVT) is immediately available, there is uncertainty regarding the role of intravenous thrombolysis agents before or concurrently with EVT. To support a rapid guideline, we conducted a systematic review and meta-analysis to examine the impact of EVT alone versus EVT with intravenous alteplase in patients who had an acute ischaemic stroke due to large vessel occlusion.

Methods In November 2021, we searched MEDLINE, Embase, PubMed, Cochrane, Web of Science, clinicaltrials.gov and the ISRCTN registry for randomised controlled trials (RCTs) comparing EVT alone versus EVT with alteplase for acute ischaemic stroke. We conducted meta-analyses using fixed effects models and assessed the certainty of evidence using the GRADE approach.

Results In total 6 RCTs including 2334 participants were eligible. Low certainty evidence suggests that, compared with EVT and alteplase, there is possibly a small decrease in the proportion of patients independent with EVT alone (risk ratio (RR) 0.97, 95% CI 0.89 to 1.05; risk difference (RD) −1.5%; 95% CI −5.4% to 2.5%), and possibly a small increase in mortality with EVT alone (RR 1.07, 95% CI 0.88 to 1.29; RD 1.2%, 95% CI −2.0% to 4.9%). Moderate certainty evidence suggests that there is probably a small decrease in symptomatic intracranial haemorrhage (sICH) with EVT alone (RR 0.75, 95% CI 0.52 to 1.07; RD −1.0%; 95% CI −1.8% to 0.27%).

Conclusions Low certainty evidence suggests that there is possibly a small decrease in the proportion of patients that achieve functional independence and a small increase in mortality with EVT alone. Moderate certainty evidence suggests that there is probably a small decrease in sICH with EVT alone. The accompanying guideline provides contextualised guidance based on this body of evidence.

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INTRODUCTION

Over 2.7 million people die of ischaemic stroke each year, and many who recover are left with permanent disabilities. Approximately 21% of acute ischaemic stroke are due to large vessel occlusion for which the standard of care has historically been intravenous alteplase, a thrombolytic medication. More recently, direct mechanical reperfusion with endovascular thrombectomy (EVT) has proven effective. Both treatments are extremely time-sensitive, and delays of 15 min in treatment initiation are associated with worse outcomes.
Among patients who had an ischaemic stroke are eligible for and can be treated with both interventions immediately, there has been uncertainty regarding the role of intravenous alteplase.\textsuperscript{5} \textsuperscript{6} Thrombolytic agents, such as alteplase, may contribute to early reperfusion of the ischaemic area and resolve residual distal thrombi after EVT.\textsuperscript{7} \textsuperscript{8} \textsuperscript{9} \textsuperscript{10} For large, proximally located thrombi, however, the rate of early recanalisation is low in the first hour following alteplase administration, and fragmentation with distal embolisation of the target thrombus can result in worsening distal perfusion, potentially complicating EVT.\textsuperscript{5} \textsuperscript{11}

In the last 18 months, six randomized trials have been completed that provide evidence to address this uncertainty.\textsuperscript{13} \textsuperscript{14} \textsuperscript{15} \textsuperscript{16} \textsuperscript{17} \textsuperscript{18} We conducted a systematic review and meta-analysis to explore the benefits and harms of EVT with or without intravenous alteplase for acute stroke due to large vessel occlusion. Our findings supported the development of a clinical practice guideline (Personal communication: Ye Z, Busse J, Hill M. Endovascular thrombectomy and intravenous alteplase in patients with acute ischemic stroke: a rapid clinical practice guideline. 2022).

METHODS
We followed the Preferred Reporting Items for Systematic Review and Meta-Analysis checklist\textsuperscript{19} when writing our report. All subjective decisions (ie, study selection, data abstraction, risk-of-bias assessment) were made in duplicate by independent reviewers, and any disagreements were resolved by discussion or by referral to a third reviewer.

Guideline panel involvement
A guideline panel provided critical oversight of different steps of this review, including: (1) defining the study question; (2) prioritising outcome measures; and (3) informing if measures of precision associated with pooled effect estimates were imprecise. The panel included seven general stroke experts, three neurointerventionalists, six methodologists, four patient partners who had recovered from an acute ischaemic stroke and received thrombectomy with or without intravenous thrombolysis, one caregiver, two academic pharmacists, one emergency physician and one health economist. All patients received personal training and support to optimise contributions throughout the guideline development process. The members of the guideline panel led the interpretation of the results based on what they expected the typical values and preferences of patients to be, as well as the variation between patients.

Data sources and search strategy
We searched MEDLINE, Embase, PubMed, Cochrane Central Register of Controlled Trials, Web of Science, clinicaltrials.gov and the International Standard Randomized Controlled Trial Number (ISRCTN) registry from inception to 22 November 2021. No language restrictions were applied, and a research information specialist (RJC) developed all database-specific search strategies (online supplemental appendix 1). We reviewed the reference lists of all included studies and relevant systematic reviews for additional eligible trials. In addition, we searched abstracts for the past 3 years of proceedings of the International Stroke Conference, European Stroke Conference, Asia-Pacific Stroke Meeting and the World Stroke Congress.

Study selection
We included randomized controlled trial (RCTs) that enrolled patients who had an acute ischaemic stroke due to large vessel occlusion and randomised them to receive EVT with intravenous alteplase versus EVT alone. Pairs of reviewers independently screened titles and abstracts and reviewed the full texts of potentially eligible studies.

Data extraction
Each eligible trial underwent duplicate data abstraction by pairs of reviewers working independently, who collected study characteristics, patient information including number enrolled, age, sex, comorbidities, stroke mechanism and clot location of participants, treatment details, and all patient-important outcomes: recovery with minimal disability (modified Rankin Scale (mRS) Score of 0–2), symptomatic intracranial haemorrhage (sICH), mortality and procedure-related complications.

Risk-of-bias assessment
Using a modified Cochrane risk-of-bias instrument, pairs of reviewers independently assessed each article for risk of bias considering sequence generation, allocation sequence concealment, blinding of participants, healthcare providers, data collectors, outcome assessor/adjudicator and missing outcome data (≥10% missing data were considered high risk of bias).\textsuperscript{20} Response options for each item were ‘definitely or probably yes’ (assigned a low risk of bias) and ‘definitely or probably no’ (assigned a high risk of bias).\textsuperscript{21}

Data analysis
We conducted fixed effects meta-analysis using the Mantel-Haenszel method to calculate risk ratios (RRs) and risk differences (RDs), and the associated 95% CI, for all patient-important outcomes reported by more than one study. For computing RDs and 95% CIs, we applied the RR to the baseline risks from a high-quality observational study of 6350 ischaemic stroke from 42 centres that received EVT with or without intravenous alteplase.\textsuperscript{22} We conducted a post-hoc sensitivity analysis excluding the SKIP trial\textsuperscript{14} from our analyses on the basis that the dose of alteplase may affect results. Specifically, the SKIP trial administered alteplase at a dose of 0.6 mg/kg vs 0.9 mg/kg in other trials.

We performed all statistical analyses using Review Manager for Windows (RevMan, V.5.3). Comparisons were two-tailed using a p≤0.05 threshold.
Assessment of certainty of evidence

The authors and the guideline panel achieved consensus in categorising the certainty of evidence for all reported outcomes as high, moderate, low or very low using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.23 With the GRADE approach, RCTs start as high certainty evidence,23 but may be rated down for risk of bias,24 imprecision,25 indirectness,26 inconsistency27 or publication bias.28 We also rated down significant effects for imprecision if they were informed by <300 patients for continuous outcomes or <300 events for dichotomised outcomes.25 We did not rate down for risk of bias if the only criterion not met was blinding of study participants or personnel on the basis that a recent meta-epidemiological study found no evidence for an average difference in estimated treatment effect between trials with and without blinded patients, healthcare providers or outcome assessors.29 We also did not rate down the same effect estimate two times for both inconsistency and imprecision.

Rating of imprecision was fully contextualised by the guideline panel,30 and we followed GRADE guidance for communicating our findings.31 We presented our evidence syntheses in a GRADE summary of findings tables as both relative and absolute effects to optimise interpretability. The minimally important difference (MID) was informed by a survey of guideline panel members’ views of patient values and preferences, and their subsequent discussion. The thresholds for MID were 1% for recovery with minimal disability, 0.8% for mortality and 1% for sICH; the panel, however, acknowledged both their uncertainty around patient values and likely large variability between patients. We assessed inconsistency among studies by differences in point estimates and overlap of the CI, and the I² statistic. According to Cochrane Review Handbook, an I² of 0%–40% might not be important, 30%–60% may represent moderate heterogeneity, 50%–90% may represent substantial heterogeneity and 75%–100% indicates considerable heterogeneity.32

RESULTS

Of 11121 citations, 4 published RCTs13–16 including 1633 patients and 2 RCTs described at conference presentations17 18 including 701 patients met eligibility criteria (figure 1). Characteristics of included clinical trials, which were all published in 2020 and 2021, are presented in online supplemental appendix 2. Sample size ranges from 200 to 700 and two doses of alteplase (0.6 mg/kg14 and 0.9 mg/kg1315–18) were administered to participants. All eligible trials adequately generated their randomisation...
sequence, appropriately concealed allocation, blinded outcome assessors and reported <10% missing outcome data. Due to the nature of the interventions, patients and healthcare providers were unblinded (online supplemental appendix 3).

**Outcomes for EVT with intravenous alteplase versus EVT alone**

**Recovery with minimal disability (mRS Score 0–2)**

Low certainty evidence from 6 RCTs13–18 (2331 patients) suggests that, compared with EVT with alteplase, EVT alone possibly results in a small decrease in the proportion of patients that achieve functional independence (RR 0.97, 95% CI 0.89 to 1.05; RD −1.5%; 95% CI −5.4% to 2.5%) (figure 2, table 1).

**Mortality**

Low certainty evidence from 6 RCTs13–18 (2333 patients) suggests that, compared with EVT with alteplase, EVT alone possibly results in a small increase in mortality (RR 1.07, 95% CI 0.88 to 1.29; RD 1.2%, 95% CI −2.0% to 4.9%) (figure 3, table 1).

**Symptomatic intracranial haemorrhage (sICH)**

Moderate certainty evidence from 6 RCTs13–18 (2328 patients) suggests that, compared with EVT with alteplase, EVT alone probably results in a small decrease in sICH (RR 0.75, 95% CI 0.52 to 1.07; RD −1.0%; 95% CI −1.8% to 0.27%) (figure 4, table 1).

Sensitivity analysis excluding the SKIP trial14 did not appreciably change recovery with minimal disability (mRS Score 0–2), mortality and sICH (online supplemental appendix 4).

**Procedure-related complications**

Overall, 2 studies13 15 including 886 patients reported on procedure-related complications and the results showed

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**Figure 2** Forest plot for endovascular thrombectomy (EVT) alone versus EVT with intravenous alteplase for modified Rankin Scale (mRS) score 0–2.

**Table 1** GRADE summary of findings for EVT alone versus EVT with alteplase in patients who had an acute ischaemic stroke secondary to large vessel occlusion

<table>
<thead>
<tr>
<th>Outcomes (timeframe)</th>
<th>Relative effects (95% CI); number of patients and trials.</th>
<th>Absolute effect estimates</th>
<th>Certainty of evidence</th>
<th>Plain language summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal disability measured by modified Rankin Score 0–2 (90 days)</td>
<td>RR 0.97 (0.89 to 1.05) 2331 patients in six trials.13–18</td>
<td>49.1%</td>
<td>−1.5% (−5.4% to 2.5%)</td>
<td>Low (very serious imprecision)</td>
</tr>
<tr>
<td>Mortality (90 days)</td>
<td>RR 1.07 (0.88 to 1.29) 2333 patients in six trials.13–18</td>
<td>16.8%</td>
<td>1.2% (−2.0% to 4.9%)</td>
<td>Low (very serious imprecision)</td>
</tr>
<tr>
<td>Symptomatic intracranial haemorrhage (90 days)</td>
<td>RR 0.75 (0.52 to 1.07) 2328 patients in six trials.13–18</td>
<td>3.8%</td>
<td>−1.0% (−1.8% to 0.27%)</td>
<td>Moderate (serious imprecision)</td>
</tr>
</tbody>
</table>

*The baseline risk for modified Rankin Score 0–2, mortality and symptomatic intracranial haemorrhage at 90 days was obtained from patients with anterior circulation large artery occlusion stroke receiving EVT with alteplase.22

EVT, endovascular thrombectomy; GRADE, Grading of Recommendations Assessment, Development and Evaluation; RR, risk ratio.
no significant difference in procedure-related complications for EVT with or without alteplase (RR 0.89, 95% CI 0.69 to 1.15, p=0.38; online supplemental appendices 5 and 6).

**Interpretation**

For patients who had an ischaemic stroke with large vessel occlusion who present to comprehensive stroke centres and are eligible for both immediate thrombolysis and EVT, compared with EVT and intravenous alteplase, low certainty evidence suggests that there is possibly a small decrease in the proportion of patients that achieve functional independence and a small increase in mortality with EVT alone; CI are wide with very serious imprecision. Moderate certainty evidence suggests that there is probably a small decrease in sICH with EVT alone. Considering the small differences with very serious imprecision, this evidence supports only weak recommendations for future clinical care. The accompanying guideline provides contextualised guidance based on this body of evidence.

Strengths of our systematic review include a comprehensive search for eligible RCTs in any language, and independent study selection, data abstraction and the risk-of-bias assessment by paired reviewers. We engaged a guideline panel of patients and clinical experts to fully contextualise our assessment of the evidence, and to establish MIDs for all outcomes. We used the GRADE approach to assess the certainty of evidence and converted all pooled relative effects to RDs to facilitate interpretation.

Compared with two recent published systematic reviews addressing EVT alone versus EVT with intravenous thrombolysis in acute ischaemic stroke from large vessel occlusion, our review had the following distinctions. First, we used the GRADE approach to evaluate the certainty of evidence, which formally acknowledges imprecision in effect estimates. The results of our study suggested that EVT alone may decrease the proportion of patients that achieve functional independence and increase mortality, whereas previous systematic reviews concluded no difference between groups in functional independence and mortality. Second, we engaged a guideline panel, which involved patient partners, to contextualise the findings—including assessment of precision associated with pooled effect estimates. Third, prior reviews reported both patient-important and surrogate outcomes. In the systematic review of four trials, surrogate endpoints (successful reperfusion and any intracranial haemorrhage) showed significant improvement, the first favouring EVT plus alteplase and the second favouring EVT alone, and the authors did not address this issue. In the systematic review of three trials, there were no significant differences in successful reperfusion. Surrogate outcomes are less important when we have evidence to directly inform patient-important outcomes. Our review recognised this and hence did not report these surrogate outcomes. Finally, on the definition of sICH used in these RCTs, we chose the Heidelberg criteria for DIRECT-MT, DEVt and MR CLEAN-NO IV trials and the Safe Implementation of Thrombolysis in Stroke–Monitoring Study (SITS–MOST) criteria for the SKIP trial; for the SWIFT DIRECT and DIRECT SAFE trials, we used their own trial-specific definitions (online supplemental appendices 2 and 6); the previous systematic review of four trials used Heidelberg criteria for DIRECT-MT and MR CLEAN-NO IV trials and National Institute of Neurological Disorders and Stroke (NINDS) criteria for SKIP and DEVt trials (online supplemental appendix

![Figure 3](http://svn.bmj.com/) Forest plot for endovascular thrombectomy (EVT) alone versus EVT with intravenous alteplase for mortality.

![Figure 4](http://svn.bmj.com/) Forest plot for endovascular thrombectomy (EVT) alone versus EVT with intravenous alteplase for symptomatic intracranial haemorrhage.
The previous systematic review of three trials, used Heidelberg criteria for DIRECT-MT trials and NINDS criteria for SKIP and DEVT trials. Notwithstanding these differences in methods, our conclusion is essentially the same—there is little to no differences in outcomes with EVT alone compared with EVT plus alteplase.

On 3 February 2022, the European Stroke Organisation (ESO)—European Society for Minimally Invasive Neurological Therapy (ESMINT) published a guideline that made a strong recommendation in favour of intravenous thrombolysis plus mechanical thrombectomy over mechanical thrombectomy alone for patients who had an acute stroke presenting with anterior circulation large vessel occlusion and who are eligible for both treatments. Their associated evidence synthesis concluded moderate certainty evidence (due to inconsistency) for no difference in functional recovery without impairment or sICH, and high certainty evidence for no difference in mortality but greater chance of successful reperfusion with EVT plus alteplase. They rated down for inconsistency for recovery and sICH even though all CI in these forest plots overlapped and the I² was 0% for both pooled effect estimates.

The difference in our appraisal of certainty of evidence is due to our approach of assessing imprecision. Specifically, we assessed values and preferences of patients presenting with acute stroke and found that most would consider a 1% absolute difference in functional recovery without impairment to be important. Accordingly, we judged the pooled effect for EVT alone versus combination therapy as imprecise as the 95% CI ranged from 5.4% more to 2.5% less recovering with no impairment; a range that includes both important benefits and harms associated with EVT alone and thus warranted rating down twice for imprecision according to the GRADE approach. The ESO–ESMINT guideline, alternatively, applied a non-inferiority margin of 1.3% and concluded that non-inferiority was not met and did not rate down for imprecision. The same issue affected the assessment of mortality. We viewed the associated 95% CI, which included a 2% decrease and a 4.9% increase in mortality with EVT alone, as including both important benefits and harms and so rated down two times for imprecision. The ESO–ESMINT guideline, again, did not consider this imprecise. The ESO–ESMINT guideline’s strong recommendation in favour of EVT plus alteplase appears to rest on significant effects on surrogate outcomes that favoured combination therapy; specifically, successful reperfusion and any intracranial haemorrhage. We did not include these outcomes in our review, and instead focused only on outcomes of direct important to patients: functional recovery, mortality and sICH.

**Limitations**

There are some limitations to our review. First, eligible trials used multiple criteria to define sICH. Based on feedback from our clinical experts, we chose the Heidelberg criteria for three trials, SITS–MOST criteria for the SKIP trial. The SWIFT DIRECT trial defined sICH as any parenchymal haematoma type 1, parenchymal haematoma type 2, remote intracranial haemorrhage, subarachnoid haemorrhage or intraventricular haemorrhage associated with a ≥4 point worsening on the National Institutes of Health Stroke Scale (NIHSS) at 24±6 hours post randomisation and the DIRECT SAFE trial defined sICH as NIHSS increase of 4 or more points at 24 hours window post stroke with ICH on CT scan; the lack of statistical heterogeneity in our pooled estimate of effect (I²=0%) suggests our approach was valid. Second, although we found no difference in treatment effects between EVT with intravenous alteplase versus EVT alone, the associated estimates of precision included patient-important benefits and harms, which reduced our certainty of evidence to low or moderate. Third, our findings are only relevant to alteplase. Tenecteplase may be a more effective thrombolytic agent. If so, additional trials will be needed to determine whether the combination of tenecteplase and EVT is superior to EVT alone. Fourth, we relied on conference publications for two (SWIFT DIRECT and DIRECT SAFE) trials, and we contacted the lead investigators of each trial and confirmed the data presented at conferences.

**CONCLUSIONS**

Low certainty evidence suggests that there is possibly a small decrease in the proportion of patients that achieve functional independence and a small increase in mortality with EVT alone. Moderate certainty evidence suggests that there is probably a small decrease in sICH with EVT alone. The accompanying guideline provides contextualised guidance based on this body of evidence.

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Zhouding An http://orcid.org/0000-0002-7996-5002

**REFERENCES**


Appendix 1: Summary of search strategy

Database: OVID Medline Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present

Search Strategy:

1. exp Stroke/ (151427)
2. (Cerebrovascular event or Stroke or apoplex or CVA or cerebrovascular accident or brain vascular accident or brain isch* or brain infarc* or cerebral infarc$ or cerebral isch$ or cerebral vessel occlusion or large vessel occlusion or intracranial isch* or intracranial infarction or intracranial vessel occlusion or brain vessel occlusion).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (390015)
3. 1 or 2 (393519)
4. exp Thrombectomy/ (9289)
5. (Thrombectomy or thrombectomie$ or mechanical or endovascular or embolectomy or intracranial intervention or Stent-retriever or stentretriever or preset or solitaire or trevo or catch).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (532741)
6. 4 or 5 (532741)
7. 3 and 6 (22234)
8. exp Tissue Plasminogen Activator/ (19562)
9. ((plasminogen adj2 (activator or recombinant)) or (bridging* or thrombolysis or rtPA or tpA or rt PA or alteplase or Tenecteplase or reteplase or Metalysate or tknase or tenecteplase or ecokinase or rapalysin or retavase or actilyse or activase or alteplase or lysatec rt pa or lysatec rt-pa or atlepase or cathflo activase or bridging-therapy)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (19562)
concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (130860)
10 8 or 9 (130860)
11 7 and 10 (5276)
12 (direct or combined or with or alone or combination or preceding or preinterventional or prior or before or previous or concomitant or stand-alone or together or following or followed or eligible or contraindication or ineligible or preproced$ or preinterv$ or prethrom$ or pre-proced$ or pre-inter$ or pre-throm$).mp. (20428682)
13 11 and 12 (4887)
14 randomized controlled trial.pt. (550704)
15 controlled clinical trial.pt. (94547)
16 randomized.ab. (541037)
17 placebo.ab. (223248)
18 drug therapy.fs. (2404278)
19 randomly.ab. (370115)
20 trial.ab. (576336)
21 groups.ab. (2273783)
22 or/14-21 (5179308)
23 exp animals/ not humans.sh. (4917301)
24 22 not 23 (4505655)
25 11 and 24 (2245)
26 random.:tw. or placebo:.mp. or double-blind:.tw. (1378661)
27 ((treatment or control) adj3 group*).ab. (665358)
28 (allocat* adj5 group*).ab. (29061)
29 ((clinical or control*) adj3 trial).ti,ab,kw. (324097)
30 or/26-29 (1918347)
31 30 not 23 (1654690)
32 11 and 31 (1138)
33 25 or 32 (2337)
34 limit 33 to ed=20210419-20211122 (232)
Database: Embase <1974 to 2021 November 19>

Search Strategy:

1. exp cerebrovascular accident/ (247559)
2. (Cerebrovascular event or Stroke or apoplex or CVA or cerebrovascular accident
or brain vascular accident or brain isch* or brain infarc* or cerebral infarc$ or cerebral
isch$ or cerebral vessel occlusion or large vessel occlusion or intracranial isch* or
intracranial infarction or intracranial vessel occlusion or brain vessel occlusion).mp.
(655054)
3. 1 or 2 (655054)
4. exp thrombectomy/ (31288)
5. (Thrombectomy or thrombectomie$ or mechanical or endovascular or
embolectomy or intracranial intervention or Stent-retriever or stentretriever or preset or
solitaire or trevo or catch).mp. (641195)
6. 4 or 5 (643465)
7. 3 and 6 (43522)
8. tissue plasminogen activator/ (30971)
9. (bridging$ or thrombolysis or rtPA or tpA or rt PA or alteplase or bridging-
therapy or plasminogen activator or recombinant-plasminogen or plasminogen-
activator).mp. (183948)
10. 8 or 9 (183948)
11. 7 and 10 (11978)
12. (direct or combined or with or alone or combination or preceding or
preinterventional or prior or before or previous or concomitant or stand-alone or together
or following or followed or eligible or contraindication or ineligible or preproced$ or
preinterv$ or prethrom$ or pre-proced$ or pre-inter$ or pre-throm$).mp. (25262604)
13. 11 and 12 (11097)
14. limit 13 to yr="2017 -Current" (6400)
15. randomized controlled trial/ (683426)
16. Controlled clinical study/ (464339)
17. random$.ti,ab. (1723999)
18. randomization/ (92125)
interven
tmethod comparison/ (277105)

placebo.ti,ab. (332140)

(compare or compared or comparison).ti. (550422)

((evaluated or evaluate or evaluating or assessed or assess) and (compare or
compared or comparing or comparison)).ab. (2397242)

(open adj label).ti,ab. (92320)

((double or single or doubly or singly) adj (blind or blinded or blindly)).ti,ab.
(250276)

double blind procedure/ (189607)

parallel group$1.ti,ab. (28397)

(crossover or cross over).ti,ab. (113472)

((assign$ or match or matched or allocation) adj5 (alternate or group$1 or
intervention$1 or patient$1 or subject$1 or participant$1)).ti,ab. (366751)

(assigned or allocated).ti,ab. (432042)

(controlled adj7 (study or design or trial)).ti,ab. (392334)

(volunteer or volunteers).ti,ab. (262212)

human experiment/ (558858)

trial.ti. (343162)

or/15-33 (5572251)

(random$ adj sampl$ adj7 ("cross section$" or questionnaire$1 or survey$ or
database$1)).ti,ab. not (comparative study/ or controlled study/ or randomi?ed
controlled.ti,ab. or randomly assigned.ti,ab.) (8759)

Cross-sectional study/ not (randomized controlled trial/ or controlled clinical
study/ or controlled study/ or randomi?ed controlled.ti,ab. or control group$1.ti,ab.)
(288322)

(((case adj control$) and random$) not randomi?ed controlled).ti,ab. (19134)

(Systematic review not (trial or study)).ti. (191316)

(nonrandom$ not random$).ti,ab. (17382)

"Random field$".ti,ab. (2603)

(random cluster adj3 sampl$).ti,ab. (1392)

(review.ab. and review.pt.) not trial.ti. (940188)
"we searched".ab. and (review.ti. or review.pt.) (39021)
"update review".ab. (118)
(databases adj4 searched).ab. (46422)
(rat or rats or mouse or mice or swine or porcine or murine or sheep or lambs or pigs or piglets or rabbit or rabbits or cat or cats or dog or dogs or cattle or bovine or monkey or monkeys or trout or marmoset$1).ti. and animal experiment/ (1128444)
Animal experiment/ not (human experiment/ or human/) (2368551)
or/35-47 (3826805)
34 not 48 (4942605)
11 and 49 (3566)
random:.tw. or placebo:.mp. or double-blind:.tw. (1988253)
((treatment or control) adj3 group*).ab. (963695)
(allocat* adj5 group*).ab. (37958)
((clinical or control*) adj3 trial).ti,ab,kw. (458102)
or/51-54 (2778117)
11 and 55 (2486)
56 not 48 (2136)
50 or 57 (3886)
limit 58 to dc=20210416-20211122 (466)

**Cochrane Library (Wiley)**

Date Run: 22/11/2021

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<td>#1 or #277428</td>
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#6  #4 or #5 34519
#7  #3 and #6 4017
#8  MeSH descriptor: [Tissue Plasminogen Activator] explode all trees 1729
#9  bridging$ or thrombolysis or rtPA or tpA or rt PA or alteplase or bridging-therapy or "plasminogen activator" or recombinant-plasminogen or plasminogen-activator 12868
#10 placminogen near/2 (activator or recombinant) 4833
#11 bridging* or thrombolysis or rtPA or tpA or rt PA or alteplase or Tenecteplase or reteplase or Metalyse or tnpkase or tenecteplase or ecokinase or rapilysin or retavase or actilyse or activase or alteplase or lysatec rt pa or lysatec rt-pa or lysatec rtpa or atlepase or cathflo activase or bridging-therapy 10919
#12 #9 or #10 or #11 13058
#13 #7 and #12 in Trials 1029
#14 #13 with Cochrane Library publication date Between Apr 2021 and Nov 2021 97

Web of Science (Clarivate)
10 #8 and #9 194
9 LD=(2021-04-16/2021-11-22) 2,345,234
8 #7 AND #6 2,563
7 TS= clinical trial* OR TS=controlled trial* OR TS=random* OR TS=placebo* OR TS=(single blind*) OR TS=(double blind*) 2,812,250
6 #5 AND #2 AND #1 6,724
5 #4 OR #3 224,286
4 TS=(bridging* or thrombolysis or rtPA or tpA or rt PA or alteplase or Tenecteplase or reteplase or Metalyse or tnpkase or tenecteplase or ecokinase or rapilysin or retavase or actilyse or activase or alteplase or lysatec rt pa or lysatec rt-pa or lysatec rtpa or atlepase or cathflo activase or bridging-therapy) 178,080
3 TS=(plasminogen NEAR/2 (activator or recombinant) ) 63,775
2 TS=(Thrombectomy OR thrombectomie* OR mechanical OR endovascular OR embolectomy OR intracranial intervention OR Stent-retriever OR stentretriever OR preset OR solitaire OR trevo OR catch) 1,549,779
1 TS=(Cerebrovascular event OR Stroke OR apoplex OR CVA OR cerebrovascular accident OR brain vascular accident OR brain isch* OR brain infarc* OR cerebral infarc* OR cerebral isch* OR cerebral vessel occlusion OR large vessel occlusion OR intracranial isch* OR intracranial infarction OR intracranial vessel occlusion OR brain vessel occlusion) 504,353

**PubMed**

((((((publisher[sb] OR inprocess[sb] OR pubmednotmedline[sb] OR pubstatusaheadofprint)) AND (stroke or cerebrovascular accident)) AND (Thrombectomy)) AND ((bridging* or thrombolysis or rtPA or tPA or rt PA or alteplase or Tenecteplase or reteplase or Metalyse or tnkase or tenecteplase or ecokinase or rapilysin or retavase or actilyse or activase or alteplase or lysatec rt pa or lysatec rt-pa or lysatec rtpa or atlepase or cathflo activase or bridging-therapy) OR (Tissue Plasminogen Activator)) AND (((random* or placebo or double-blind) OR (randomized clinical trial)) OR (controlled trial))))
# Appendix 2: Characteristics of included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>DIRECT-MT¹</th>
<th>SKIP²</th>
<th>DEVT³</th>
<th>MR CLEAN-NO IV⁴</th>
<th>SWIFT DIRECT⁵</th>
<th>DIRECT SAFE⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country</strong></td>
<td>China</td>
<td>Japan</td>
<td>China</td>
<td>Europe</td>
<td>North America and Europe</td>
<td>Australia, New Zealand, China and Vietnam</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>327</td>
<td>101</td>
<td>116</td>
<td>273</td>
<td>201</td>
<td>146</td>
</tr>
<tr>
<td>EVT with alteplase</td>
<td>329</td>
<td>103</td>
<td>118</td>
<td>266</td>
<td>207</td>
<td>147</td>
</tr>
<tr>
<td><strong>Age, median (IQR), y</strong></td>
<td>69(61-76)</td>
<td>74(67-80)</td>
<td>70(60-77)</td>
<td>72(62-80)</td>
<td>73(64-81)</td>
<td>70 (61-78)</td>
</tr>
<tr>
<td>EVT with alteplase</td>
<td>69(61-76)</td>
<td>76(67-80)</td>
<td>70(60-78)</td>
<td>69(61-77)</td>
<td>72(65-81)</td>
<td>69 (60-79)</td>
</tr>
<tr>
<td><strong>Sex (Male%)</strong></td>
<td>189 (57.8)</td>
<td>56(55)</td>
<td>66(56.9)</td>
<td>161(59)</td>
<td>96(48)</td>
<td>78 (53.4)</td>
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<tr>
<td>EVT with alteplase</td>
<td>181 (55.0)</td>
<td>72(70)</td>
<td>66(55.9)</td>
<td>144(54.1)</td>
<td>103(50)</td>
<td>88 (59.9)</td>
</tr>
<tr>
<td><strong>Alteplase Dose (mg/kg)</strong></td>
<td>0.9</td>
<td>0.6</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Inclusion criteria</strong></td>
<td>ICA, MCA-M1 or M2 occlusion on CTA</td>
<td>ICA or MCA-M1 occlusion on CTA or MRA</td>
<td>ICA or MCA-M1 occlusion on CTA or MRA</td>
<td>ICA, MCA-M1 or proximal M2 occlusion or both on CTA or MRA</td>
<td>ICA or MCA-M1 occlusion or both on CTA or MRA</td>
<td>CTA or MRA of the ICA, M1, M2 or basilar artery</td>
</tr>
<tr>
<td>mRS score</td>
<td>mRS ≤2</td>
<td>mRS ≤2</td>
<td>mRS &lt; 2</td>
<td>mRS ≤2</td>
<td>mRS ≤2</td>
<td>mRS &lt; 4</td>
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<tr>
<td>NIHSS score</td>
<td>≥2</td>
<td>≥6</td>
<td>No limit</td>
<td>≥2</td>
<td>≥5 and &lt; 30</td>
<td>No limit</td>
</tr>
<tr>
<td>Onset to randomization time, median (IQR), min</td>
<td>EVT</td>
<td>167 (125-206)</td>
<td>170 (129-204)</td>
<td>94 (60-137)</td>
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<tr>
<td>RANDOMIZATION TO GROIN PUNCTURE TIME, MEDIAN (IQR), MIN</td>
<td>EVT</td>
<td>31 (20-45)</td>
<td>20 (20)*</td>
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<td>NA</td>
<td>NA</td>
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<tr>
<td>EVT WITH ALTEPLASE</td>
<td>36 (22-50.5)</td>
<td>22 (16)*</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>NIHSS score, median (IQR), min</td>
<td>EVT</td>
<td>17 (12-21)</td>
<td>19 (13-23)</td>
<td>16 (12-20)</td>
<td>16 (10-20)</td>
<td>17 (13-20)</td>
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<tr>
<td>EVT WITH ALTEPLASE</td>
<td>17 (14-22)</td>
<td>17 (12-22)</td>
<td>16 (13-20)</td>
<td>16 (10-20)</td>
<td>17 (12-20)</td>
<td>15 (10-20)</td>
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<tr>
<td>ASPECTS, median (IQR), min</td>
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<td>7 (6-9)</td>
<td>8 (7-9)</td>
<td>9 (8-10)</td>
<td>8 (7-9)</td>
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<td>8 (6-9)</td>
<td>8 (7-9)</td>
<td>9 (8-10)</td>
<td>8 (7-9)</td>
<td>10 (9-10)</td>
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<td>COMORBIDITIES</td>
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<td>--------</td>
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<tr>
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<td>EVT with alteplase</td>
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<td>69/118</td>
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<td>Large artery atherosclerosis</td>
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<tr>
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<td>Intracranial atherosclerosis</td>
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<td>28/116</td>
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<td>23/118</td>
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<td>Unknown/other</td>
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<td>13/101</td>
<td>19/116</td>
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<td>NA</td>
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<td>16/103</td>
<td>21/118</td>
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<td>Clot location</td>
<td>ICA</td>
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<td>18/116</td>
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<td>M1</td>
<td>EVT</td>
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<td>95/116</td>
<td>156/272</td>
<td>142/201</td>
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<td>47/103</td>
<td>99/118</td>
<td>174/266</td>
<td>148/207</td>
<td>83/147</td>
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<td>M2</td>
<td>EVT</td>
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<td>10/101</td>
<td>3/116</td>
<td>45/272</td>
<td>1/201</td>
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<td>EVT with alteplase</td>
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<td>20/103</td>
<td>2/118</td>
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<td>23/147</td>
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<td>Tandem occlusion</td>
<td>EVT</td>
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<td>9/101</td>
<td>NA</td>
<td>48/257</td>
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<td>EVT with alteplase</td>
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<td>13/103</td>
<td>NA</td>
<td>40/250</td>
<td>33/207</td>
<td>20/147</td>
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</tbody>
</table>
EVT = endovascular thrombectomy, ICA = internal carotid artery, MCA = middle cerebral artery, MRA = magnetic resonance angiography, CTA = computed tomographic angiography, mRS = modified Rankin Scale, NIHSS = National Institutes of Health Stroke Scale, ASPECTS = Alberta Stroke Program Early Computed Tomography Score, sICH = symptomatic intracranial hemorrhage, SITS-MOST = Safe Implementation of Thrombolysis in Stroke–Monitoring Study, NA = not available.
* mean (SD)
## Appendix 3: Risk of bias assessment

<table>
<thead>
<tr>
<th>Study</th>
<th>Sequence Generation</th>
<th>Allocation Sequence Concealment</th>
<th>Blinding</th>
<th>Missing Outcome Data</th>
<th>Free of selective outcome reporting</th>
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<td>DIRECT-MT&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
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<tr>
<td>SKIP&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Low</td>
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<td>Low</td>
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<tr>
<td>DEVT&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>MR CLEAN-NO IV&lt;sup&gt;4&lt;/sup&gt;</td>
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<td>Low</td>
<td>High</td>
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<td>Low</td>
</tr>
<tr>
<td>SWIFT DIRECT&lt;sup&gt;5&lt;/sup&gt;</td>
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<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>DIRECT SAFE&lt;sup&gt;6&lt;/sup&gt;</td>
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Stroke Vasc Neurol

doi: 10.1136/svn-2022-001547

### Appendix 4: Sensitivity analysis by excluding SKIP trial

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Relative effects (95% CI)</th>
<th>Results from 6 RCTs</th>
<th>Sensitivity analysis by excluding SKIP trial</th>
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</thead>
<tbody>
<tr>
<td>Minimal disability measured by modified Rankin Score 0-2</td>
<td>RR 0.97 (0.89-1.05)</td>
<td>RR 0.96 (0.88-1.04)</td>
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</tr>
<tr>
<td>Mortality</td>
<td>RR 1.07 (0.88-1.29)</td>
<td>RR 1.07 (0.89-1.30)</td>
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</tr>
<tr>
<td>Symptomatic intracranial hemorrhage</td>
<td>RR 0.75 (0.52-1.07)</td>
<td>RR 0.75 (0.51-1.09)</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5: Forest plots of procedure-related complications

Forest plot for endovascular thrombectomy (EVT) alone versus EVT with intravenous alteplase for procedure-related complications

Supplemental material

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Stroke Vasc Neurol

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Appendix 6: The definition of procedure-related complications and symptomatic hemorrhage

The definition of procedure-related complications
DIRECT-MT: Vessel dissection, contrast extravasation, embolization into a new territory and femoral access complications
DEVT: Clot migration, distal occlusion present at procedure end, contrast extravasation, arterial perforation and puncture access complications

The definition of symptomatic hemorrhage
Heidelberg: Symptomatic intracerebral hemorrhage detected by brain imaging as a relevant change in neurological status; absence of another explanation for deterioration; an event leading to intubation, hemicraniectomy, or external ventricular draining placement; or other major medical or surgical intervention.
Safe Implementation of Thrombolysis in Stroke–Monitoring Study (SITS-MOST): Local or remote parenchymal hematoma type 2 on the imaging scan obtained 22 to 36 hours after treatment, plus neurological deterioration.
National Institute of Neurological Disorders and Stroke (NINDS): Symptomatic if hemorrhage had not been seen on a previous computed tomographic (CT) scan but either subsequent suspicion of hemorrhage or decline in neurological status existed.
References