ORIGINAL RESEARCH

# Influence of ASPECTS and endovascular thrombectomy in acute ischemic stroke: a meta-analysis

Kevin Phan,[1] Serag Saleh,[1] Adam A Dmytriw,[2,3] Julian Maingard,[4] Christen Barras,[5] Joshua A Hirsch,[6] Hong Kuan Kok,[7] Mark Brooks,[4] Ronil V Chandra,[8,9] Hamed Asadi[10]

► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/neurintsurg-2018-014250).

For numbered affiliations see end of article.

**Correspondence to**
Dr Kevin Phan, NeuroSpine Surgery Research Group (NSURG), Sydney, New South Wales 2109, Australia; kphan.vc@gmail.com

Received 11 July 2018
Revised 16 October 2018
Accepted 18 October 2018

Check for updates



**To cite:** Phan K, Saleh S, Dmytriw AA, *et al*. *J NeuroIntervent Surg* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/neurintsurg-2018-014250

## ABSTRACT

**Background** Prompt revascularization of the ischemic penumbra following an acute ischemic event (AIS) has established benefit within the literature. However, use of the semi-quantitative Alberta Stroke Program Early CT Score (ASPECTS) to evaluate patient suitability for revascularization has been inconsistent in patient risk stratification and selection.

**Objective** To conduct a meta-analysis to evaluate the available evidence for a clinically valid ASPECTS threshold in assessment of suitability for revascularization following AIS.

**Methods** Two independent reviewers searched Medline (Ovid) and Cochrane Central Register of Systematic Reviews databases for studies appraising outcomes of endovascular thrombectomy (EVT) in relation to a variably-defined preoperative ASPECTS.

**Results** A total of 13 articles were included. The pooled good outcome proportion after EVT was 41.4% (95% CI 36.4% to 46.6%; p<0.001), with subjective study-specific definitions of favorable and unfavorable subgroup outcomes of 49.7% (95% CI 44.2% to 55.3%; $I^2$=76.5%; p<0.001) and 33.2% (95% CI 28.5% to 38.3%; $I^2$=33.16%), respectively. Objective trichotomization into low (0–4), intermediate (5–7), and high (8–10) subgroups yielded pooled good outcome proportions of 17.1% (95% CI 6.8% to 36.8%; $I^2$=64.24%; p=0.039), 35.7% (95% CI 30.5% to 41.3%; $I^2$=23.11%; p=0.245), and 49.7% (95% CI 44.2% to 55.3%; $I^2$=76.5%; p<0.001) for low, intermediate, and high ASPECTS, respectively.

**Conclusions** A subjectively favorable ASPECTS is associated with significantly better outcomes after EVT than an unfavorable ASPECTS, regardless of the cut-off used. EVT is unlikely to be useful in patients with an objectively low ASPECTS and is likely to be useful for those with high ASPECTS; findings in patients with intermediate ASPECTS were equivocal.

## INTRODUCTION

Prompt revascularization of the brain to salvage the ischemic penumbra is of proven benefit for patients with acute ischemic stroke (AIS).[1] Endovascular thrombectomy (EVT) has emerged as the standard of care for patients with AIS secondary to emergent large-vessel occlusion (ELVO) within 24 hours of symptom onset.[2 3] Several recent large-scale randomized trials have shown that EVT together with intravenous (IV) thrombolysis results in more successful recanalization and better clinical outcomes than thrombolysis alone.[4–9] Nevertheless, candidates for EVT must be carefully selected, based on established criteria, to maximize the likelihood of clinical benefit and prevent futile or even harmful reperfusion.[10]

The Alberta Stroke Program Early CT Score (ASPECTS) is a 10-point semi-quantitative system used to assess early ischemic changes on non-contrast CT after an anterior circulation AIS.[11] Although baseline ASPECTS is often obtained before revascularization therapy to identify patients likely to respond poorly, the threshold below which a score is considered unfavorable varies considerably between studies. A cut-off of ASPECTS ≤7 to define a moderate/large core that is associated with an unfavorable response that was proposed by Barber *et al* in their original publication for use with IV thrombolysis[11] was adopted in much of the early literature and subsequent trials of EVT.[10 12 13] The SWIFT-PRIME and ESCAPE trials used ASPECTS ≤5 on baseline non-contrast CT as an exclusion criterion. The treatment recommendations of the 2015 American Heart Association/American Stroke Association (Class I; Level of Evidence A) also define patients with unfavorable ASPECTS ≤5.[14] Other studies have defined an unfavorable ASPECTS ≤6.[8 15]

The efficacy of EVT in patients with unfavorable ASPECTS is variable in the literature. Early trials concluded that patients with a large infarct core on MRI diffusion-weighted imaging (DWI) or CT ASPECTS had a significantly worse functional outcome and increased mortality compared with patients with a higher ASPECTS score.[10 16] More recently, studies using later-generation endovascular devices, which offer increased speed, better recanalization rates and lower complication rates relative to older technologies,[17 18] have suggested that patients with ASPECTS ≤6 may derive similar or equivalent benefit from EVT.[15 17] To address this important issue, we performed a comprehensive and updated meta-analysis of EVT data to determine the interaction of baseline ASPECTS and outcome, with a focus on patients with both favorable and unfavorable baseline ASPECTS.

## METHODS

### Search strategy

A literature search was conducted through the electronic medical database Medline (Ovid) and the Cochrane Central Register of Systematic Reviews from their commencement until February 2018, in line with recommended meta-analysis guidelines such as PRISMA, to identify eligible articles for this meta-analysis and systematic review. Key MeSH terms and search terms within the search strategy included 'cerebrovascular accident', 'stroke', 'ischaemia', 'endovascular', 'thrombectomy', and 'thrombolysis'. The cited references within the relevant articles were also searched for pertinent articles for inclusion in this study.

### Study selection

The inclusion criteria for this study included papers that recruited patients who were eligible for endovascular therapy, described functional outcomes in terms of modified Rankin Scale (mRS) at 90 days, and used contemporary endovascular techniques. Exclusion criteria were duplicate studies, pediatric populations, case reports, abstract papers, and studies with small sample sizes less than 10.

### Data extraction and quality assessment

Each retrieved article was critically appraised by two independent reviewers (KP, SS). Clinical data were extracted from text, tables or figures through use of a standardized computerized spreadsheet. Discrepancies or disagreements between the reviewers were resolved by discussion and consensus.

Primary outcomes for this study were performance on mRS, mortality, and spontaneous intracerebral hemorrhage (sICH). These outcomes were stratified by preoperative ASPECTS assessment.

A favorable ASPECTS score has a variable definition in the reviewed literature, ranging from >5 to 7 out of 10. Accordingly, a primary analysis compared outcomes for each of the favorable and unfavorable ASPECTS definitions defined on a per article basis. A secondary analysis was performed with objective subgrouping of reported ASPECTS scores into low (0–4), intermediate (5–7), and high (8–10) subgroups correlated with rates of the same outcome variables.[10]

### Statistical analysis

A meta-analysis of proportions was performed. Heterogeneity within the sample was anticipated and hence proportions were combined using DerSimonian–Laird random effects models. Subgroup analysis according to ASPECTS score subgroups was performed using meta-regression analysis. Heterogeneity was evaluated using the Cochran Q and $I^2$ test. All analyses were performed using the metaphor package for R version 3.01. P values <0.05 were considered statistically significant.

## RESULTS

### Search results

A total of 667 articles were identified through our electronic database searches. Of these, 13 met the inclusion criteria,[5 7 8 15 17 19–26] yielding a total of 2171 patients included in the final analysis. A PRISMA flow diagram describing the process of study selection

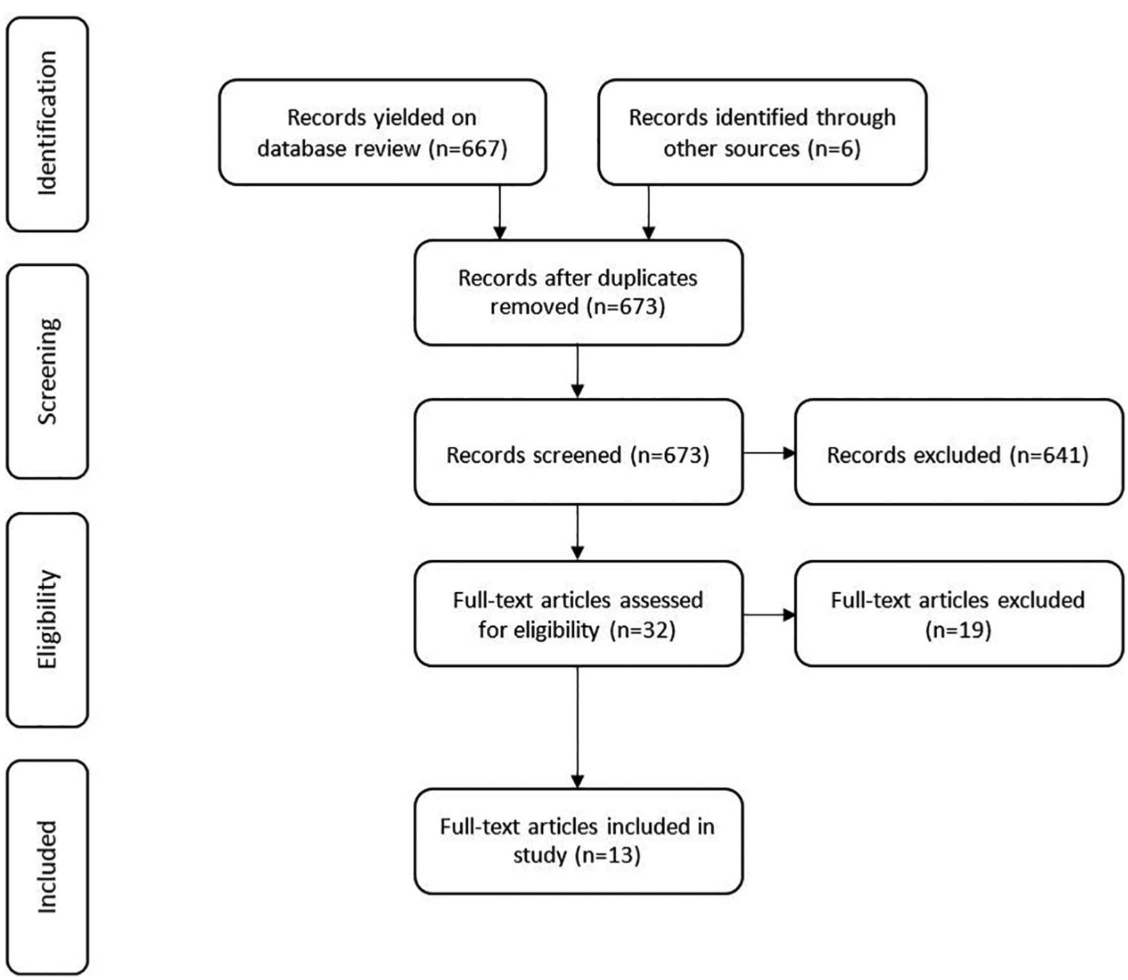


**Figure 1** PRISMA flow diagram of search strategy.

**Table 1** Summary of methodological characteristics of included studies

| Study | Year | Study type | Study period | Number of patients (n) | ASPECTS cut-off | Clinical measure | Imaging for ASPECTS |
|---|---|---|---|---|---|---|---|
| Goyal *et al*[6] (ESCAPE) | 2015 | Randomized controlled trial | Dec 2014– present | 316 | 6–7, 8–10 | 90-day mRS ≤2 | Non-contrast CT |
| Saver *et al*[7] (SWIFT-PRIME) | 2015 | Randomized controlled trial | Dec 2012–present | 196 | 6–7, 8–10 | 90-day mRS ≤2 | Non-contrast CT or MRI DWI |
| Jovin *et al*[8] (REVASCAT) | 2015 | Randomized controlled trial | Nov 2012– Dec 2014 | 206 | ≥7 (score <7 on non-contrast CT or <6 on MRI DWI excluded) | 90-day mRS ≤2 | Non-contrast CT or MRI DWI |
| Yoo *et al*[23] (MR CLEAN) | 2016 | Retrospective cohort study | Dec 2010– June 2014 | 496 | 0–4, 5–7, 8–10 | mRS ≤2 at discharge | – |
| Bracard *et al* (THRACE)[5] | 2016 | Randomized controlled trial | June 2010- Feb 2015 | 414 | 0–4, 5–7, 8–10 | 90-day mRS ≤2 | – |
| Wasser *et al*[25] | 2016 | Retrospective cohort study | Jan 2008–Dec 2014 | 734 | 0–5, 6–7, 8–10 | mRS ≤2 at discharge | Non-contrast CT |
| Kim *et al*[22] | 2016 | Retrospective cohort study | Dec 2010- Dec 2013 | 171 | 4–6, 7–10 | 90-day mRS ≤2 | MRI (DWI) |
| Haussen *et al*[26] | 2016 | Retrospective cohort study | Sept 2010– Sept 2015 | 332 | <6 | 90-day mRS ≤2 | Non-contrast CT |
| Logan *et al*[15] | 2017 | Retrospective cohort study | 2014–2016 | 355 | ≤6 | 90-day mRS ≤2 | Non contrast CT |
| Hungerford *et al*[20] | 2017 | Retrospective cohort study | Dec 2012– May 2015 | 154 | ≤6 | 90-day mRS ≤2 | Non-contrast CT |
| Desilles *et al*[21] | 2017 | Retrospective cohort study | Jan 2012–Aug 2015 | 218 | ≤6 | 90-day mRS ≤2 | MRI (DWI) |
| Li *et al*[24] | 2017 | Retrospective cohort study | Jan 2014– June 2016 | 41 | 5 vs 6 | 90-day mRS ≤2 | Non-contrast CT |
| Mourand *et al*[19] | 2018 | Retrospective cohort study | Jan 2009– Dec 2014 | 108 | ≤5 | 90-day mRS ≤2 | MRI (DWI) |

*mRS, modified Rankin Score; CT, computed tomography; MRI, magnetic resonance imaging; DWI, diffusion-weighted imaging.

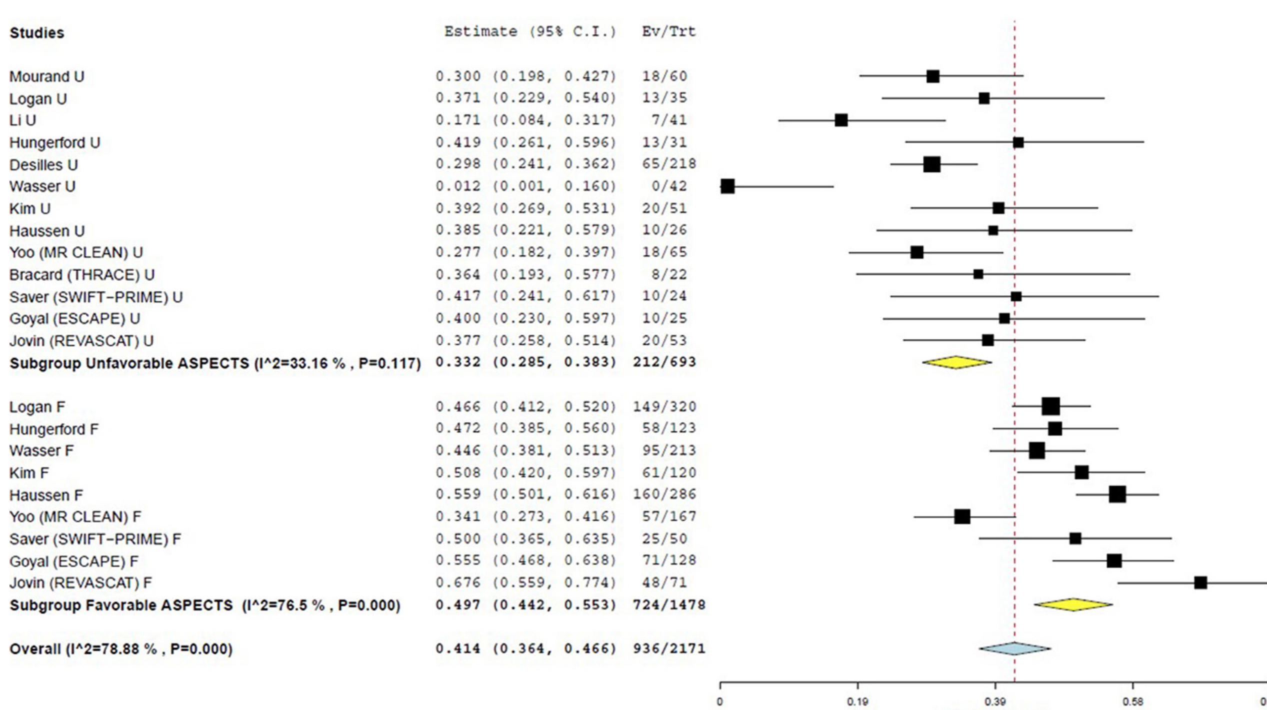


**Figure 2** Good outcome (mRS 0–2) in patients with unfavorable versus favorable ASPECTS score (p<0.001).

is presented in figure 1. The methodological and baseline clinical characteristics of the included studies are presented in table 1.

### Favorable versus unfavorable ASPECTS

The initial analysis compared outcomes between patients with favorable and unfavorable baseline ASPECTS, individually defined for each study. The results of this analysis are presented in figure 2.

The overall pooled proportion of good outcome (mRS 0–2) after EVT was 41.4% (95% CI 36.4% to 46.6%; $p<0.001$), although significant heterogeneity was noted in the 13 included studies ($I^2=78.88\%$) (figure 2). Subgroup analysis of patients with unfavorable ASPECTS in these studies revealed an estimate of good outcome of 33.2% (95% CI 28.5% to 38.3%; $p=0.117$), with non-significant heterogeneity ($I^2=33.16\%$). Data for the subgroup with favorable ASPECTS were obtained from nine studies and showed that these patients had significantly better functional outcome (49.7%; 95% CI 44.2% to 55.3%; $I^2=76.5\%$; $p<0.001$). The OR of good outcome in patients with an unfavorable ASPECTS was 0.46 (95% CI 0.38 to 0.56; $p<0.001$). Differences in ASPECTS cut-off, imaging modality, and treatment regimen likely accounted for the heterogeneity observed in this result.

Meta-analysis of the seven studies with available data demonstrated that the overall proportion of sICH was 8.3% (95% CI 5.9% to 11.6%; $p=0.04$; $I^2=61.55\%$) (see online Appendix, supplementary figure 1a). Rates of sICH for unfavorable ASPECTS (10.9%; 95% CI 7.3% to 16.1%; $p=0.076$; $I^2=47.56\%$) were significantly higher than those for favorable ASPECTS (5.9%; 95% CI, 3.8% to 9.1%; $p=0.129$; $I^2=47.08\%$). The OR was found to be 1.75 (95% CI 1.17 to 2.62; $p=0.007$).

As determined from the eight studies with data available, the overall pooled mortality rate for patients in both subgroups was 19.5% (95% CI 15% to 25%; $I^2=80.05\%$; $p<0.001$) (see online Appendix, supplementary figure 1b). When comparing the two subgroups, mortality after EVT was more likely among patients with unfavorable ASPECTS relative to favorable ASPECTS (25.4%, 95% CI 19% to 33.2%; $I^2=64.44\%$ vs 13.8%, 95% CI 9.5% to 19.6%; $I^2=80.63\%$). The odds of mortality in the unfavorable ASPECTS group was 1.86 (95% CI 1.44 to 2.41; $p<0.001$). Significant heterogeneity was observed across all three results for this outcome measure.

### Low versus intermediate versus high ASPECTS

In the secondary analysis, patients from the 13 studies were trichotomized according to their baseline ASPECTS into low (0–4), intermediate (5–7), and high (8–10), where possible. Subgroups were then compared with respect to the stated outcome measures.

Data on functional outcomes for low ASPECTS patients were available in four studies. The pooled proportion of good outcome (mRS 0–2) was 17.1% (95% CI 6.8% to 36.8%; $I^2=64.24\%$; $p=0.039$) (figure 3). This result was significantly lower than that for intermediate ASPECTS (35.7%, 95% CI 30.5% to 41.3%; $I^2=23.11\%$; $p=0.245$) and high ASPECTS (49.7%, 95% CI 44.2% to 55.3%; $I^2=76.5\%$; $p<0.001$).

Minimal data on the incidence of sICH after EVT were available for stratification by ASPECTS subgroup. sICH rates for high ASPECTS (5.9%, 95% CI 3.8% to 9.1%; $I^2=47.08\%$; $p=0.129$), intermediate ASPECTS (11.9%, 95% CI 5.5% to 23.9%; $I^2=57.62\%$; $p=0.094$) and low ASPECTS (9.1%, 95% CI 1.3% to 43.9%) followed no observable trend (see online Appendix, supplementary figure 2a). For the low ASPECTS subgroup, only data from the post-hoc analysis of the MR CLEAN trial were available, limiting the size of the sample and the power of the analysis.

Mortality after EVT for patients in the low ASPECTS subgroup (42.2%, 95% CI 32.5% to 52.6%; $I^2=0\%$; $p=0.675$) was significantly increased relative to intermediate ASPECTS (24.2%, 95% CI 12.5% to 41.6%; $I^2=85.79\%$; $p<0.001$) and

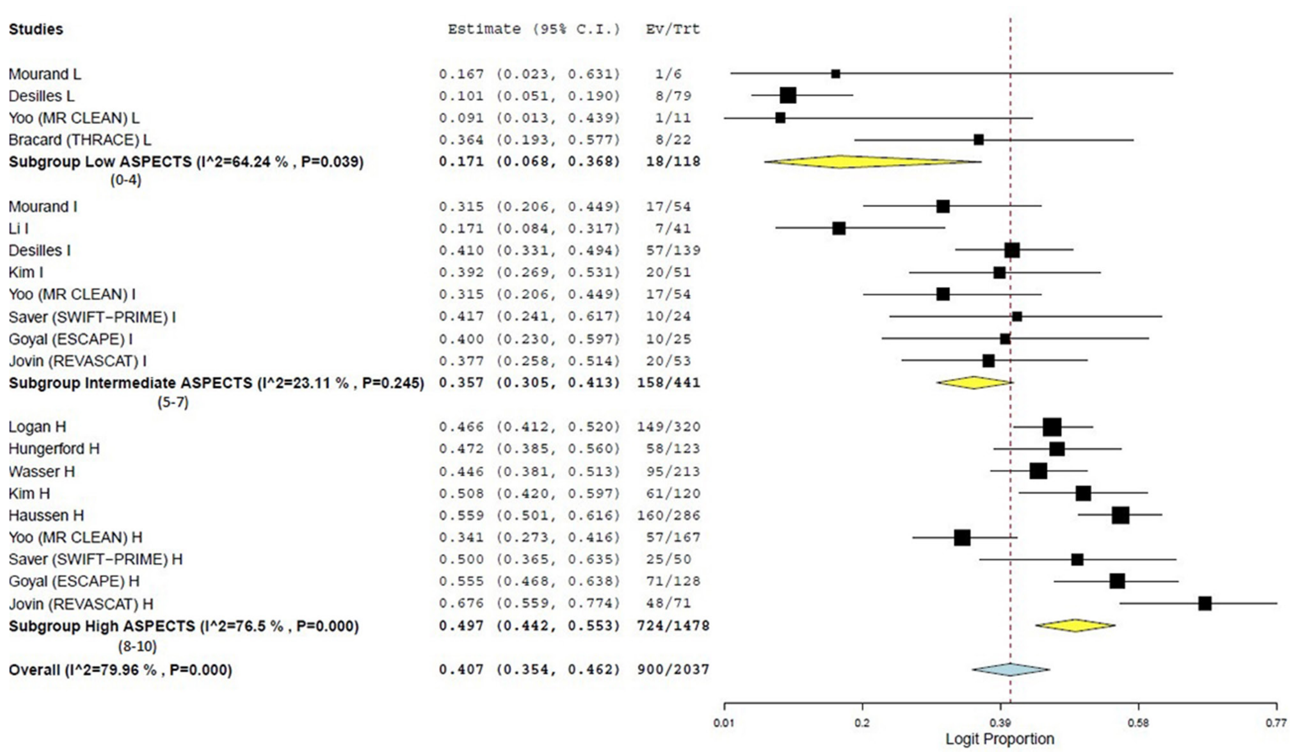


**Figure 3** Good (mRS 0–2) outcome in patients with low (0–4) versus intermediate (4–7) versus high (8–10) ASPECTS scores ($p<0.001$).

high ASPECTS (13.8%, 95% CI 9.5% to 19.6%; $I^2=80.63\%$; $p<0.001$) (see online Appendix, supplementary figure 2b). The result overall (20.1%, 95% CI 14.3% to 27.5%; $I^2=86.85\%$) was significant ($p<0.001$). Heterogeneity was significant overall, and among the studies analyzed for the upper two subgroups.

### Endovascular therapy versus standard care in low ASPECTS cases

We performed a pooled analysis of EVT versus standard care for patients with low ASPECTS scores (0–4). Fifty-one EVT cases were compared with 68 standard care patients. We found no significant difference in good outcome (mRS 0–2) between the two groups after meta-analysis (OR 1.82, 95% CI 0.70 to 4.69, $p=0.22$) with low heterogeneity ($I^2=0\%$).

## DISCUSSION

This meta-analysis shows that a favorable ASPECTS after AIS with ELVO is associated with significantly better functional outcome, lower sICH rates, and lower mortality than an unfavorable ASPECTS. Furthermore, as ASPECTS increases from low to intermediate to high subgroups, functional outcome improves and mortality decreases significantly. A similar pattern is observed for sICH rates, although this trend is non-significant.

### Favorable versus unfavorable ASPECTS

The finding in this study that unfavorable ASPECTS is associated with significantly worse outcomes than favorable ASPECTS for all measures, regardless of the cut-off used, is inconsistent with some recent literature regarding EVT. Of the major randomized trials since 2015, all those with data stratified by ASPECTS demonstrated no difference in functional outcome, mortality, or likelihood of parenchymal hematoma between patients above and below the chosen threshold,[5–8] a result attributable in part to the increased speed, better recanalization rates, and lower complication rates with second-generation endovascular devices.[18 27] However, due to the strict exclusion criteria employed in all but one of these trials, patients with ASPECTS ≤6 were under-represented in the data. Subsequent studies by Kim *et al*,[22] Logan *et al*[15] and Hungerford *et al*,[20] all retrospective reviews of prospectively-maintained databases in which patients with ASPECTS ≤6 were included, also demonstrated similar or equivalent functional outcomes after EVT for patients with unfavorable baseline ASPECTS. Limitations of study design may have affected these results as well. Kim *et al* excluded patients with DWI-ASPECTS ≤3. In the study by Logan *et al*, many more patients with an unfavorable ASPECTS (≤6) had ASPECTS 5 or 6 than ASPECTS ≤4. The poor ASPECTS group (≤6) in the analysis by Hungerford *et al* experienced significantly more loss to follow-up than other groups. These factors are likely to have decreased the chance of detecting a significant difference in outcomes between ASPECTS cohorts. Nevertheless, the results of the present study find support in the literature. Other recent meta-analyses[28 29] and several retrospective analyses[25 30] confirm that, despite advances in thrombectomy techniques and imaging protocols, patients with lower ASPECTS on pretreatment CT imaging derive significantly less benefit from EVT than those with higher ASPECTS. Consequently, ASPECTS remains a reliable prognostic tool in predicting outcomes for patients with AIS with ELVO who are considered for EVT.

### EVT for low ASPECTS (0–4)

The exposure–response relationship for functional outcome and mortality evident on subgroup analysis in this study suggests that patients with baseline low ASPECTS (0–4) are significantly less likely to benefit from EVT. This is consistent with the findings of the HERMES (Highly Effective Reperfusion evaluated in Multiple Endovascular Stroke Trials) collaboration, which pooled data from 1287 patients and concluded that extensive irreversible injury on non-contrast CT of the brain is significantly associated with low rates of good clinical outcome.[17] Likewise, Wasser *et al* demonstrated that patients with an ASPECTS 0–5 obtained from source images on CT angiography had very high rates of poor outcome (86%), in-hospital death (38%), and sICH (7.9%).[25] Some of the studies included in this analysis proposed relative benefits of EVT for low ASPECTS patients.[19–21] Mourand *et al* demonstrated good clinical outcomes in patients with DWI-ASPECTS 4–5, and suggested that younger patients (≤70 years) could be considered for EVT even with DWI-ASPECTS 0–3.[31] Desilles *et al* described a positive although non-significant trend towards better functional outcome (23.1% vs 9.5%), lower mortality rate (45.7% vs 57.1%), and lower rate of sICH (23.9% vs 45.5%) in successfully reperfused patients compared with non-reperfused patients from the DWI-ASPECTS 0–4 subgroup.[21] Nevertheless, given these patients' overall poor prognosis, any absolute benefit with current treatment would be likely to be minimal.[23] Therefore, ASPECTS ≤4 may offer a viable exclusion criterion in the selection of patients for EVT to prevent futile or even harmful recanalization.

### EVT for intermediate ASPECTS (5–7)

There may be a subset of patients with intermediate ASPECTS for whom EVT offers significant clinical benefit after AIS due to ELVO. Results from the subgroup analysis in this study, as well as the published results of studies included in our analysis[19 20 22 26] and several other meta-analyses,[17 28 29] indicate that patients with ASPECTS 5–7 may achieve similar or equivalent functional outcomes to those with higher ASPECTS, with similar rates of morbidity and mortality. Naturally, not all patients of this ASPECTS subgroup will respond well to EVT.[24] Rather, an intermediate ASPECTS score can be considered alongside other criteria such as age group,[32] National Institutes of Health Stroke Scale (NIHSS) score, and extent of collateral circulation on CT angiography or CT perfusion.[3] Bhole *et al*[33] showed that, among 62 patients undergoing EVT who did not meet top-tier evidence criteria and had baseline ASPECTS <6, 33% achieved mRS ≤2 by 3 months. Similar findings were published more recently by Goyal *et al*.[27] Our results, alongside the findings of these studies, suggest that patients with intermediate ASPECTS represent a distinct clinical subpopulation and subsequently have distinct outcomes when compared with the low ASPECTS subgroup of which they have traditionally been considered a part. This distinction warrants further consideration and study of this intermediate group, which has previously been contraindicated for EVT, and by adopting a more case-by-case selection process for patients with intermediate ASPECTS, institutions can ensure that patients who could potentially benefit from EVT are not excluded from treatment.

### Study strengths and limitations

This meta-analysis pools a large amount of data from available trials and observational studies on EVT to achieve a substantial sample size. The inclusion of studies from 2015 onwards is likely to better represent recent endovascular technology and management, although the possibility remains that these studies may have included some cases done with older generation technology. Our study has several limitations. First, the amount of data available for each subgroup after ASPECTS trichotomization varied greatly, with notable heterogeneity. In particular, outcomes with low baseline ASPECTS may have been underpowered to accurately determine clinical benefit in our analysis. Further controlled trials on EVT in patients with large infarct cores using second- and third-generation thrombectomy devices are required. In addition, there were inconsistencies in the imaging modalities used: three of the included studies reported DWI-ASPECTS[19 21 22] and two assessed baseline infarct extent on contrast-enhanced CT.[15 25] Comparisons between imaging modalities can be misleading, especially given the discrepancy rate of up to 20% between CT ASPECTS and MRI DWI-ASPECTS.[34] Once the literature on the association between low or intermediate ASPECTS and outcomes of EVT is more robust, further analyses specific to each modality are warranted. In addition, there is a major limitation in dichotomization given the reported inter-observer variability in assigning ASPECTS, with disagreement in up to 1–4 cases ($\kappa$=0.5).[35] These limitations of current data suggest an equipoise for intermediate ASPECTS as contraindication for EVT, and indicate a significant potential opportunity for a randomized controlled trial to clarify patient outcomes in this subgroup.

## CONCLUSION

This meta-analysis of recent clinical trials and retrospective studies demonstrates that a favorable ASPECTS obtained after AIS with ELVO is associated with significantly better outcomes after EVT than an unfavorable ASPECTS, regardless of the cut-off used. Since functional outcome and mortality follow an exposure–response pattern relative to ASPECTS, EVT is unlikely to be useful for low (0–4) ASPECTS patients and is useful for patients with high (8–10) ASPECTS. There may be a subset of patients with intermediate (5–7) ASPECTS for whom EVT offers clinical benefit.

**Author affiliations**
[1]NeuroSpine Surgery Research Group (NSURG), Sydney, New South Wales, Australia
[2]Department of Medical Imaging, University of Toronto, Toronto, Ontario, Canada
[3]Department of Medical Imaging, St Michael's Hospital, Toronto, Ontario, Canada
[4]Interventional Neuroradiology, Austin Health, Heidelberg, Victoria, Australia
[5]University of Adelaide, Adelaide, South Australia, Australia
[6]NeuroEndovascular Program, Massachusetts General Hospital, Boston, Massachusetts, USA
[7]Department of Radiology, Beaumont Hospital, Dublin, Ireland
[8]Interventional Neuroradiology Unit, Monash Health, Clayton, Victoria, Australia
[9]Department of Imaging, Monash University, Clayton, Victoria, Australia
[10]Department of Radiology, Beaumont Hospital, Dublin, Ireland

**Contributors** Study inception: KP, HA. Data extraction: KP, SS, AAD, JM. Data analysis: KP, SS, AAD. Interpretation: all authors. Initial draft of manuscript: KP, SS, AAD, HA. Review and editing: all authors. Supervision: DMB, RC, HA.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent** Not required.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** All data available in manuscript.

## REFERENCES

1 Davis S, Lees K, Donnan G. Treating the acute stroke patient as an emergency: current practices and future opportunities. *Int J Clin Pract* 2006;60:399–407.
2 Leslie-Mazwi T, Chandra RV, Baxter BW, *et al*. ELVO: an operational definition. *J Neurointerv Surg* 2018;10:507–9.
3 Linfante I, Dabus G. Predicting outcomes in the era of endovascular therapy. *Stroke* 2017;48:6–7.
4 Berkhemer OA, Fransen PS, Beumer D, *et al*. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med* 2015;372:11–20.
5 Bracard S, Ducrocq X, Mas JL, *et al*. Mechanical thrombectomy after intravenous alteplase versus alteplase alone after stroke (THRACE): a randomised controlled trial. *Lancet Neurol* 2016;15:1138–47.
6 Goyal M, Demchuk AM, Menon BK, *et al*. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med* 2015;372:1019–30.
7 Saver JL, Goyal M, Bonafe A, *et al*. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med* 2015;372:2285–95.
8 Jovin TG, Chamorro A, Cobo E, *et al*. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med* 2015;372:2296–306.
9 Muir KW, Ford GA, Messow CM, *et al*. Endovascular therapy for acute ischaemic stroke: the Pragmatic Ischaemic Stroke Thrombectomy Evaluation (PISTE) randomised, controlled trial. *J Neurol Neurosurg Psychiatry* 2017;88:38–44.
10 Hill MD, Demchuk AM, Goyal M, *et al*. Alberta Stroke Program early computed tomography score to select patients for endovascular treatment: Interventional Management of Stroke (IMS)-III Trial. *Stroke* 2014;45:444–9.
11 Barber PA, Demchuk AM, Zhang J, *et al*. Validity and reliability of a quantitative computed tomography score in predicting outcome of hyperacute stroke before thrombolytic therapy. *The Lancet* 2000;355:1670–4.
12 Psychogios MN, Schramm P, Frölich AM, *et al*. Alberta Stroke Program Early CT Scale evaluation of multimodal computed tomography in predicting clinical outcomes of stroke patients treated with aspiration thrombectomy. *Stroke* 2013;44:2188–93.
13 Lum C, Ahmed ME, Patro S, *et al*. Computed tomographic angiography and cerebral blood volume can predict final infarct volume and outcome after recanalization. *Stroke* 2014;45:2683–8.
14 Powers WJ, Derdeyn CP, Biller J, *et al*. 2015 American Heart Association/American Stroke Association focused update of the 2013 guidelines for the early management of patients with acute ischemic stroke regarding endovascular treatment: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2015;46:3020–35.
15 Logan C, Maingard J, Phan K, *et al*. Borderline Alberta Stroke Programme Early CT Score patients with acute ischemic stroke due to large vessel occlusion may find benefit with endovascular thrombectomy. *World Neurosurg* 2018;110.
16 Penumbra Pivotal Stroke Trial Investigators. The penumbra pivotal stroke trial: safety and effectiveness of a new generation of mechanical devices for clot removal in intracranial large vessel occlusive disease. *Stroke* 2009;40:2761–8.
17 Goyal M, Menon BK, van Zwam WH, *et al*. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet* 2016;387:1723–31.
18 Turk AS, Frei D, Fiorella D, *et al*. ADAPT FAST study: a direct aspiration first pass technique for acute stroke thrombectomy. *J Neurointerv Surg* 2014;6:260–4.
19 Mourand I, Abergel E, Mantilla D, *et al*. Favorable revascularization therapy in patients with ASPECTS ≤ 5 on DWI in anterior circulation stroke. *J Neurointerv Surg* 2018;10:5–9.
20 Hungerford JP, Hyer M, Turk AS, *et al*. Impact of ASPECT scores and infarct distribution on outcomes among patients undergoing thrombectomy for acute ischemic stroke with the ADAPT technique. *J Neurointerv Surg* 2017;9:823–9.
21 Desilles JP, Consoli A, Redjem H, *et al*. Successful reperfusion with mechanical thrombectomy is associated with reduced disability and mortality in patients with pretreatment diffusion-weighted imaging-Alberta Stroke Program Early Computed Tomography Score ≤6. *Stroke* 2017;48:963–9.
22 Kim SK, Yoon W, Park MS, *et al*. Outcomes are not different between patients with intermediate and high DWI-ASPECTS after stent-retriever embolectomy for acute anterior circulation stroke. *AJNR Am J Neuroradiol* 2016;37:1080–5.
23 Yoo AJ, Berkhemer OA, Fransen PSS, *et al*. Effect of baseline Alberta Stroke Program Early CT Score on safety and efficacy of intra-arterial treatment: a subgroup analysis of a randomised phase 3 trial (MR CLEAN). *Lancet Neurol* 2016;15:685–94.
24 Li W, Li S, Dai M, *et al*. Comparisons of ASPECTS 5 and 6 for endovascular treatment in anterior circulation occlusive stroke. *Interv Neuroradiol* 2017;23:516–20.
25 Wasser K, Papanagiotou P, Brunner F, *et al*. Impact of ASPECTS on computed tomography angiography source images on outcome after thrombolysis or endovascular therapy in large vessel occlusions. *Eur J Neurol* 2016;23:1599–605.
26 Haussen DC, Dehkharghani S, Rangaraju S, *et al*. Automated CT Perfusion Ischemic Core Volume and Noncontrast CT ASPECTS (Alberta Stroke Program Early CT Score): correlation and clinical outcome prediction in large vessel stroke. *Stroke* 2016;47:2318–22.
27 Goyal N, Tsivgoulis G, Frei D, *et al*. A multicenter study of the safety and effectiveness of mechanical thrombectomy for patients with acute ischemic stroke not meeting top-tier evidence criteria. *J Neurointerv Surg* 2018;10:10–16.
28 Ouyang F, Chen Y, Zhao Y, *et al*. Selection of patients and anesthetic types for endovascular treatment in acute ischemic stroke: a meta-analysis of randomized controlled trials. *PLoS One* 2016;11:11.
29 Ryu CW, Shin HS, Park S, *et al*. Alberta stroke program early CT score in the prognostication after endovascular treatment for ischemic stroke: a meta-analysis. *Neurointervention* 2017;12:20–30.

30 Sarzetto F, Gupta S, Alotaibi NM, *et al*. Outcome evaluation of acute ischemic stroke patients treated with endovascular thrombectomy: a single-institution experience in the era of randomized controlled trials. *World Neurosurg* 2017;99:593–8.
31 Sandercock P, Wardlaw JM, Lindley RI, *et al*. The benefits and harms of intravenous thrombolysis with recombinant tissue plasminogen activator within 6 h of acute ischaemic stroke (the third International Stroke Trial [IST-3]): a randomised controlled trial. *Lancet* 2012;379:2352–63.
32 Danière F, Lobotesis K, Machi P, *et al*. Patient selection for stroke endovascular therapy–DWI-ASPECTS thresholds should vary among age groups: insights from the RECOST study. *AJNR Am J Neuroradiol* 2015;36.
33 Bhole R, Goyal N, Nearing K, *et al*. Implications of limiting mechanical thrombectomy to patients with emergent large vessel occlusion meeting top tier evidence criteria. *J Neurointerv Surg* 2017;9:225–8.
34 Hui FK, Obuchowski NA, John S, *et al*. ASPECTS discrepancies between CT and MR imaging: analysis and implications for triage protocols in acute ischemic stroke. *J Neurointerv Surg* 2017;9:240–3.
35 Gupta AC, Schaefer PW, Chaudhry ZA, *et al*. Interobserver reliability of baseline noncontrast CT Alberta Stroke Program Early CT Score for intra-arterial stroke treatment selection. *AJNR Am J Neuroradiol* 2012;33:1046–9.