Endovascular thrombectomy for basilar artery occlusion: translating research findings into clinical practice

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Summary

Background **Basilar artery occlusion is a rare and severe condition. The effectiveness of endovascular thrombectomy in patients with basilar artery occlusion was unclear until recently, because these patients were excluded from most trials of endovascular thrombectomy for large-vessel occlusion ischaemic stroke.**

Recent developments **The Basilar Artery International Cooperation Study (BASICS) and the Basilar Artery Occlusion Endovascular Intervention versus Standard Medical Treatment (BEST) trials, specifically designed to investigate the benefit of thrombectomy in patients with basilar artery occlusion, did not find significant evidence of a benefit of endovascular thrombectomy in terms of disability outcomes at 3 months after stroke. However, these trials suggested a potential benefit of endovascular thrombectomy in patients presenting with moderate-to-severe symptoms. Subsequently, the Endovascular Treatment for Acute Basilar Artery Occlusion (ATTENTION) and the Basilar Artery Occlusion Chinese Endovascular (BAOCHE) trials, which compared endovascular thrombectomy versus medical therapy within 24 h of onset, showed clear benefit of endovascular thrombectomy in reducing disability and mortality, particularly in patients with moderate-to-severe symptoms. The risk of intracranial haemorrhage with endovascular thrombectomy was similar to the risk in anterior circulation stroke. Thrombectomy was beneficial regardless of age, baseline characteristics, the presence of intracranial atherosclerotic disease, and time from symptom onset to randomisation. Therefore, the question of whether endovascular thrombectomy is beneficial in basilar artery occlusion now appears to be settled in patients with moderate-to-severe symptoms, and endovascular thrombectomy should be offered to eligible patients.**

Where next? **Key outstanding issues are the potential benefits of endovascular thrombectomy in patients with mild symptoms, the use of intravenous thrombolysis in an extended time window (ie, after 4·5 h of symptom onset), and the optimal endovascular technique for thrombectomy. Dedicated training programmes and automated software to assist with the assessment of imaging prognostic markers could be useful in the selection of patients who might benefit from endovascular thrombectomy. Large international research networks should be built to address knowledge gaps in this field and allow the conduct of clinical trials with fast and consecutive enrolment and a diverse ethnic representation.**

Introduction

Since the publication of landmark randomised controlled trials in 2015 and 2018,[1–3] endovascular thrombectomy has been established as the standard of care within 24 h of symptom onset for ischaemic strokes caused by the occlusion of large vessels in the anterior circulation. However, the value of endovascular thrombectomy in patients with basilar artery occlusion had remained uncertain because these patients were excluded from most endovascular thrombectomy trials. Exclusion from trials was due to concerns about the heterogeneity that would be introduced by the inclusion of this less common (ie, 1% of events of ischaemic stroke) and severe stroke subtype,[4] but also because of the limited equipoise to randomly assign patients to not receive thrombectomy for a condition with a dismal prognosis if untreated.[5] Basilar artery occlusion is associated with a high risk of disability and mortality[4,6] in the absence of recanalisation. Four randomised trials were completed in these patients between 2020 and 2022.[7–10] In this Rapid Review, we provide an update on the evidence for endovascular thrombectomy for basilar artery occlusion and discuss how to translate the trial results into clinical practice. We also discuss key outstanding issues that need to be evaluated in future clinical trials to address knowledge gaps in the field.

Recent research developments

The Basilar Artery Occlusion Endovascular Intervention versus Standard Medical Treatment (BEST)[7] trial and the Basilar Artery International Cooperation Study (BASICS)[8] trial, both comparing endovascular thrombectomy with medical management, did not find significant evidence of a benefit of endovascular thrombectomy in terms of disability at 3 months after stroke. The BEST[7] trial, which compared endovascular thrombectomy with medical management within 8 h of symptom onset, was hindered by crossovers from the medical therapy to the endovascular thrombectomy arm. Although the intention-to-treat analysis did not find a difference between groups in ambulatory outcome (modified Rankin scale [mRS] 0–3) at 90 days after stroke, significant increases were observed in the per-protocol analysis (44% endovascular thrombectomy *vs* 25% medical therapy; adjusted odds ratio [OR] 2·90 [95% CI 1·20–7·03]) and as-treated analysis (47% endovascular thrombectomy *vs* 24% medical therapy; adjusted OR 3·02 [1·31–7·0]). The BASICS[8] trial, comparing endovascular thrombectomy to

medical therapy within 6 h of the estimated time of occlusion, took over 8 years to be completed, despite the involvement of 23 centres in Europe and Brazil. The slow recruitment suggested non-consecutive enrolment and results did not differ between groups overall (90-day mRS 0–3; 44·2% for endovascular thrombectomy *vs* 37·7% medical therapy; risk ratio [RR] 1·18 [95% CI 0·92–1·50]), with similar rates of symptomatic intracranial haemorrhage in both groups. Of note, the BASICS trial protocol was modified during the trial due to the slow enrolment, allowing patients with milder presentations to be included. These patients with milder symptoms (National Institutes of Health Stroke Scale [NIHSS] <10) did not appear to benefit from thrombectomy and might have led to the overall neutral result, despite evidence of benefit in patients with NIHSS of 10 or more. Furthermore, the BASICS trial was most likely underpowered to detect differences in treatment effect because of better-than-expected outcomes in the control group. The outcomes in the control group might have been due to the high rate (79%) of intravenous thrombolysis use in this group. In the BASICS trial, intravenous thrombolysis was allowed 4·5 h from the estimated time of basilar artery occlusion, rather than from symptom onset as it was in the BEST trial. Endovascular thrombectomy had to be feasible within 6 h, whereas in the BEST trial, randomisation had to occur within 8 h of estimated occlusion time, which might explain the higher rates of intravenous thrombolysis use in BASICS. Recanalisation rates in these trials were lower than those of subsequent positive trials (table 1), which is likely to have been because of the use of older endovascular techniques. Initial

	BASICS trial		BEST trial		ATTENTION trial		BAOCHE trial	
	Endovascular thrombectomy (n=154)	Medical care (n=146)	Endovascular thrombectomy (n=66)	Medical care (n=65)	Endovascular thrombectomy (n=226)	Medical care (n=114)	Endovascular thrombectomy (n=110)	Medical care (n=107)
Age (years), mean (SD) or median (IQR)	66·8 ± 13.1	67·2 ± 11·9	62 (50–74)	68 (57–74)	66·0 ± 11·1	67·3 ± 10·2	64·2 ± 9·6	63·7 ± 9·8
Sex								
Male	100 (64·9%)	96 (65·8%)	48 (72·7%)	52 (80·0%)	149 (65·9%)	82 (71·9%)	80 (72·7%)	79 (73·8%)
Female	54 (35·1%)	50 (34·2%)	18 (27·3%)	13 (20·0%)	77 (34·1%)	32 (28.1%)	30 (27·3%)	28 (26·2%)
Median NIHSS (IQR)	21	22	32 (18–38)	26 (13–37)	24 (15–35)	24 (14–35)	20	19
Medical history								
Hypertension	93 (60·4%)	82/145 (56·6%)‡	45 (68·2%)	42 (64·6%)	162 (71·7%)	81 (71·1%)	90 (81·8%)	79/106 (74·5%)‡
Diabetes	34/153 (22·2%)‡	31 (21·2%)	10 (15·2%)	11 (16·9%)	48 (21·2%)	24 (21·1%)	30 (27·3%)	29 (27·1%)
Atrial fibrillation	44 (28·6%)	22 (15·1%)	18 (27·3%)	20 (15·4%)	45 (19·9%)	26 (22·8%)	14 (12·7%)	13 (12·1%)
Previous stroke	26 (16·9%)	26 (17·8%)	14 (21·2%)	20 (30·8%)	50 (22·1%)	25 (21·9%)	25 (22·7%)	28 (26·2%)
Intravenous thrombolytic therapy	121 (78·6%)	116 (79·5%)	18 (27·3%)	21 (32·3%)	69 (30·5%)	39 (34·2%)	15 (13·6%)	23 (21·5%)
Alteplase intravenous thrombolytic therapy	NA	NA	NA	NA	60 (26·5%)	35 (30·7%)	NA	NA
Urokinase intravenous thrombolytic therapy	NA	NA	NA	NA	9 (4·0%)	4 (3·5%)	NA	NA
Median time from onset to randomisation (IQR)	4·4 h (3·3–6·2)	NA	4·1 h (2·3–6·0)	4·6 h (3·2–6·4)	5·1 h (3·6–7·2)	4·9 h (3·5–7·0)	11·1 h (8·5–14·3)	11 h (8·2–13·9)
Location of basilar artery occlusion								
Proximal third	46/145 (31·7%)‡	49/137 (35·8%)‡	NA	NA	69/225 (30·6%)‡	39 (34·2%)	53/107 (49·5%)‡	45/105 (42·9%)‡
Middle third	49/145 (33·8%)‡	41/137 (29·9%)‡	NA	NA	62/225 (27·5%)‡	29 (25·4%)	40/107 (37·4%)‡	37/105 (35·2%)‡
Distal third	50/145 (34·5%)‡	47/139 (34·3%)‡	NA	NA	74/225 (32·8%)‡	40 (35·1%)	13/107 (12·1%)‡	23/105 (21·9%)‡
pc-ASPECTS score (IQR)	10 (8–10)	NA	8 (7–9)	NA	9 (8–10)	NA	8 (7–10)	NA
Cause of stroke								
Large artery atherosclerosis	53/146 (36·3%)‡	43/142 (32·6%)‡	37 (56·1%)	32 (49·2%)	108 (47·8%)	42 (36·8%)	75 (68·2%)	69 (64·5%)
Cardioembolism	51/146 (34·9%)‡	24/132 (18·2%)‡	14 (21·2%)	17 (26·2%)	46 (20·4%)	26 (22·8%)	11 (10·0%)	7 (6·5%)
Other determined cause*	12/146 (8·2%)‡	9/132 (6·8%)‡	15 (22·7%)	16 (24·6%)	3 (1·3%)	0 (0%%)	5 (4·5%)	4 (3·7%)
Undetermined cause*	30/146 (20·5%)‡	55/132 (41·7%)‡	..	..	69 (30·5%)	46 (40·4%)	19 (17·3%)	27 (25·2%)

(Table 1 continues on next page)

	BASICS trial		BEST trial		ATTENTION trial		BAOCHE trial	
	Endovascular thrombectomy (n=154)	Medical care (n=146)	Endovascular thrombectomy (n=66)	Medical care (n=65)	Endovascular thrombectomy (n=226)	Medical care (n=114)	Endovascular thrombectomy (n=110)	Medical care (n=107)
(Continued from previous page)								
Successful reperfusion (mTICI 2b/3 score)	63/88 (72·0%)‡	NA	45/63 (71·0%)‡	NA	208/223 (93·3%)‡	NA	89/101 (88·1%)‡	NA
Endovascular therapy details								
Urokinase rt- PA	21/144 (14·6%)‡	NA	NA	NA	NA	NA	NA	NA
Heparin used	48/131 (36·6%)‡	NA	NA	NA	NA	NA	NA	NA
Stent retriever thrombectomy	60/118 (50·8%)‡	NA	64 (83·1%)†	NA	11 (4·9%)	NA	103 (93·6%)	NA
Aspiration	58/118 (49%)‡	NA	NA	NA	77/221 (34·8%)‡	NA	3 (2·7%)	NA
Angioplasty	30/138 (21·7%)‡	NA	3/77 (3·9%)†	NA	NA	NA	NA	NA
Stent placement	23/137 (16·8%)‡	NA	20/77 (26·0%)†	NA	NA	NA	NA	NA
Intra-arterial thrombolysis	NA	NA	4/77 (5·2%)†	NA	12/221 (5·4%)‡	NA	NA	NA
Combined technique	NA	NA	NA	NA	110/221 (49·8%)‡	NA	NA	NA
Intracranial angioplasty or stenting	NA	NA	NA	NA	88/221 (39·8%)‡	NA	60 (54·5%)	NA
Extracranial angioplasty or stenting	NA	NA	NA	NA	18/221 (8·1%)‡	NA	6 (5·5%)	NA
Intravenous tirofiban	NA	NA	NA	NA	89/221 (40·3%)‡	NA	59 (53·6%)	NA
Balloon guide catheter use	NA	NA	NA	NA	NA	NA	15 (13·6%)	NA

BASICS=Basilar Artery International Cooperation Study. BEST=Basilar Artery Occlusion Endovascular Intervention versus Standard Medical Treatment. ATTENTION=Endovascular Treatment for Acute Basilar Artery Occlusion. BAOCHE=Basilar Artery Occlusion Chinese Endovascular. pc-ASPECTS=posterior circulation acute stroke prognosis early CT score. NA=not applicable. NIHSS=National Institutes of Health Stroke Scale. mTICI=modified treatment in cerebral ischemia score. mRS=modified Rankin scale. rT-PTA=recombinant tissue-type plasminogen activator. *These data were recorded together as other determined cause or undertermined cause in the BEST trial. †Due to crossover from the medical group into the endovascular thrombectomy group, the total number of patients who received endovascular thrombectomy was 77. ‡Denominator differs from the n value due to missing data in the trial.

Table 1: **Randomised controlled trials in patients with basilar artery occlusion**

endovascular approaches used intra-arterial thrombolytic therapies[8,11] or earlier generation devices.[8] Although the BASICS and BEST trials were hampered by methodological issues, these trials did suggest a potential benefit of endovascular thrombectomy in basilar artery occlusion and were instrumental in shaping the design of subsequent positive trials.

The non-randomised Endovascular Treatment for Acute Basilar Artery Occlusion (ATTENTION) registry is the largest prospective registry to date, including 2134 patients who presented within 24 h of estimated basilar artery occlusion.[12] Patients receiving endovascular thrombectomy were more likely to have lower disability and mortality at 90 days, despite an increased risk of symptomatic intracranial haemorrhage, than patients receiving standard medical therapy. In accordance with the results from the BASICS[8] trial, endovascular thrombectomy was not beneficial in patients with baseline NIHSS of less than 10. No treatment-effect modification was found according to time to treatment, which is consistent with the results of the BASILAR study (another non-randomised, prospective cohort of patients with basilar artery occlusion who were treated with endovascular thrombectomy within 24 h).[13]

Two randomised controlled trials were completed in China in 2022: the ATTENTION[9] and the Basilar Artery Occlusion Chinese Endovascular (BAOCHE)[10] trials (tables 1, 2). Both trials used imaging scores to assess the extent of baseline ischaemic changes and found a benefit of endovascular thrombectomy in the absence of large baseline infarct (posterior circulation Alberta stroke programme early CT [pc-ASPECTS] score ≥6 if aged ≤80 years and ≥8 if older than 80 years in the ATTENTION trial; pc-ASPECTS ≥6 and pons-midbrain-index of ≤2 in the BAOCHE trial), with an acceptable risk of symptomatic intracranial haemorrhage. In the ATTENTION trial, patients treated with endovascular thrombectomy within 12 h of estimated basilar artery occlusion had better outcomes than patients treated with medical therapy (90-day mRS 0–3: 46% for endovascular thrombectomy *vs* 22·8% for medical therapy,

	BASICS trial	BEST trial	ATTENTION trial	BAOCHE trial
mRS 0–3 at 3 months for endovascular thrombectomy *vs* medical care	44·2% *vs* 37·7% (aRR 1·18 [95% CI 0·92–1·50])	Intention-to-treat 42·0% *vs* 32·0% (aOR 1·74 [95% CI 0·81–3·74]); per-protocol: 44·0% *vs* 25·0% (aOR 2·90 [95% CI 1·20–7·03]); as-treated: 47·0% *vs* 24·0% (aOR 3·02 [95% CI 1·31–7·00])	46·0% *vs* 22·8% aRR (2·06 [95% CI 1·46–2·91]) p<0·001	46·4% *vs* 24·3% aOR 1·81 (95% CI 1·26–2·60) p=0·001
mRS ordinal analysis at 3 months	cOR 1·35 (95% CI 0·88–2·88)	Intention-to-treat aOR 1·36 (95% CI 0·72–2·55); per-protocol aOR 2·19 (95% CI 1·08–4·44); as-treated aOR 2·36 (95% CI 1·20–4·62)	cOR 2·87 (95% CI 1·84–4·47)	cOR 2·64 (95% CI 1·54–4·5)
Symptomatic haemorrhage for endovascular thrombectomy *vs* medical care	3·9% *vs* 0·7%* (aRR 5·6 [95% CI 0·7–45])	8% *vs* 0%† p=0·06	5·3% *vs* 0%† p=0·001	5·9% *vs* 1·1%† (aRR 5·18 [95% CI 0·6–42]) p=0·125
Mortality at 3 months for endovascular thrombectomy *vs* medical care	38·3% *vs* 43·2%, aRR 0·9 (95% CI 0·7–1·1)	33·0% *vs* 38·0%, aOR 0·8 (95% CI 0·37–1·64)	36·7% *vs* 55·3%, aRR 0·66 (95% CI 0·52–0·82)	30·9% *vs* 42·1%, aRR 0·75 (95% CI 0·54–1·04)

aOR=adjusted odds ratio. aRR=adjusted risk ratio. ATTENTION=Endovascular Treatment for Acute Basilar Artery Occlusion. BAOCHE=Basilar Artery Occlusion Chinese Endovascular. BASICS=Basilar Artery International Cooperation Study. BEST=Basilar Artery Occlusion Endovascular Intervention versus Standard Medical Treatment. cOR=common odds ratio. mRS=modified Rankin scale. *Heidelberg bleeding classification. †Safe Implementation of Thrombolysis in Stroke-Monitoring Study definition.

Table 2: **Outcomes of the randomised controlled trials in patients with basilar artery occlusion**

adjusted RR 2·06, [95% CI 1·46–2·91] p<0·001; mRS ordinal analysis: common odds ratio [cOR] 2·87 [95% CI 1·84–4·47]). The number of patients needed to treat to achieve an additional ambulatory outcome was 4·3. This trial was executed with minimal crossover and consecutive recruitment. The trial showed a clear benefit in reduced disability after endovascular thrombectomy in patients with basilar artery occlusion presenting with moderate-to-severe symptoms. In the BAOCHE trial, patients with basilar artery occlusion were assigned to either endovascular thrombectomy or medical therapy in the 6–24 h time window. During this trial, the inclusion criteria were expanded to patients with NIHSS 6–9 and the primary outcome was changed from mRS 0–4 to mRS 0–3 to align with the BASICS and BEST trials. Although the initial sample size was 318 patients, the data safety monitoring board recommended stopping enrolment after the planned interim analysis at 212 patients, which indicated the crossing of prespecified boundaries. This trial confirmed a significant benefit in reducing disability after endovascular thrombectomy in the 6–24 h time window (90-day mRS 0–3: 46·4% for endovascular thrombectomy vs 24·3% for medical therapy, adjusted OR 1·81 [95% CI 1·26–2·60] p=0·001, number needed to treat 4·5; mRS ordinal analysis, cOR 2·64 [95% CI 1·54–4·5]). The difference in time window for treatment most likely contributed to the lower rates of intravenous thrombolysis in these trials (table 1), compared with the BASICS trial. Additionally, patients in China often had to pay for thrombolytic therapies, which could have further reduced their use.

Of note, the magnitude of treatment effect in these trials is similar to that reported for endovascular thrombectomy in patients with anterior circulation stroke.[1,2] Despite a higher risk of symptomatic intracerebral haemorrhage (5·3% for endovascular thrombectomy vs 0% for medical therapy, p=0·001, in ATTENTION; 5·9% for endovascular thrombectomy *vs* 1·1% for medical therapy, p=0·125, in BAOCHE), endovascular thrombectomy reduced 90-day mortality in ATTENTION (36·7% for endovascular thrombectomy *vs* 55·3% for medical therapy, adjusted RR 0·66 [95% CI 0·52–0·82]) with a similar finding in BAOCHE (30·9% for endovascular thrombectomy *vs* 42·1% for medical therapy, 0·75 [0·54–1·04]), which is clinically important given the poor prognosis of this condition. Therefore, the question of whether endovascular thrombectomy is beneficial in patients with basilar artery occlusion presenting with moderate-to-severe symptoms now appears settled and endovascular thrombectomy should be offered to eligible patients.

Identifying eligible patients

Clinical severity

The results of the randomised controlled trials in basilar artery occlusion showed an overwhelming benefit of endovascular thrombectomy in patients with moderate-to-severe symptoms (NIHSS ≥10). However, whether a benefit is retained in patients with milder symptoms (NIHSS <10) is uncertain. The ATTENTION trial included only patients with NIHSS of 10 or more, whereas the BASICS trial included patients with NIHSS of less than 10 and the BAOCHE trial included patients with NIHSS of at least 6. The inclusion of patients with NIHSS of less than 10 most likely diluted the treatment effect, which was driven by the benefit in the subgroup of patients with moderate-to-severe symptoms. Therefore, the management of patients with basilar artery occlusion with milder symptoms requires further research. In this context, it is important to emphasise that low NIHSS in posterior circulation stroke does not necessarily mean absence of disabling symptoms. The NIHSS is predominantly weighted towards anterior circulation stroke symptoms and might underestimate clinical severity in the posterior circulation.[14] Notably, a proportion of patients with basilar artery occlusion who are initially affected mildly can subsequently deteriorate and become

disabled.[15] Although patients with coma were included in these trials, the severity and duration of consciousness alterations, which are important prognostic factors of outcome in basilar artery occlusion,[6,16] were not considered among the inclusion criteria. Alternative clinical tools designed for patients with basilar artery occlusion could be useful to reliably assess clinically disabling symptoms for prognosis and treatment decision making in the acute setting.[17] Given the results from the BASICS trial, use of intravenous thrombolysis beyond 4·5 h of symptom onset might be considered for patients with NIHSS of less than 10. Importantly, previous observational studies have suggested that the use of intravenous thrombolysis beyond 4·5 h, in the absence of extensive ischaemic changes, might benefit patients with basilar artery occlusion[18,19] and that the risk of haemorrhagic transformation in posterior circulation stroke is lower than in the anterior circulation.[20,21]

Age, premorbid status, and time to treatment

The ATTENTION and BAOCHE trials had strict inclusion criteria in terms of age and premorbid function. In the BAOCHE trial, only patients aged 80 years or younger with no functional disability before stroke (mRS ≤1) were eligible. In the ATTENTION trial, patients older than 80 years could be enrolled only if they had an mRS of 0. To avoid over selection, the age and mRS criteria should not be strictly translated to clinical practice. Chronological age has consistently not been a treatment effect modifier for stroke reperfusion therapies.[22] Within the patients randomly assigned into the trials, no heterogeneity was found in the association of treatment with outcome according to age, baseline clinical severity, location of the occlusion, and time from onset to randomisation. A case-by-case approach, assessing the individual risks and benefits and considering the poor natural history (ie, the prognosis of the disease but in the absence of treatment) of basilar artery occlusion, is advisable. The absence of treatment effect modification according to time-to-treatment in basilar artery occlusion is consistent with the findings for endovascular thrombectomy in anterior circulation strokes when imaging indicates the presence of salvageable brain tissue.[1,2]

Imaging selection criteria

The ATTENTION and BAOCHE trials were pragmatic and predominantly used non-contrast CT brain or CT angiography source images to assess pc-ASPECTS and pons-midbrain index, with no requirement for advanced imaging (ie, MRI or CT perfusion) to select patients for treatment in the late time window (ie, beyond 6 h of symptom onset). This approach facilitates the implementation and translation of the trial results in settings where advanced imaging might not be available. However, an important limitation is that both pc-ASPECTS and the pons-midbrain index have not been routinely adopted in treatment decision making and the reliability of these scores might vary according to

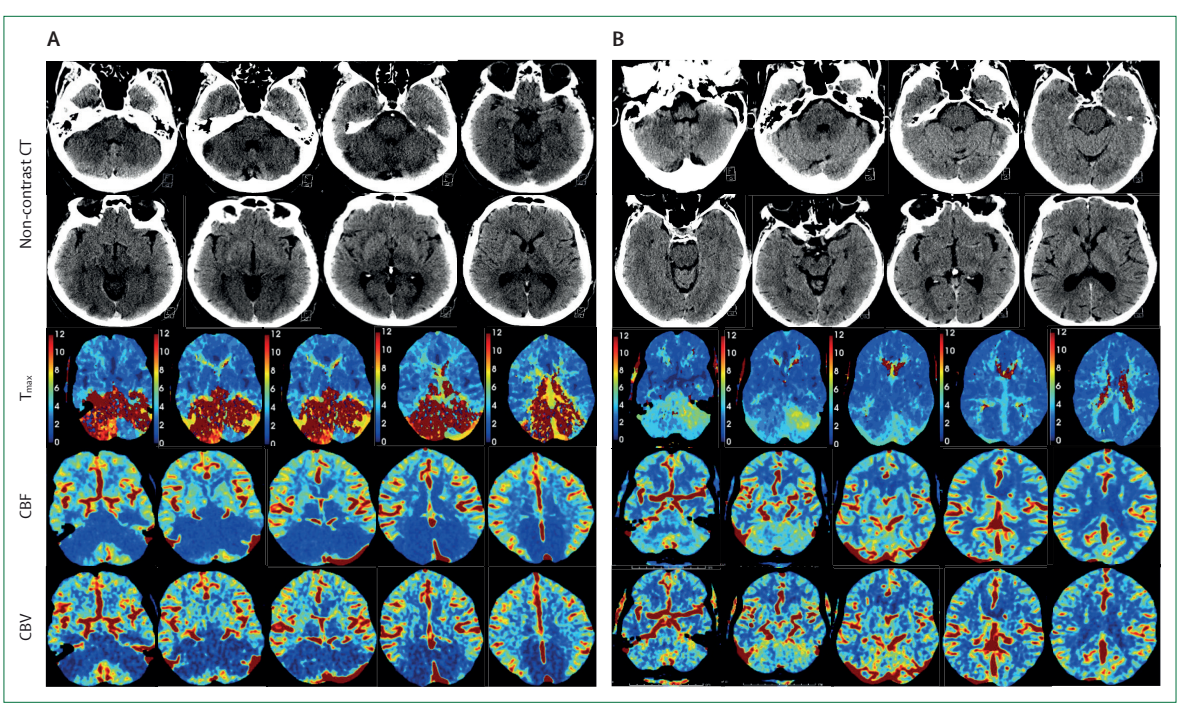

Figure: **Practicalities of imaging selection for patients with basilar artery occlusion**
(A) Unfavourable brain imaging profile in a patient with basilar artery occlusion showing extensive non-contrast CT hypodensity, severely delayed blood flow (Tmax), and severely reduced CBF and CBV. (B) Favourable brain imaging profile in a patient with basilar artery occlusion with absence of hypodensity on non-contrast CT, relatively mildly delayed blood flow (Tmax), and preserved CBF and CBV. CBF=cerebral blood flow. CBV=cerebral blood volume.

the assessor's experience. In settings where whole-brain coverage CT perfusion is routinely performed as part of standard care imaging, CT perfusion maps could provide additional useful information, assisting clinicians to evaluate ischaemic changes in the posterior fossa and identifying patients with favourable and unfavourable imaging profiles (figure).[23–25] Importantly, CT perfusion is faster and has fewer contraindications than MRI in the acute setting.[25] There was effect modification favouring the endovascular thrombectomy group for larger infarcts in post-hoc subgroup analyses of both the ATTENTION and BAOCHE trials, suggesting that a larger stroke burden might yield stronger treatment effects.

Atherosclerotic versus embolic causes of basilar artery occlusion

The ATTENTION and the BAOCHE trials exclusively included Asian patients, potentially affecting the generalisability of the results. This ethnic group is characterised by a high prevalence of intracranial atherosclerosis compared with other ethnicities.[26] The presence of intracranial atherosclerosis might augment the complexity of thrombectomy and increase the need for adjuvant antiplatelet agents, particularly if angioplasty or stenting is required, potentially increasing the risk of haemorrhage. However, despite this increased complexity of treatment,[27] the strong benefit observed indicates the robust effect of endovascular thrombectomy. Observational studies suggested that patients with atrial fibrillation with smaller or more distal cardioembolic thrombi might be more responsive to intravenous thrombolysis or have limited benefit after endovascular thrombectomy because of less developed collateral blood vessels than patients with atherosclerotic disease.[28] However, in the ATTENTION trial, subgroup analyses showed no treatment effect modification based on the presence of intracranial atherosclerosis, with a benefit of endovascular thrombectomy preserved in patients without atherosclerotic disease. Patients with atherosclerotic disease might present with mild, stuttering symptoms ongoing for hours or days. In this context, the definition of time of onset as the estimated time of basilar artery occlusion (ie, onset of severe symptoms or coma), rather than the last time the patient was known to be well, might be more appropriate. In these patients, a longstanding basilar stenosis is likely to be associated with more developed collaterals,[4] which might extend the time window for treatment, hence expanding the patient population that could benefit from thrombectomy;[21] however, this hypothesis requires further research and could be analysed in a meta-analysis of individual patient data from the four trials.

Conclusions and future directions

The overwhelming benefit of endovascular thrombectomy in the early and late time window seen in anterior circulation ischaemic strokes has now been shown in the posterior circulation. The 2019 American Stroke Association guidelines[29] state that endovascular thrombectomy might be reasonable in selected patients, and the 2019 European Stroke Organisation guidelines[30] advise that endovascular thrombectomy should be strongly considered. These guidelines are likely to be updated to reflect the most recent trial results. The Australian and New Zealand living guidelines already reflect the latest data.[31] The benefit of endovascular thrombectomy is less certain in patients with basilar artery occlusion presenting with NIHSS less than 10 than in those with NIHSS of at least 10. Although further research is warranted, the low NIHSS population is probably a heterogeneous group in whom additional clinical testing[17] and advanced imaging[32] might be necessary to identify patients with potentially disabling symptoms or who are at risk of subsequent clinical deterioration and would benefit from immediate endovascular thrombectomy.

Endovascular therapy is highly effective but resource intensive, and access is currently restricted in many countries. Therefore, intravenous thrombolytic therapies remain the standard of care in basilar artery occlusion, particularly in patients who initially present to a primary stroke centre without the capacity to perform endovascular thrombectomy. Extending intravenous thrombolysis use beyond 4·5 h after symptom onset in patients with basilar artery occlusion is practised in some centres and is the subject of an ongoing randomised trial (NCT05105633) that is testing tenecteplase, a potentially more effective thrombolytic therapy than alteplase.[33,34] Notably, the risk of symptomatic intracranial haemorrhage was low (0–1%) in the medical arm of all four endovascular thrombectomy trials,[7–10] including the BASICS trial, in which 79% of patients were treated with intravenous thrombolysis, and lower than the risk reported in anterior circulation stroke,[1,2,19] which supports the safety of extending intravenous thrombolysis beyond 4·5 h. Wider use of thrombolytic therapies in an extended time window in basilar artery occlusion, analogous to what has proven effective for anterior circulation strokes,[35,36] could greatly expand access to reperfusion therapies for patients requiring long transfers to an endovascular-capable centre or in settings where endovascular therapy is not widely available, including low-income countries.

Given the powerful treatment effect of endovascular thrombectomy, caution is required when considering the exclusion of patients from endovascular thrombectomy on the basis of imaging profiles in both early and extended time windows. Non-contrast CT assessment of the brainstem is challenged by beam-hardening artifacts. Therefore, dedicated training programmes to assess imaging prognostic markers in patients with basilar artery occlusion might be useful in clinical practice. Furthermore, automated software with artificial intelligence and machine-learning approaches that aid detection of ischaemic changes might improve the

Search strategy and selection criteria

We searched the Cochrane Library, MEDLINE, and Embase for articles published in any language between Jan 1, 2015, and Nov 1, 2022. We used the search terms "ischaemic/ischemic stroke", "basilar", "endovascular thrombectomy/mechanical thrombectomy/thrombectomy", and "clinical trial" or "meta-analysis". We searched the reference lists of articles identified by this search strategy and selected those that we judged to be relevant. We largely selected those published within the 12 months before our search, but did not exclude commonly referenced and highly regarded publications that were older. Review articles are cited to provide readers with more details and references than those included in this Rapid Review.

diagnostic and prognostic accuracy of validated imaging scores in the posterior circulation.[37] Dedicated training programmes and automated software could assist clinicians with the diagnosis of this condition, which can be challenging when fluctuating symptoms are present at onset, and with the identification of patients who are more likely to benefit from reperfusion therapies in the early and extended time window.

Device technology is continuing to evolve and might further improve treatment response in patients with basilar artery occlusion. Observational data suggested that a first-line aspiration approach might achieve higher recanalisation rates than would stent retrievers.[38] Balloon-guide catheters are less applicable in the posterior circulation due to size constraints and difficulty controlling flow from the contralateral vertebral artery.[39] A randomised controlled trial addressing this question is ongoing (NCT05320263).

To optimise patient outcomes, endovascular thrombectomy needs to be delivered as part of a holistic, high-quality system of care across the continuum, from early recognition to expedited transport to a hospital, improved neuroimaging markers to select patients for reperfusion therapies, organised care in the stroke unit, prevention of post-procedure complications, and effective rehabilitation and neurorecovery approaches. In this context, mobile stroke units might have an increasing role in pre-hospital triage, as evidence for their effectiveness mounts,[40] and could facilitate earlier delivery of thrombolysis in patients with basilar artery occlusion. Tools for the recognition of large vessel occlusion in the prehospital setting to deliver faster treatment,[41] adjuvant therapies to reduce the degree of ischaemic injury and improve collateral blood flow, and agents to reduce secondary injury[42,43] are all under active investigation in anterior circulation strokes. Further efforts are required to include patients with basilar artery occlusion in these clinical trials and address current knowledge gaps and unmet needs in this field.[44] Given the rarity of basilar artery occlusion, heterogeneity of clinical presentation, and the poor natural history, the conduct of clinical trials remains challenging. Therefore, the contribution of observational data to inform the design of future clinical trials is paramount. More efforts to build large international research networks are required so that clinical trials on rare diseases, such as basilar artery occlusion, can achieve rapid and consecutive enrolment and a more diverse ethnic representation to increase the generalisability of results.

Contributors

FA and BCVC conceptualised the Rapid Review, searched the literature, and drafted the manuscript. All authors reviewed and edited the manuscript.

Declaration of interests

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