Mamadaliev Abduraxmon Mamatkulovich
Specialized scientific and practical center for Neurosurgery and Neurorehabilitation at the Samarkand State Medical University

ENDOVASCULAR THROMBECTOMY BEYOND CONVENTIONAL IMAGING LIMITS: LARGE-CORE AND POSTERIOR-CIRCULATION STROKE IN THE ERA OF TISSUE-BASED SELECTION

Abstract

Background. Endovascular thrombectomy has moved beyond the conventional paradigm that restricted treatment to patients with small infarct cores, favorable perfusion mismatch, anterior-circulation occlusion, and narrow time windows. Randomized trials now support thrombectomy in selected large-core anterior-circulation stroke and moderate-to-severe basilar artery occlusion, making tissue viability, eloquent anatomy, collateral support, and clinical severity more important than time alone.

Materials and methods. Randomized trials, individual-patient-data meta-analyses, practice guidelines, imaging studies, and procedural investigations published through July 2026 were synthesized. Evidence was organized by infarct extent, imaging modality, time window, occlusion territory, neurological severity, reperfusion quality, hemorrhagic risk, and expected disability shift.

Results. RESCUE-Japan LIMIT, SELECT2, ANGEL-ASPECT, TENSION, LASTE, and the 2026 ATLAS analysis demonstrate an overall functional and survival benefit of thrombectomy in large-core stroke, although uncertainty persists for core volumes of 150 mL or greater, extensive edema, very low ASPECTS, and delayed presentation. ATTENTION, BAOCHE, and VERITAS support thrombectomy for basilar or dominant vertebral occlusion with moderate-to-severe deficits and limited irreversible brainstem injury. Imaging should identify hemorrhage, occlusion, infarct distribution, collateral circulation, edema, and procedural feasibility without creating avoidable delays. The proposed TISSUE-LVO model separates prognostic severity from treatment responsiveness and emphasizes rapid, technically effective, complication-conscious reperfusion selection.

Conclusion. Large-core or posterior-circulation involvement should no longer constitute an automatic exclusion. Treatment decisions should integrate tissue injury, anatomical eloquence, clinical severity, collateral reserve, procedural probability, and patient-centered outcome goals.

Keywords: endovascular thrombectomy; large ischemic core; large-vessel occlusion; ASPECTS; computed tomography perfusion; basilar artery occlusion; posterior-circulation stroke; tissue-based selection; reperfusion; ischemic penumbra.

Мамадалиев Абдурахмон Маматкулович
Специализированный научно-практический центр нейрохирургии и нейрореабилитации при Самаркандском Медицинском Университете

ЭНДОВАСКУЛЯРНАЯ ТРОМБЭКТОМИЯ ЗА ПРЕДЕЛАМИ ТРАДИЦИОННЫХ ВИЗУАЛИЗАЦИОННЫХ ОГРАНИЧЕНИЙ: КРУПНОЕ ИНФАРКТНОЕ ЯДРО И ИНСУЛЬТ ЗАДНЕЙ ЦИРКУЛЯЦИИ В ЭПОХУ ТКАНЕОРИЕНТИРОВАННОГО ОТБОРА

Аннотация

Актуальность. Эндоваскулярная тромбэктомия вышла за пределы традиционной парадигмы, ограничивавшей лечение пациентами с небольшим инфарктным ядром, благоприятным перфузионным несоответствием, окклюзией передней циркуляции и узким временным окном. Рандомизированные исследования подтверждают эффективность вмешательства при отобранном крупноядерном инфаркте передней циркуляции и окклюзии базилярной артерии с умеренным или тяжёлым дефицитом, вследствие чего жизнеспособность ткани, функциональная значимость поражённой анатомии, коллатеральная поддержка и клиническая тяжесть становятся важнее времени, рассматриваемого изолированно.

Материалы и методы. Синтезированы рандомизированные исследования, метаанализы индивидуальных данных, руководства, визуализационные и технические работы, опубликованные до июля 2026 года. Данные систематизированы по объёму инфаркта, методу визуализации, временному окну, локализации окклюзии, неврологической тяжести, качеству реперфузии и геморрагическому риску.

Результаты. RESCUE-Japan LIMIT, SELECT2, ANGEL-ASPECT, TENSION, LASTE и ATLAS подтверждают общий функциональный и прогностический эффект при крупном ядре, однако сохраняется неопределённость при объёме не менее 150 мл, выраженном отёке, крайне низком ASPECTS и позднем поступлении. ATTENTION, BAOCHE и VERITAS поддерживают лечение базилярной или доминантной позвоночной окклюзии при ограниченном необратимом повреждении ствола мозга. Предложенная модель TISSUE-LVO отделяет исходную прогностическую неблагоприятность от вероятности терапевтического ответа, предотвращая отказ от вмешательства только из-за ожидаемой инвалидизации. Она требует быстрого исключения кровоизлияния, подтверждения доступной окклюзии, оценки распределения инфаркта, отёка, коллатералей, предшествующей функциональной независимости и рисков технически сложной реканализации в конкретной клинической ситуации до начала эндоваскулярного вмешательства без задержки.

Заключение. Крупное ядро или задняя локализация не должны служить автоматическим противопоказанием. Решение должно объединять тканевое повреждение, анатомическую значимость, тяжесть симптомов, коллатеральный резерв, техническую вероятность реперфузии и ориентированные на пациента цели.

Ключевые слова: эндоваскулярная тромбэктомия; крупное инфарктное ядро; окклюзия крупного сосуда; ASPECTS; КТ-перфузия; окклюзия базилярной артерии; инсульт задней циркуляции; тканеориентированный отбор; реперфузия; ишемическая пенумбра.

Mamadaliyev Abdurahmon Mamatkulovich
Samarqand davlat tibbiyot universiteti huzuridagi Neyroxirurgiya va neyroreabilitatsiya ixtisoslashtirilgan ilmiy-amaliy markazi

AN’ANAVIY TASVIRLASH CHEKLOVLARIDAN TASHQARIDA ENDOVASKULYAR TROMBEKTOMIYA: TO‘QIMAGA ASOSLANGAN TANLASH DAVRIDA KATTA YADROLI VA ORQA SIRKULYATSIYA INSULTI

Annotatsiya

Dolzarblik. Endovaskulyar trombektomiya davolashni kichik infarkt yadrosi, qulay perfuzion nomuvofiqlik, oldingi qon aylanishi okklyuziyasi va tor vaqt oynasi bilan cheklagan an'anaviy paradigmaning chegaralaridan chiqdi. Randomizatsiyalangan tadqiqotlar tanlangan katta yadroli oldingi sirkulyatsiya insultida hamda o'rtacha yoki og'ir nevrologik yetishmovchilik bilan kechuvchi bazilyar arteriya okklyuziyasida trombektomiyani qo'llab-quvvatlaydi. Shu sababli to'qimaning saqlanish imkoniyati, zararlangan anatomiyaning funksional ahamiyati, kollateral ta'minot va klinik og'irlik vaqt omilidan alohida baholanganda muhimroq bo'lmoqda.

Material va usullar. 2026-yil iyuligacha chop etilgan randomizatsiyalangan sinovlar, individual ma'lumotlar meta-tahlillari, klinik tavsiyalar, tasvirlash va texnik tadqiqotlar sintez qilindi.

Natijalar. RESCUE-Japan LIMIT, SELECT2, ANGEL-ASPECT, TENSION, LASTE va ATLAS katta yadroli insultda funksional natija hamda yashab qolish foydasini ko'rsatdi, biroq 150 ml va undan katta yadro, yaqqol shish, juda past ASPECTS va kech murojaatda noaniqlik saqlanadi. ATTENTION, BAOCHE va VERITAS qaytmas miya ustuni shikastlanishi cheklangan, o'rtacha yoki og'ir deficitli bazilyar yoxud dominant umurtqa arteriyasi okklyuziyasida trombektomiyani qo'llab-quvvatlaydi. Taklif etilgan TISSUE-LVO modeli dastlabki yomon prognozni davolashga javob berish ehtimolidan ajratadi va faqat kutilayotgan nogironlik sababli foydali reperfuziyadan voz kechishni kamaytiradi. Model qon ketishni tez istisno qilish, davolash mumkin bo'lgan okklyuziyani tasdiqlash, infarkt tarqalishi, shish, kollaterallar, insultgacha bo'lgan funksional holat va murakkab rekanalizatsiya xavfini kechiktirmasdan har bir individual bemorning real klinik sharoitida aniq baholashni talab etadi.

Xulosa. Katta yadro yoki orqa sirkulyatsiya lokalizatsiyasi avtomatik qarshi ko'rsatma bo'lmasligi kerak. Qaror to'qima zarari, anatomik ahamiyat, simptomlar og'irligi, kollateral rezerv, texnik reperfuziya ehtimoli va bemorga yo'naltirilgan maqsadlarni birlashtirishi lozim.

Kalit so'zlar: endovaskulyar trombektomiya; katta infarkt yadrosi; yirik tomir okklyuziyasi; ASPECTS; KT-perfuziya; bazilyar arteriya okklyuziyasi; orqa sirkulyatsiya insulti; to'qimaga asoslangan tanlash; reperfuziya; ishemik penumbra.

Introduction. Endovascular thrombectomy is one of the most effective treatments in modern clinical neuroscience. The pivotal anterior-circulation trials and the HERMES individual-patient meta-analysis established that rapid mechanical reperfusion substantially reduces disability in patients with proximal large-vessel occlusion. Initial eligibility criteria, however, were intentionally restrictive. Most trials selected patients with intracranial internal carotid artery or proximal middle cerebral artery occlusion, relatively small early ischemic changes, favorable premorbid function, and treatment within six hours. DAWN and DEFUSE 3 subsequently extended the therapeutic window to 24 and 16 hours by selecting patients with clinical–core or perfusion mismatch[1, 2, 3]. These advances created a highly influential but potentially misleading concept: thrombectomy was most beneficial only when imaging demonstrated a small infarct core and a large volume of salvageable penumbra. Patients with an Alberta Stroke Program Early Computed Tomography Score of 5 or less, a perfusion-estimated core exceeding 50–70 mL, extensive diffusion restriction, or posterior-circulation occlusion were frequently excluded from treatment. The exclusion was based on concern that reperfusion of severely injured tissue would provide little functional benefit while increasing edema, hemorrhagic transformation, procedural

complications, and mortality[3, 6, 10]. The prognostic association between large infarct volume and poor outcome is real. It does not, however, prove absence of treatment effect. Prognosis describes the likely outcome under a given clinical condition, whereas treatment responsiveness describes the difference between outcomes with and without intervention. A patient may have a high probability of severe disability regardless of treatment and still obtain a clinically meaningful shift from death or complete dependency to assisted ambulation, communication, or independent self-care after reperfusion. Conflating poor prognosis with therapeutic futility was a major conceptual limitation of earlier selection models[11, 12, 20].

From 2022 onward, a sequence of randomized trials changed the evidence base. RESCUE-Japan LIMIT demonstrated benefit in patients with ASPECTS values of 3–5. SELECT2 and ANGEL-ASPECT extended the findings across broader populations, imaging modalities, and treatment windows. TENSION supported thrombectomy using predominantly noncontrast CT selection, while LASTE included patients with very extensive infarction in the early window. TESLA produced a directionally favorable but statistically inconclusive result using noncontrast CT alone across a 24-hour window. The 2026 ATLAS individual-patient-data analysis integrated six randomized trials and confirmed an overall improvement in disability distribution and survival with thrombectomy in large-core stroke[7, 14, 19]. A parallel transformation occurred in posterior-circulation stroke. Basilar artery occlusion is uncommon but devastating because the basilar artery supplies the pons, midbrain, cerebellum, thalami, and occipital structures. Untreated persistent occlusion may result in locked-in syndrome, coma, tetraplegia, respiratory failure, or death. Earlier randomized trials, including BEST and BASICS, were neutral or inconclusive because of slow recruitment, crossover, heterogeneous clinical severity, substantial intravenous thrombolysis use, and selection bias. ATTENTION and BAOCHE subsequently demonstrated clear functional benefit from thrombectomy within 12 and 6–24 hours, respectively, in patients with moderate-to-severe basilar artery occlusion and limited established posterior-fossa infarction[4, 7, 14].

The concept of “conventional imaging limits” therefore requires reconsideration. ASPECTS, core volume, mismatch ratio, time from last known well, and occlusion territory remain important, but none should be treated as an isolated biological boundary. ASPECTS is an ordinal topographic score rather than a direct measure of tissue viability. Perfusion-derived core is a probabilistic estimate influenced by acquisition quality, delay correction, collateral circulation, cardiac output, motion, and software thresholds. Posterior-circulation infarction is incompletely represented by the anterior-circulation NIHSS and cannot be assessed adequately using anterior-circulation ASPECTS. The current challenge is no longer simply to identify a small core. It is to estimate whether rapid, technically[3, 6, 15, 18] successful reperfusion can improve the patient’s probable functional trajectory despite substantial established injury. This requires integration of infarct distribution, eloquent tissue involvement, collateral reserve, edema, occlusion anatomy, neurological severity, premorbid function, procedural complexity, time, and the patient’s values.

The objective of this integrative review is to analyze contemporary evidence for endovascular thrombectomy in large-core anterior-circulation and posterior-circulation stroke and to propose a structured tissue-based selection framework termed TISSUE-LVO. The model differentiates

prognostic severity from treatment responsiveness and aims to prevent both unjustified therapeutic exclusion and indiscriminate intervention.

Materials and Methods. This article was designed as a structured integrative review with an original clinical–imaging synthesis. Randomized controlled trials, individual-patient-data meta-analyses, contemporary practice guidelines, imaging investigations, procedural studies, and relevant secondary analyses published through July 2026 were evaluated. The principal evidence base for anterior-circulation large-core stroke included RESCUE-Japan LIMIT, SELECT2, ANGEL-ASPECT, TENSION, LASTE, TESLA, and the ATLAS collaboration. The posterior-circulation analysis included BEST, BASICS, ATTENTION, BAOCHE, the VERITAS individual-patient-data meta-analysis, and the European Stroke Organisation–European Society for Minimally Invasive Neurological Therapy guideline on basilar artery occlusion[2, 3, 10, 18]. Evidence was classified into eight domains: clinical severity; infarct topography; quantitative and semiquantitative core assessment; occlusion anatomy; collateral circulation; temporal profile; probability of technically effective reperfusion; and risks of edema, hemorrhagic transformation, and procedural injury. Clinical outcomes were interpreted primarily through ordinal modified Rankin Scale shifts rather than only dichotomized functional independence.

Large-core stroke was defined according to the criteria used in the major randomized trials: ASPECTS of 5 or less, estimated ischemic core volume of at least 50–70 mL, or a combination of both. Posterior-circulation selection incorporated the posterior-circulation ASPECTS, brainstem involvement, cerebellar and thalamic infarction, collateral anatomy, occlusion level, and neurological severity. No original patient cohort was created and no pooled statistical analysis was independently performed. The tables represent a structured synthesis of published data. The proposed TISSUE-LVO model is a conceptual framework requiring prospective validation.

Results. RESCUE-Japan LIMIT was the first completed randomized trial to demonstrate benefit in a population selected principally by ASPECTS 3–5. The trial enrolled 203 patients with intracranial internal carotid or proximal middle cerebral artery occlusion. At 90 days, an mRS score of 0–3 occurred in 31.0% of patients assigned to endovascular therapy and 12.7% assigned to medical care. Intracranial hemorrhage was more frequent after thrombectomy, but the functional shift favored intervention[11, 12, 20]. SELECT2 enrolled patients with ASPECTS 3–5 on noncontrast CT or an estimated ischemic core of at least 50 mL on perfusion CT or diffusion MRI. Treatment was permitted within 24 hours. Thrombectomy improved the ordinal distribution of 90-day mRS scores, with a generalized odds ratio of 1.51. Functional independence occurred in 20% of the thrombectomy group and 7% of the medical-care group. The trial was particularly influential because it demonstrated benefit across different imaging definitions of large core rather than requiring a uniform perfusion-mismatch profile[8, 9, 25].

ANGEL-ASPECT enrolled 456 patients in China using ASPECTS, core volume, or combined criteria. Endovascular treatment improved the ordinal mRS distribution, with a generalized odds ratio of 1.37. Symptomatic intracranial hemorrhage was numerically more frequent after endovascular treatment, and any radiological intracranial hemorrhage was substantially more common. Nevertheless, the net functional outcome favored thrombectomy [5–8]. TENSION recruited patients with established large infarction, mostly identified using noncontrast CT, and randomized them within

approximately 11 hours. It demonstrated improved functional outcome and reduced mortality after thrombectomy. The study was important for stroke systems without immediate access to automated perfusion software because it showed that carefully interpreted conventional CT could support treatment selection[4, 7, 14, 19].

LASTE enrolled 333 patients with ASPECTS of 5 or less within 6.5 hours, including patients with no predefined maximum infarct volume. The early-window design addressed whether extensive infarction should preclude treatment when reperfusion could still be achieved rapidly. The trial demonstrated a favorable shift in functional outcome and lower mortality, although the absolute probability of independence remained limited in patients with the most extensive injury[13, 15, 17, 27]. TESLA enrolled 300 patients with ASPECTS 2–5 identified by noncontrast CT alone within 24 hours. It did not cross the prespecified Bayesian superiority threshold for the primary utility-weighted mRS endpoint. The adjusted difference remained directionally favorable, and the credible interval included a clinically meaningful benefit. Mortality was similar, while symptomatic hemorrhage and several radiological hemorrhage categories were more frequent after thrombectomy. TESLA should therefore be interpreted as a caution against oversimplified CT-only selection across the entire 24-hour window rather than proof that large-core thrombectomy is ineffective[4, 7, 14, 19]. The ATLAS collaboration provided the most comprehensive synthesis available by July 2026. Individual data from 1,886 patients in six randomized trials were centrally readjudicated. Thrombectomy improved the 90-day mRS distribution, with an adjusted generalized odds ratio of 1.63, and reduced mortality from 37.3% to 31.1%. Symptomatic intracranial hemorrhage did not differ significantly. Benefit was generally consistent across ASPECTS and core-volume strata, but evidence remained limited for core volumes of at least 150 mL, especially beyond six hours[7, 9, 19, 28].

Table 1. Major Randomized Evidence for Thrombectomy in Large-Core Anterior-Circulation Stroke

Trial	Principal selection	Time window	Main result	Central interpretation
RESCUE-Japan LIMIT	ASPECTS 3–5, predominantly MRI-based selection	Mainly ≤6 hours; selected later cases	mRS 0–3: 31.0% vs 12.7%	Established proof of benefit in low-ASPECTS stroke
SELECT2	ASPECTS 3–5 or core ≥50 mL	≤24 hours	Ordinal mRS gOR 1.51; independence 20% vs 7%	Benefit across CT and advanced imaging definitions
ANGEL-ASPECT	ASPECTS 3–5 or large perfusion/DWI core	≤24 hours	Ordinal mRS gOR 1.37	Benefit with increased radiological hemorrhage

TENSION	ASPECTS 3–5, mostly noncontrast CT	Approximately ≤11 hours	Improved mRS and reduced mortality	Supports conventional imaging in an earlier window
LASTE	ASPECTS ≤5 without maximum core restriction	≤6.5 hours	Improved functional distribution and survival	Supports treatment of very extensive early infarction
TESLA	ASPECTS 2–5 on noncontrast CT alone	≤24 hours	Primary endpoint not statistically significant	Highlights uncertainty in broad late-window CT-only selection
ATLAS	Individual data from six trials; ASPECTS ≤5 or core ≥50 mL	≤24 hours	aGenOR 1.63; mortality 31.1% vs 37.3%	Confirms overall benefit; uncertainty persists at core ≥150 mL late

Imaging Beyond a Single Core Threshold. Noncontrast CT remains the fastest and most widely available method for excluding hemorrhage and estimating early ischemic change. ASPECTS is useful because it is rapid, familiar, and topographically informative. Its limitations include interobserver variability, unequal weighting of small deep and large cortical regions, reduced sensitivity early after onset, and dependence on image quality and reader expertise. An ASPECTS value of 3 does not represent a uniform biological state: one patient may have extensive eloquent cortical injury, while another has predominantly noneloquent or deep involvement with a different expected functional trajectory [17,20,22]. CT perfusion provides estimated core, critically hypoperfused tissue, mismatch volume, and mismatch ratio. These measures should not be interpreted as histological truth. Estimated core can be overcalled in patients with very early severe hypoperfusion, poor cardiac output, motion, inadequate contrast bolus, or delay-sensitive processing. Conversely, infarction may be underestimated when reperfusion occurs before imaging or when thresholds fail to capture posterior-fossa injury. Perfusion maps must be reviewed with source images, noncontrast CT, and CTA rather than accepted automatically [5, 16, 20, 31]. Diffusion-weighted MRI is more sensitive for early infarction and posterior-fossa lesions. It is particularly valuable when the extent of brainstem injury is uncertain. MRI, however, may delay puncture, is less available, and may be impractical in unstable, agitated, ventilated, or device-dependent patients. The presence of diffusion restriction does not prove complete biological irreversibility; some lesions may partially reverse after rapid reperfusion, although extensive diffusion abnormality remains strongly prognostic[2, 6, 18, 27]. CTA confirms the site of occlusion, evaluates tandem lesions, arterial tortuosity, thrombus extent, intracranial atherosclerotic disease, collateral filling, access difficulty, and potential need for rescue angioplasty or stenting. In large-core stroke, CTA also helps distinguish a technically accessible

embolic occlusion from diffuse intracranial atherosclerosis or a long calcified thrombus with a lower probability of rapid first-pass reperfusion.

Collateral circulation modifies infarct-growth rate and treatment tolerance. Good leptomeningeal collateral flow can preserve residual viable tissue despite a large measured core, whereas poor collaterals may indicate rapid infarct progression and edema. Collaterals are prognostic but should not be used as an absolute exclusion because their assessment is phase-dependent and treatment benefit has been observed across collateral strata[11, 12, 20]. Edema is increasingly recognized as a critical selection variable. Established sulcal effacement, ventricular compression, midline shift, extensive hemispheric swelling, or marked tissue net-water uptake may identify a biologically advanced infarct less likely to benefit from delayed reperfusion. Unlike core volume, edema reflects the temporal and microvascular consequences of tissue injury. A patient with a 100-mL core and limited swelling early after onset may differ substantially from a patient with the same estimated volume and advanced edema 18 hours later [21,23,25].

Table 2. Tissue-Based Interpretation of Acute Stroke Imaging

Imaging component	Information provided	Major limitation	Role in tissue-based selection
Noncontrast CT	Hemorrhage exclusion, ASPECTS, edema, mass effect	Limited early sensitivity and reader variability	Rapid first-line assessment; should not be reduced to a single ASPECTS threshold
CT angiography	Occlusion site, thrombus length, collaterals, vascular access	Single-phase CTA may misclassify delayed collateral filling	Confirms treatable occlusion and procedural feasibility
Multiphase CTA	Temporal collateral filling and distal vessel opacification	Additional acquisition and interpretation requirements	Differentiates delayed from absent collateral circulation
CT perfusion	Estimated core, hypoperfused tissue, mismatch	Software-, threshold-, and acquisition-dependent	Useful in uncertain late-window cases; must be checked against source images
Diffusion MRI	Sensitive infarct distribution, especially posterior fossa	Potential treatment delay and limited availability	Valuable when brainstem or very-low-ASPECTS anatomy is uncertain
FLAIR MRI	Approximate lesion age and edema	Variable lesion visibility	Supports wake-up and delayed-presentation interpretation

Quantitative edema assessment	Biological progression and swelling	Not yet universally standardized	May improve selection in very large cores and late windows
pc-ASPECTS	Posterior-fossa infarct distribution	Limited sensitivity on CT and unequal eloquence	More informative when combined with brainstem-specific assessment

Posterior-Circulation Stroke and Basilar Artery Occlusion. Posterior-circulation stroke differs biologically and clinically from anterior-circulation stroke. Small pontine lesions may produce catastrophic disability, while relatively larger cerebellar or occipital infarcts may be compatible with meaningful recovery. Infarct volume alone therefore has limited value unless anatomical eloquence is incorporated. The NIHSS underweights many posterior-circulation manifestations, including truncal ataxia, gait inability, dysphagia, diplopia, ophthalmoplegia, impaired consciousness, crossed sensory findings, and progressive respiratory dysfunction. A numerically low NIHSS does not always indicate a minor basilar stroke. Conversely, existing randomized evidence is strongest in moderate-to-severe deficits, commonly NIHSS scores of at least 10 [11,13,16]. BEST and BASICS did not demonstrate definitive superiority of thrombectomy in their primary analyses. Both trials faced substantial methodological challenges, including crossover and treatment outside randomization. BASICS included a relatively high rate of intravenous thrombolysis and patients with milder deficits, potentially reducing the difference between treatment groups [2, 3, 18]. ATTENTION randomized patients with basilar artery occlusion within 12 hours. Good functional status, defined as mRS 0–3 at 90 days, occurred in 46% of patients receiving thrombectomy and 23% receiving best medical care. The intervention increased symptomatic intracranial hemorrhage and procedural complications but reduced mortality and severe disability[4, 7, 14, 19].

BAOCHE enrolled patients 6–24 hours after basilar artery occlusion. An mRS score of 0–3 occurred in 46% of the thrombectomy group and 24% of the medical group. The findings demonstrated that selected posterior-circulation tissue can remain treatment-responsive well beyond six hours, particularly when extensive irreversible brainstem infarction is absent [12,14,16]. VERITAS pooled individual data from BEST, BASICS, ATTENTION, and BAOCHE. The analysis supported a robust overall benefit of endovascular treatment in vertebrobasilar occlusion with moderate-to-severe symptoms, with an approximately 2.5-fold greater likelihood of favorable functional outcome. Thrombectomy reduced overall disability and mortality despite an increased risk of symptomatic intracranial hemorrhage [13,15,17]. The ESO–ESMINT guideline recommends a nuanced approach. Benefit appears more convincing in patients with NIHSS scores of at least 10 and proximal or middle basilar occlusion. Evidence is insufficient to recommend thrombectomy routinely in patients with NIHSS below 10. The guideline advises against reperfusion therapy when extensive bilateral or brainstem ischemic injury is already established and supports bridging intravenous thrombolysis in eligible patients rather than automatically proceeding directly to thrombectomy[16, 23, 30].

Table 3. Randomized and Integrated Evidence for Vertebrobasilar Thrombectomy

Study	Population and window	Primary finding	Selection implication

BEST	Vertebrobasilar occlusion, mainly early window	Neutral intention-to-treat result with major crossover	Demonstrated methodological difficulty rather than definitive futility
BASICS	Basilar occlusion within 6 hours	No significant overall superiority	Possible benefit in more severe deficits; substantial IV thrombolysis use
ATTENTION	Basilar occlusion within 12 hours	mRS 0–3: 46% vs 23%	Supports thrombectomy in moderate-to-severe BAO
BAOCHE	Basilar occlusion 6–24 hours	mRS 0–3: 46% vs 24%	Confirms benefit in selected late-window BAO
VERITAS	Individual data from four randomized trials	Lower disability and mortality with EVT	Strongest integrated evidence for moderate-to-severe VBAO
ESO–ESMINT guideline	Evidence and consensus synthesis	Favors EVT mainly with NIHSS ≥10 and limited irreversible injury	Discourages automatic treatment of extensive bilateral brainstem infarction

Procedural Strategy in High-Risk Tissue. Large-core thrombectomy places an increased premium on procedural efficiency. Tissue with limited residual reserve may not tolerate repeated device passes, distal embolization, vasospasm, dissection, perforation, or prolonged anesthesia. First-pass complete or near-complete reperfusion should be considered the procedural objective rather than merely achieving eventual eTICI 2b flow [5, 11, 16]. The initial technique may involve direct aspiration, stent-retriever thrombectomy, or a combined approach. Device selection should reflect clot location, vessel diameter, cervical access, thrombus composition, tandem disease, and operator experience. No single technique is universally superior. In basilar artery occlusion, aspiration may provide a rapid initial strategy, while intracranial atherosclerotic occlusion frequently requires rescue angioplasty, antiplatelet treatment, or stenting [23,25,27]. Intravenous thrombolysis should not be omitted when the patient is eligible merely because thrombectomy is planned. Bridging thrombolysis can promote early recanalization, soften distal thrombus, and treat emboli beyond device reach. The balance becomes more complex in very large cores or when rescue stenting will require antiplatelet therapy, but current evidence does not support systematic withholding of thrombolysis in all thrombectomy candidates [3, 10, 18, 27]. Blood-pressure management should protect collateral perfusion before recanalization and reduce hemorrhagic and reperfusion injury afterward. Hypotension during induction, transfer, or the procedure may accelerate infarct progression. After successful thrombectomy, excessive hypertension may promote edema and hemorrhage, but intensive reduction

to systolic pressure below 140 mmHg has not improved outcomes and may be harmful. Current recommendations favor individualized control rather than an aggressively low universal target [17, 26, 29]. General anesthesia and conscious sedation can both be appropriate. The decisive issues are avoidance of treatment delay, hypoxemia, hypercapnia, hypotension, agitation, and patient movement. Posterior-circulation patients with depressed consciousness, dysphagia, respiratory compromise, or severe agitation frequently require general anesthesia for airway protection. Postprocedural management is integral to the effectiveness of thrombectomy. Large-core patients require surveillance for malignant cerebral edema, hemorrhagic transformation, early neurological worsening, seizures, aspiration, cardiac complications, and reperfusion injury. Decompressive hemicraniectomy remains potentially life-saving in selected patients with malignant hemispheric infarction and should not be delayed solely because thrombectomy was performed [24, 26, 29]. Patients with basilar artery occlusion require careful respiratory monitoring, swallowing assessment, prevention of aspiration, and repeated evaluation of consciousness and cranial nerve function. Successful arterial recanalization does not guarantee microvascular reperfusion or reversal of brainstem injury.

Proposed TISSUE-LVO Selection Framework. The proposed TISSUE-LVO model consists of nine interacting domains: Time and biological progression; Infarct distribution; Symptoms and clinical severity; Salvageable or functionally threatened anatomy; Underlying vascular lesion; Edema and hemorrhagic risk; Likelihood of effective reperfusion; Values and premorbid function; and Outcome trajectory. Time remains important, but it is interpreted through biological progression. Early presentation generally increases benefit, yet late presentation does not imply completed infarction. Slow infarct growth, collateral support, and posterior-circulation anatomy can preserve treatment responsiveness. Infarct distribution is considered alongside volume. Involvement of both corticospinal tracts, dominant-hemisphere language regions, bilateral thalami, extensive pons, or midbrain has a different functional effect from injury of equivalent volume in less eloquent tissue. Symptoms and severity determine the immediate clinical threat. Severe deficits generally increase the absolute opportunity for disability reduction. Posterior-circulation symptoms should be interpreted beyond the NIHSS. Salvageable anatomy includes tissue that is not yet irreversibly injured as well as critically important neural structures at risk of secondary infarct expansion. A large established core does not imply that all tissue in the arterial territory is unsalvageable. The underlying vascular lesion affects technical strategy. An embolic M1 occlusion with favorable access differs from long-segment intracranial atherosclerotic occlusion, tandem cervical disease, vertebrobasilar stenosis, or a heavily calcified thrombus. Edema and hemorrhagic risk indicate biological advancement and vulnerability to reperfusion injury. Existing mass effect, severe blood–brain barrier disruption, coagulopathy, uncontrolled hypertension, or extensive microbleeding may reduce net benefit. Likelihood of reperfusion includes vascular access, operator experience, transfer delay, clot anatomy, collateral status, and the probability of eTICI 2c–3 flow with few passes. A technically low-probability procedure may not provide the same expected benefit as rapid first-pass reperfusion. Values and premorbid function should be considered explicitly. Prestroke disability is not an automatic contraindication, but the desired treatment effect may be return to baseline rather than mRS 0–2. The patient's previously expressed preferences regarding survival with severe dependency are relevant. Outcome trajectory focuses on the difference between expected outcomes with and without thrombectomy. Treatment may

be justified even when independence is unlikely if it reduces the probability of death, locked-in syndrome, or complete dependency.

Table 4. Scientific Originality of the TISSUE-LVO Framework

Conventional limitation	Traditional interpretation	Proposed TISSUE-LVO element	Expected clinical contribution
Large core predicts poor outcome	Poor prognosis interpreted as no treatment benefit	Separates prognosis from treatment responsiveness	Prevents unjustified therapeutic nihilism
ASPECTS used as a binary threshold	ASPECTS ≤5 treated as completed infarction	Integrates topography, eloquence, edema, and modality	Reduces oversimplification of semiquantitative scores
Perfusion core considered irreversible	Automated volume accepted without source-image review	Treats core as an estimate influenced by physiology and software	Reduces false exclusion from core overestimation
Late time window interpreted uniformly	Delay equated with tissue death	Uses collateral-supported biological progression	Identifies slow progressors without unnecessary delay
Posterior stroke assessed by NIHSS alone	Low NIHSS interpreted as mild disease	Incorporates consciousness, bulbar, ocular, gait, and respiratory deficits	Improves recognition of clinically severe BAO
Recanalization treated as a binary endpoint	eTICI 2b considered adequate	Prioritizes rapid first-pass eTICI 2c–3 reperfusion	Reduces futile and incomplete reperfusion
Functional independence used as the only meaningful outcome	mRS 0–2 defines success	Evaluates ordinal disability shift and return to baseline	Captures patient-relevant benefit in severe stroke
Large core and BAO managed by separate paradigms	Different anatomical territories treated independently	Uses a shared tissue–anatomy–severity framework	Supports consistent multidisciplinary decision-making

Discussion. The large-core trials and posterior-circulation trials have changed the philosophical basis of thrombectomy selection. The earlier objective was to find patients with the greatest probability of independence. The current objective is to identify patients in whom reperfusion produces a better outcome distribution than medical management, even when the baseline probability of full independence is low. This distinction is clinically and ethically important. Selecting only patients likely

to achieve mRS 0–2 can systematically disadvantage older patients, patients with large infarcts, patients with posterior-circulation disease, and patients with limited premorbid disability. An ordinal improvement from mRS 5 to mRS 3 may represent recovery from continuous nursing dependence to assisted ambulation and home living. A change from death to mRS 4 may be valued differently by different patients but cannot be dismissed automatically as futile[3, 6, 15, 18]. ATLAS substantially strengthens the large-core evidence. Its centrally adjudicated analysis demonstrated improved disability distribution and lower mortality without a significant excess of symptomatic intracranial hemorrhage. The consistency across imaging and clinical subgroups indicates that benefit is not confined to a single software-defined mismatch profile. The major residual uncertainty concerns extremely large cores of at least 150 mL, particularly in the late window[6, 11, 12, 20].

This uncertainty should not be converted into a new rigid exclusion threshold. Core-volume measurement varies among software platforms and may be distorted by severe hypoperfusion, motion, delay artifacts, or early imaging. A reported volume of 151 mL is not biologically different from 149 mL. Decisions near the boundary should incorporate age, eloquent involvement, edema, collaterals, time, occlusion site, technical feasibility, and patient values. TESLA introduces necessary caution. Unlike trials with earlier treatment or advanced imaging components, TESLA used noncontrast CT alone and enrolled many patients relatively late. Its primary endpoint was not statistically significant, and hemorrhagic imaging abnormalities were more frequent after thrombectomy. The trial suggests that large-core expansion should not become indiscriminate late-window intervention based only on the presence of a proximal occlusion and ASPECTS 2–5[4, 7, 14, 19]. The difference between TESLA and TENSION also demonstrates that “noncontrast CT selection” is not a single strategy. Treatment window, ASPECTS distribution, edema, reader expertise, transfer delay, center volume, and procedural performance influence the observed effect. Conventional CT can be sufficient when it is interpreted within an efficient and experienced stroke system, but advanced imaging remains valuable in biologically ambiguous late-window cases.

Posterior-circulation selection presents an even greater need for anatomy-based reasoning. A small bilateral pontine infarct can eliminate meaningful motor function, whereas a larger unilateral cerebellar infarct may remain surgically and functionally manageable. Automated perfusion thresholds developed for the anterior circulation do not adequately capture this difference.

ATTENTION and BAOCHE resolved much of the prior uncertainty surrounding moderate-to-severe basilar artery occlusion. Both trials produced similar absolute differences in mRS 0–3 despite different time windows. VERITAS subsequently showed that the aggregate randomized evidence favors thrombectomy with reduced disability and mortality [12, 14, 16]. Nevertheless, important posterior-circulation gaps remain. Patients with low NIHSS scores were underrepresented or did not demonstrate a clear benefit in guideline analyses. The NIHSS may underestimate their severity, but routine thrombectomy of every mildly symptomatic basilar occlusion may expose patients with stable collateral flow to procedural harm. Randomized studies focused on mild or fluctuating posterior-circulation deficits are still needed. Occlusion location also matters. Proximal and middle basilar occlusions often produce more severe brainstem ischemia and may have a stronger treatment effect. Distal basilar emboli may respond to intravenous thrombolysis and may involve perforator-rich anatomy with a different risk profile. Underlying intracranial atherosclerosis is more common in

several Asian trial populations, potentially increasing the need for angioplasty, stenting, and periprocedural antiplatelet therapy. Tissue-based selection should not become synonymous with performing every available imaging sequence. Imaging is beneficial only if it improves the decision more than it delays reperfusion. In a patient presenting early with a disabling syndrome, proximal occlusion, limited edema, and technically favorable anatomy, noncontrast CT and CTA may be sufficient. Perfusion CT or MRI is most valuable when the biological stage is uncertain, when ASPECTS is very low, when symptoms and imaging are discordant, or when posterior-fossa infarction cannot be defined reliably. The shift toward broader eligibility also places greater responsibility on procedural quality. Large-core tissue has less tolerance for delayed, incomplete, or traumatic recanalization. A prolonged procedure ending in eTICI 2b after multiple passes may produce limited benefit and substantial vascular injury. Treatment expansion should therefore be accompanied by quality standards emphasizing rapid arterial access, first-pass effect, near-complete reperfusion, complication auditing, and experienced rescue strategies [23, 27, 29]. Successful macrovascular recanalization is not equivalent to tissue reperfusion. Distal embolization, microvascular no-reflow, pericyte constriction, endothelial swelling, blood–brain barrier injury, and impaired autoregulation may produce futile recanalization. Future trials should incorporate angiographic tissue-perfusion measures, quantitative DSA, collateral transit, and early postprocedural perfusion imaging rather than relying only on the final eTICI score. Post-thrombectomy neurocritical care is especially important in large-core stroke. Reperfusion can reduce infarct expansion while simultaneously increasing edema or hemorrhagic transformation in severely injured tissue. Blood pressure, glucose, oxygenation, temperature, fluid balance, antithrombotic timing, and early decompressive surgery should be managed through coordinated stroke-neurocritical care pathways. The 2026 AHA/ASA guideline reflects the new evidence by broadening thrombectomy eligibility to selected patients with larger ischemic cores and by providing updated guidance for basilar artery occlusion. This represents a formal shift from earlier exclusionary imaging thresholds toward broader, evidence-based reperfusion assessment [10, 15, 18]. Implementation remains a global challenge. Advanced perfusion imaging, MRI, neurointerventional teams, and round-the-clock thrombectomy are unevenly distributed. The large-core evidence may have particular value in lower-resource systems because it supports treatment without obligatory advanced perfusion imaging in many earlier-window cases. However, broader eligibility will increase transfer volume and may strain comprehensive stroke centers. Regional systems should develop imaging and transfer algorithms that avoid both undertriage and indiscriminate transfer. Artificial intelligence may assist detection of large-vessel occlusion, ASPECTS, perfusion abnormality, and posterior-fossa injury, but automated outputs must remain subject to expert review. Algorithmic confidence should not replace clinical responsibility.

The TISSUE-LVO model offers an integrative alternative to binary thresholds. Its originality lies in separating the probability of poor outcome from the probability of treatment benefit, incorporating anatomical eloquence, and applying a common conceptual structure to anterior large-core and posterior-circulation stroke. The framework has limitations. It is not a validated score and does not provide a numerical treatment threshold. Some domains, including edema quantification, technical reperfusion probability, patient preferences, and expected ordinal benefit, cannot yet be measured with sufficient precision in emergency practice. The model should therefore guide

multidisciplinary reasoning rather than replace evidence-based guidelines. Future research should focus on core volumes exceeding 150 mL, ASPECTS 0–2, prestroke disability, patients older than 85 years, distal or medium-vessel occlusions with large established injury, mild basilar syndromes, very late treatment beyond 24 hours, and posterior cerebral or vertebral occlusions. Trials should also compare imaging strategies rather than only treatment strategies. Outcomes should include quality of life, cognitive and language recovery, return to prior residence, caregiver burden, survival with severe disability, and patient-defined acceptable outcome. The mRS remains useful but incompletely represents posterior-circulation deficits, aphasia, cognition, fatigue, and psychosocial recovery.

Conclusion. Endovascular thrombectomy has moved beyond the conventional limits defined by a small infarct core, favorable perfusion mismatch, anterior-circulation anatomy, and a narrow time window. Randomized evidence now demonstrates that selected patients with large-core anterior-circulation stroke and moderate-to-severe basilar artery occlusion benefit from mechanical reperfusion.

RESCUE-Japan LIMIT, SELECT2, ANGEL-ASPECT, TENSION, LASTE, and ATLAS support thrombectomy across diverse large-core definitions and imaging strategies. TESLA tempers indiscriminate expansion by demonstrating continued uncertainty when noncontrast CT alone is used across the entire 24-hour window. Evidence is least certain in core volumes of at least 150 mL, very advanced edema, extremely low ASPECTS, and delayed presentation. ATTENTION, BAOCHE, and VERITAS establish thrombectomy as an effective therapy for appropriately selected vertebrobasilar occlusion with moderate-to-severe deficits and limited irreversible brainstem injury. Patients with mild deficits, extensive bilateral pontine or midbrain infarction, or uncertain symptom–occlusion concordance require individualized assessment. Large-core volume, low ASPECTS, posterior-circulation location, advanced age, or predicted disability should not function as isolated automatic exclusions. The appropriate question is not whether the patient has a poor prognosis, but whether rapid and technically effective reperfusion can produce a better functional trajectory than medical treatment alone. The proposed TISSUE-LVO framework integrates biological time, infarct distribution, neurological severity, functionally threatened anatomy, vascular pathology, edema, hemorrhagic risk, procedural feasibility, premorbid function, patient values, and expected ordinal outcome shift.

Imaging should be comprehensive enough to identify hemorrhage, treatable occlusion, infarct distribution, edema, collateral support, and access anatomy, but streamlined enough to avoid preventable delay. Noncontrast CT and CTA remain sufficient for many early-window decisions, whereas perfusion CT and MRI are most valuable in late, posterior, or biologically ambiguous presentations. The expansion of eligibility must be accompanied by rapid workflow, first-pass near-complete reperfusion, careful blood-pressure and airway management, neurocritical monitoring, early recognition of malignant edema, and transparent patient-centered communication. Tissue-based selection does not eliminate imaging limits; it replaces rigid thresholds with integrated clinical, anatomical, physiological, and procedural reasoning.

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Muallif bilan bog'lanish uchun e-mail	Author's contact email	Email
info@healtway.uz	*info@healtway.uz*	*info@healtway.uz*