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Review

Mechanical Thrombectomy Access for All? Challenges in Increasing Endovascular Treatment for Acute Ischemic Stroke in the United States

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Mechanical thrombectomy (MT) is the most effective treatment for selected patients with an acute ischemic stroke due to emergent large vessel occlusions (LVOs). There is an urgent need to identify and address challenges in access to MT to maximize the numbers of patients who can benefit from this treatment. Barriers in access to MT include delays in evaluation and accurate diagnosis of LVO leading to inappropriate triage, logistical delays related to availability of facilities and trained interventionalists, and financial hurdles that affect treatment reimbursement. Collection of regional data related to these barriers is critical to better understand current access gaps and a measurable access score to thrombectomy could be useful to plan local public health intervention.

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Introduction

Mechanical thrombectomy (MT) is the most effective treatment for acute ischemic stroke due to emergent large vessel occlusions (LVO) in appropriately selected patients. Clinical trials provide consistent evidence of improved functional outcomes and reduced mortality in patients receiving MT with a number needed to treat of 2.6.[1] The numbers of patients with LVO who may benefit from MT have increased with the advent of 'tissue-based' patient selection and the extension of the 'time window' for MT to up to 24 hours for some patients.[2,3] However, many eligible patients are excluded from treatment or do not receive maximal benefit of MT because of access delays. Every 10-minute delay in revascularization lowers a patient's disability-free lifetime by approximately 40 days and reduces the net monetary benefit in terms of health care costs for MT by $10,000.[4] The indications for thrombectomy might further expand based on the results of ongoing studies of patients with milder strokes (low National Institutes of Health Stroke Scale [NIHSS] score strokes[5,6]) those with medium-sized

vessel occlusion[7] and those having strokes with a large ischemic core.[8] There is a critical need to understand gaps to timely access to MT. This narrative review outlines important issues related to access, identifies key barriers to thrombectomy and aims to provide a framework of how to define, measure and improve access to thrombectomy for eligible patients.

Measuring access

LVOs account for approximately 30% of all patients with acute ischemic stroke[9] with studies showing prevalence ranging from 15% to 52%.[10] Yet approximately only 3.1% of acute ischemic stroke patients received MT in 2016.[11] This number increased to 8.4 % among patients treated at 176 endovascular centers in 2018.[12] Despite the increasing use of MT, there continues to be a large proportion of patients who do not receive MT or receive it in a delayed fashion because of a lack of access to treatment, defined as the "timely use of personal health services to achieve the best health outcomes."[13] One of the most important considerations in measuring access is whether patients have the opportunity to benefit in those circumstances in which medical care can affect meaningful outcomes. In the context of MT, access can be measured as the ratio of the number of MT procedures performed to the total number of eligible patients. Despite the availability of national databases such as National Inpatient Sample and Get with the Guidelines, an accurate estimate of the incidence and prevalence of LVO is still challenging. There are limited data assessing LVO detection rates in patients presenting at community hospitals and primary stroke centers compared to comprehensive stroke centers (CSCs). While International Classification of Diseases 10th Revision (ICD-10) billing codes have improved stroke diagnosis with documentation of the artery involved and mechanism of stroke, they are not optimized to classify whether the stroke is LVO.[14] Further, patients who have poor functional baseline or terminal cancer diagnosis would not be considered candidates for thrombectomy. To accurately measure access, a better understanding of the total number of eligible patients with LVO is needed.

Barriers to access

There are three general types of barriers to access (1) information and diagnostic access (the ability of the patient to access accurate diagnosis and treatment); (2) physical access (the ability of the patient to access health facilities geographically); and (3) financial access (the ability of the patient to pay for treatment) (Sharma A, personal communication, Pharma and Medtech in Latin America Conference, 2018). Improving access is dependent on being able to measure, monitor, and address these barriers.

Information and diagnostic access

Timely prehospital stroke recognition is an important component of overall access. There is a lost opportunity to provide critical prehospital care and appropriate rapid triage for patients who are transported to the hospital by private vehicle. Awareness of stroke symptoms is low even among high-risk patients; with the most frequently identified symptoms being unilateral weakness and slurred speech.[15,16] A study showed that patients living alone are particularly susceptible to delays in seeking care with reduced thrombolysis rates[17] and are therefore more likely to have lower thrombectomy rates. The use of transport services differs by race and ethnicity, with underrepresented populations less likely to utilize emergency services and less likely to call 911.[18] Public health campaigns can increase recognition of the signs and symptoms of stroke with mass media campaigns associated with the increased use of thrombolytics.[19] These types of campaigns may have similar effects on increasing the timely utilization of MT.

The timely diagnosis of LVO in stroke patients presenting to the hospital is another barrier to MT. Delays in diagnosis and transfer not only lead to worse treatment outcomes but can also deprive some patients from receiving any treatment because they may become ineligible as illustrated in Figure 1. In a large, real-world prospective multicenter study of MT, the main factors associated with an increase in inter-hospital transfer times were delays in medical decision-making or the logistics of arranging transport.[20] Atypical presentations such as sudden unresponsiveness due to a basilar artery occlusion may be unrecognized.[21] Intracranial vascular imaging is not performed routinely at many centers as its usefulness beyond identifying thrombectomy eligibility is not well established.[22] As a result, patients who have a LVO stroke with mild deficits or negative symptoms on clinical LVO scales could also be missed. The diagnosis of LVO might be increased by improved emergency medical service (EMS) and emergency department provider knowledge and assistance from tele-neurology services. Prehospital LVO scales have been developed for use by EMS to assist in triage of MT eligible patients directly to endovascular treatment (EVT) centers.[23] Mobile stroke units may reduce door to needle times and can assist in triage to the most appropriate facility.[24] Tele-stroke can provide an effective solution for many small or under-resourced hospitals to access acute stroke expertise and has been shown to increase thrombolysis rates.[25] It could potentially increase access to MT by improving detection of LVO. It would, however, be important to determine if the

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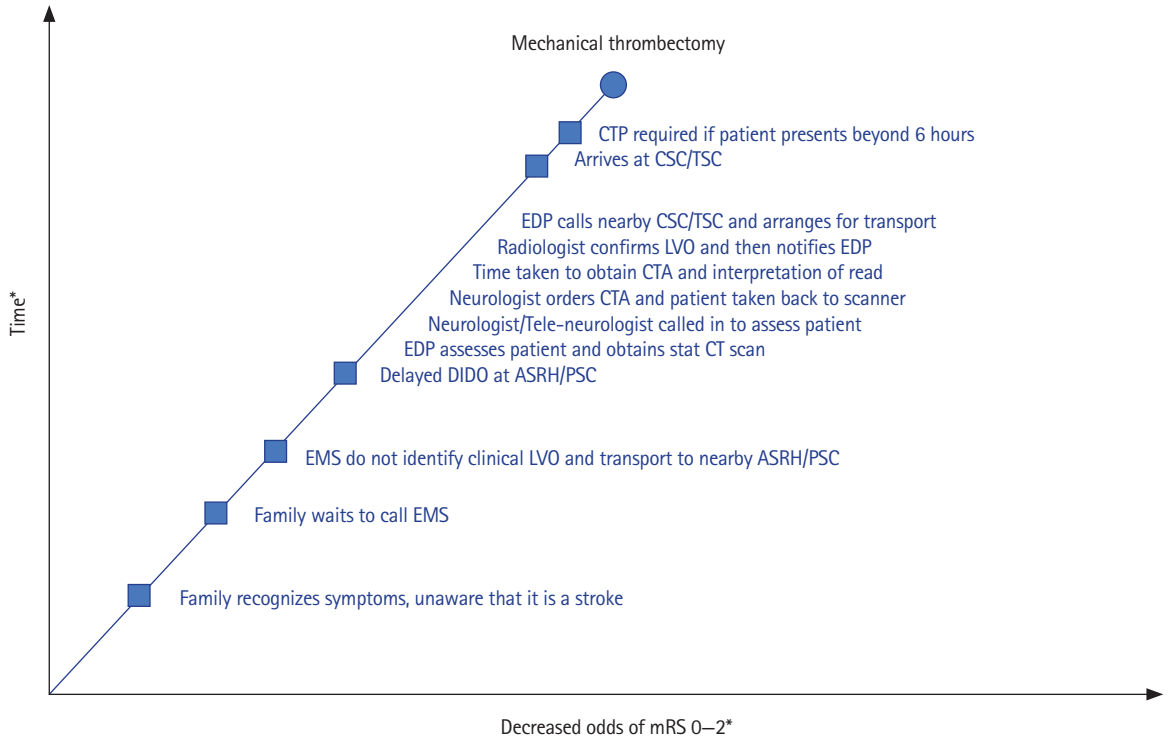

Figure 1. Factors contributing to delay in the information and diagnostic access leading to decreased odds of good functional outcome (modified Rankin Scale [mRS] 0–2) for mechanical thrombectomy. CTP, computerized tomography perfusion; CSC, comprehensive stroke center; TSC, thrombectomy capable stroke center; EDP, emergency department physician; LVO, large vessel occlusion; CTA, computed tomography angiogram; CT, computed tomography; DIDO, door in-door out; ASRH, acute stroke ready hospital; PSC, primary stroke center; EMS, emergency medical service. *Not to scale.

utilization of tele-neurology has an impact on door in-door out times. A protocol change to include a computed tomography angiogram (CTA) in addition to non-contrast computed tomography (CT) for all patients with presumed acute ischemic stroke presenting within 24 hours at a large academic center improved LVO detection and increased the frequency of MT.[26] Artificial intelligence-based software can assist in the rapid detection of LVO on CTA in eligible patients and are currently being used by some hospital systems in the United States;[27] however, can be expensive for small community hospitals.

Physical (geographic) access

Access to MT varies by region in the United States. The numbers of patients undergoing MT were higher in large central metropolitan areas and lower in rural settings than the national average. The East North-Central and West South-Central regions had lower proportions of patients treated with thrombectomy.[11] One-third of the United States population were beyond a 60-minute driving distance to EVT centers; 27.3% of patients were transferred to an endovascular center from a different hospital, with that percentage climbing to 44.3% among patients undergoing MT.[28] This study identified 713 EVT capable centers of a total of 1,941 acute stroke ready hospitals; a center was considered EVT capable if it had submitted at least one ICD-10 code for a thrombectomy procedure in 2017 based on Center for Medicare and Medicaid Services (CMS) Medpar data. Another study that considered only 322 centers as EVT capable based on either national accreditation or state designation found that only 49.6% of United States residents had 60-minute ground access to EVT. After adding air ambulance access, that proportion rose to 62.3%. In addition, of the total of 1,622 non-endovascular capable centers, only 45.4% had an endovascular capable center within a 30-minute drive.[29] Another study showed patients who initially received care at non-EVT centers were substantially less likely to ultimately undergo thrombectomy than patients who initially received care at thrombectomy hubs. Rural patients had particularly limited access: 27.7% of such patients initially received care at EVT capable center versus 69.5% for urban patients.[30]

Geographic access can be optimized by either increasing the number of EVT centers or bypassing non-EVT centers with direct transport to the closest thrombectomy capable center. If 10% of all acute stroke-ready hospitals became EVT capable, the 30-minute access to MT could be extended to an additional 10% of United States residents. Bypassing non-thrombectomy hospitals for direct transport to the closest thrombectomy

capable hospital within a 15-minute additional travel time limit could lead to >10% additional coverage for 30 states, with 9 gaining >20% in additional population coverage.[28] Each of these methods, however, could have potential negative effects. An increase in low-volume EVT hospitals could lead to sub-optimal outcomes following MT.[31] Also, there may be financial obstacles with providing 24/7 neurointerventional coverage at a low volume hospital. There are a limited number of neurointerventional training positions, and without an increase in elective procedures, this number may not increase substantially. Interventionalists without formal neuroendovascular training such as interventional cardiologists and peripheral radiologists are not ideally trained to perform MT for acute stroke, and there is now a consensus among stroke professionals that those with adequate and dedicated training should perform EVT for acute stroke.[32] The bypass model also has potential system-level detrimental effects. The Prehospital Stroke System of Care consensus conference recommends bypassing the closest certified stroke center if nearest CSC is within 30 minutes for patients in whom LVO is suspected.[33] Although EMS scales to identify LVO are available, the specificity for diagnosing anterior circulation LVO is approximately 50% to 70%.[34] Incorrect field LVO triage of patient's ineligible for EVT could increase the delay in receiving thrombolysis and could negatively affect their functional outcomes, unnecessarily uproot patients from their communities, and removing transport units from service for longer periods than necessary.[35] This particularly holds true in rural areas as EMS providers will encounter less stroke than those in urban areas and less likely be able to keep up with prehospital triage skills. Therefore, prehospital stroke models will need to be optimized to address specific challenges facing rural and urban areas.

Financial access

The financial barrier to MT in the United States is indirect; patients receive thrombectomy regardless of their insurance status. Since the passage of the Emergency Medical Treatment and Active Labor Act (EMTALA) in 1986,[36] all hospitals accepting funds from the Center of Medicaid and Medicare are required to provide emergency medical care regardless of the patient's ability to pay. Although financial access should not be a barrier to acute stroke treatment, concerns related to personal and financial responsibility can dissuade uninsured patients from seeking immediate care. This results in disparities in access across socioeconomic, racial, and ethnic groups. The concern of not being adequately reimbursed may also dissuade hospitals from building interventional programs. From a global perspective, healthcare financing is much more complex and a major barrier in low-income and lower-middle-income countries. More than three-fourths of the total healthcare expenditure in low-income countries is derived from direct out-of-pocket payment[37] where a robust effort is needed to make MT affordable.

Socioeconomic disparities

Studies using multiple national databases show lower thrombectomy utilization rates among uninsured patients than those who have insurance.[38] There does not appear to be sufficient information regarding disparities in income with regards to thrombectomy access. Patients living in low-income areas (zip code with median wealth <39,000), however, had a higher frequency of presentation to large volume EVT centers compared to those living in wealthier areas and suggests that low-income patients may live closer to an EVT center.

Racial and ethnic disparities

This remains a major issue affecting access to care and outcomes with Blacks, Hispanics, and Native Americans who have higher stroke prevalence rates compared to Whites.[39] Despite the increase in the number of thrombectomy capable centers over the last 10 years, minority patients continue to have lower MT rates.[12,40] Data form the National Inpatient Sample from 2016 to 2018 showed that Black/Hispanic patients' treatment rate was 2.8% lower than White/non-Hispanic patients (7% vs. 9.8%). The disparity is also present among patients who presented with LVO with a 7.8% lower utilization rate in Black/Hispanics than White patients with a middle cerebral artery or basilar artery occlusion (35.1% vs. 42.9%). For patients who received intravenous alteplase, there was no significant difference in thrombectomy rates between Black/Hispanic and White patients. This could suggest a delay in presentation resulting in ineligibility for acute stroke treatments could be responsible for lower rates of MT. Black and Hispanic, male, and uninsured patients were less likely to identify stroke symptoms than White, female, and insured participants. Black/Hispanic patients also presented to thrombectomy centers directly and were less likely to be transferred from another hospital.[41] This is likely due to demographic differences with Black and Hispanic patients residing nearby EVT-capable hospitals. The possibility that providers at non-EVT hospitals serving minority neighborhoods could be underdiagnosing LVO should also be considered. There are also data to suggest that there are inter-hospital transportation disparities for some race-ethnic groups when inter-hospital helicopter might be needed in rural regions.[42]

As uninsured patients receive thrombectomy at lower rates, factors such as reduced utilization of EMS and increased outreach to local hospitals need to be considered. Solutions in-

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Table 1. Challenges to increasing mechanical thrombectomy access and future considerations

Barriers	Current solutions	Limitations	Future considerations	Reference
Information and diagnostic barriers				19,23-26,45-48
Prehospital stroke recognition	Public stroke awareness campaigns and EMS utilization	Information may not reach those with lower socio-economic status.	Stroke symptoms knowledge incorporated in school curriculum.	
Underdiagnosis of LVO	Training EMS on LVO recognition for appropriate stroke triage. Tele-neurology at local hospital may increase LVO detection. Vascular imaging for all stroke codes may improve detection.	Lack of sensitivity and specificity of EMS performed LVO recognition scales. Time required for neurological assessment by tele-provider may impact door in door out. 24-Hour emergency neuroradiology services unavailable at many centers and using AI based software for CTA reads can be expensive.	Tele-neurology in the field/ ambulance to assist EMS in LVO recognition and triage. Sensor technology and mobile stroke units with CTA for prehospital LVO detection. Neuro-vascular imaging training and certification in LVO identification for tele-neurologists and cloud sharing images.	
Physical barriers				28,29,31,33-35,49,50
Geographic access in non-urban areas	Bypass model Increase in the total number of thrombectomy centers.	EMS performed LVO scales lack specificity and sensitivity. Concern for sub-optimal clinical outcomes in low volume EVT centers.	Above stated measures can improve the accuracy of field detection of LVO. Transfer to nearby Neuro ICU after EVT vs tele Neuro ICU monitoring.	
Insufficient number of trained neurointerventionalists	Increase training programs.	Number of non-emergent cases may be insufficient.	Interventional trained Neurologists can also provide stroke care to non-LVO patients.	
Financial barriers				4,43,44,51
Cost of building thrombectomy suite/ program	Increasing reimbursement may incentivize hospitals to establish programs.	Analysis of cost-effectiveness is currently based at the level of individual/hospital.	System based cost analysis and strategic acute stroke care planning at centralized level with assistance of a measurable access score.	
Thrombectomy procedural costs	Reduce device cost and aspiration technique when possible.	Universal health care for all Americans is still under progress and cost burden is primarily on hospitals.	Pursuing government policy change and increased budgetary provisions through an organization focused on increasing MT access.	

EMS, emergency medical service; LVO, large vessel occlusion; AI, artificial intelligence; CTA, computed tomography angiogram; EVT, endovascular treatment; ICU, intensive care unit; MT, mechanical thrombectomy.

clude increased reimbursement by the government for thrombectomy or to incentivize low volume stroke centers to develop an EVT program. Reducing the cost of stent retrievers and utilizing other cost-effective methods such as aspiration techniques could also help reduce costs and increase access.[43] The responsibility for analyzing the cost benefit of developing an EVT center, however, is with the hospital. Most studies analyzing cost effectiveness of acute stroke care and MT do not address system-based stroke care costs.[44]

Future considerations to increase access

Although several of the discussed approaches for increasing MT access are being implemented, they have limitations (Table 1). Additional solutions to further increase access should be considered. Sensor technology for LVO detection in the ambulance shows promise.[45] Software to detect LVO based on non-contrast CT is being evaluated, reducing the need to perform CTA and improving patient transfers in stroke networks.[46] This maybe particularly helpful as the use of mobile stroke units continues to increase. Low-cost alternatives to mobile stroke units include ambulance based tele-neurology consultation which has been shown to reduce both door to needle and door to groin times.[47] To help reduce further delays in transfer at centers where emergent neuroradiology coverage is not available, training and certifying neurologists in emergency stroke imaging should be considered with one study showing strong inter-rater reliability in LVO detection between neurolo-

gists and neuroradiologists.[48] Currently, neurointerventional training is open to neurosurgeons, neuroradiologists and vascular neurologists. Increasing the training positions available to vascular neurologists includes the advantage of them also being able to provide stroke care for patients not requiring thrombectomy in low volume EVT centers.[49] Tele-intensive care unit (ICU) is an emerging field and tele-consultation with neurocritical care specialists and telemonitoring with assistance of neuro ICU nurses in hospitals without a dedicated neuro intensive care unit should be evaluated.[50] The implementation of the above discussed programs is limited by financial access. Centralized planning for acute stroke care has been implemented in other countries[51] and strategic planning for developing centers with EVT capabilities should be considered with cost-effective analysis being done at a system rather than a hospital level.

The Institute of Medicine uses a variety of key health indicators in its attempt to measure health care access.[52] Although there are no indicators designed to measure access to any specific treatment, there may be an opportunity to develop a standardized measure for thrombectomy access, given its time sensitivity and importance in reducing long term stroke disability. While a wide range of issues that affect access to thrombectomy and acute stroke care have been identified and discussed, region specific data such as percentage of LVO patients who receive MT, median time from initial EMS contact to MT, percentage of LVO patients presenting directly to EVT capable center, rate of utilization of LVO scale by regional EMS and percentage of non-EVT capable acute stroke ready hospitals performing CTA is needed to get a better understanding of specific barriers that could be targets prioritized for improvement. In this regard, creating a measurable access score to thrombectomy may not only be a useful tool for state/local governments and public health officials to identify gaps in stroke MT access, but also improve stroke systems of care with the goal of optimizing patient outcomes and reducing health care costs.

Conclusions

The burden of stroke is a critical health care problem and timely access to MT reduces both mortality and long-term morbidity. Despite an increase in MT access in the United States, there are inequities in access to timely EVT for specific populations. Although progress has been made to address challenges regarding access, gaps in knowledge and systems remain. Those gaps are likely to be even more pronounced in countries with limited resources. Additional studies are needed to better understand the access gap that exists today which should be an important area of focus for public health officials and stroke organizations.

Novelty and significance

- Aims to classify barriers to Mechanical thrombectomy into three specific barriers: information and diagnostic access, financial access as well as geographic and physical access.
- Aims to provide a framework to define, measure and expand MT access in the United States.
- Identify challenges associated with access in the United States and offer potential solutions.
- While there are limited articles focusing on individual aspects of thrombectomy access in the United States, no comprehensive review is available to our knowledge on this topic that discusses all of the above barriers.

Disclosure

Dileep R. Yavagal is on the steering committee of TIGER clinical trial sponsored by Rapid Medical and steering committee of CALM-2 sponsored by Vascular Dynamics. He is a consultant to Medtronic, Cerenovus, Poseydon, Neurosave, and other Neuralanalytics. The other authors have no financial conflicts of interest.

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