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Geographic Access to High-Volume Mechanical Thrombectomy Centers in Florida, 2019

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Abstract

Background and Objectives

Mechanical thrombectomy (MT) improves outcomes for acute ischemic stroke (AIS) due to large vessel occlusion, but is time sensitive and requires specialized infrastructure. Professional organizations and certification bodies have promulgated minimum procedural volume standards for centers and for individual proceduralists but it is unclear whether enforcing these requirements would decrease geographic access to MT. Therefore, we sought to evaluate the potential impact of applying a minimum procedural volume threshold on geographic access to MT.

Methods

We identified all hospital discharges for stroke where an MT procedure was performed at any nonfederal hospital in Florida in 2019 using statewide hospital discharge data. We then generated geographic service area maps based on prespecified ground transport distances for the subset of hospitals that performed at least 1 MT and for those that performed at least 15 MTs that year, the minimum volume threshold required for thrombectomy capable and comprehensive stroke centers by the Joint Commission. Then, using zip code centroids and patient-level discharge hospital data, we computed the proportion of patients with AIS who lived within each of the generated service areas.

Results

A total of 105 of 297 hospitals performed MT; of those, 51 (17%) were low-volume centers (1–14 MTs/year) and 54 (18%) were high-volume centers (≥15 MTs/year). High-volume centers accounted for nearly 95% of all MTs performed in the state. Most patients hospitalized with AIS (87%) lived within 20 miles (or an estimated as a 1-hour driving time) of a hospital that performed at least 1 MT, and all (100%) lived within 115 miles (or estimated as 3-hour driving time). Setting a minimum MT volume threshold of 15 would decrease the proportion of stroke patients living within 1-hour driving time of an MT center from 87% to 77%.

Discussion

In 2019, most Florida stroke patients lived within a 1-hour ground transport time to a center that performed at least 1 MT and all lived within 3-hour driving time of an MT center, irrespective of whether a minimum procedural volume threshold of 15 cases per year was applied or not.

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Introduction

Acute ischemic stroke (AIS) is a leading cause of morbidity and mortality worldwide.[1] Multiple randomized controlled trials have shown that mechanical thrombectomy (MT) improves outcomes for patients hospitalized with AIS due to large vessel occlusion (LVO), but this intervention is time sensitive and requires specialized infrastructure and personnel that may not be available at all centers.[2-5] While the treatment time window for MT can be extended to 24 hours for selected patients, delays in restoring perfusion are still associated with worse outcomes.[6,7] A geographically distributed network of centers capable of performing MT could help to improve timely access to MT treatment, provided that each center has sufficient procedural volume to maintain the necessary personnel, infrastructure, and skills.

The number of MTs performed annually and the number of hospitals that perform MT have been increasing.[8] However, given that MT requires specialized equipment and infrastructure and experienced proceduralists as part of an integrated stroke system of care, Comprehensive Stroke Center (CSC) and Thrombectomy-Capable Stroke Center (TSC) programs have been developed to certify hospitals capable of performing MT. Based on recommendations from various stakeholders and certification bodies, such as the Joint Commission's Stroke Technical Advisory Panel and DNV GL Healthcare, the CSC and TSC designations require centers and individual interventionalists at those centers to maintain a minimum procedural volume of 15 MTs annually or 30 MTs over 24 months.[9,10] The World Federation of Interventional and Therapeutic Neuroradiology has also promulgated a global consensus on a minimum procedural volume threshold for MT of 15 procedures per interventionalist annually.[11]

Although TSC or CSC designation is not required for a center to offer MT, these standards highlight the potential trade-offs between applying minimum procedural volume requirements and ensuring adequate geographic access to MT. Some states have developed stroke systems of care that designate CSCs or TSCs based on criteria such as availability of 24/7 care, collaboration with emergency medical services (EMSs), availability of neurosurgical care, various diagnostic testing capabilities, center and per interventionalist volume requirements, and more.[9] Whether a hospital is CSC or TSC-certified influences referral and patient transport patterns. This is true in Florida, where patients are preferentially transferred by EMS to a certified CSC or TSC, even if a high-volume MT center that lacks certification is located nearby.[12] Parts of Florida had policies phased in as early as 2015 that specify routing patients directly to MT centers.[13] These policies would tend to facilitate the regionalization of MT procedures at high-volume centers and would further justify a closer examination of the reasons why some patients are still treated at low-volume MT centers while these policies are in place. However at the national level, MTs are still performed at other types of facilities, including primary stroke centers.

Previous studies have used both patient-level data and mathematical modeling to investigate the relationship between procedural volume and patient outcomes, but the results have been mixed and fail to fully account for referral patterns.[14,15] In cardiology, procedural volumes for percutaneous coronary intervention (PCI) are strictly monitored and set by a task force comprising representatives from the American College for Cardiology Foundation, American Heart Association, and American College of Physicians; they require at least 50 elective PCI procedures annually per interventionalist with at least 11 for STEMI in conjunction with separate hospital-level volume requirements.[16] For stroke thrombectomy, prior studies have shown a relationship between hospital procedural volume and patient outcomes; in fact, some data suggest that transferring patients to high-volume thrombectomy centers may be justified even if this results in a delay in time to treatment with the transfer.[17-19]

Prior studies have shown that patients have differing ground transport access times to centers that perform MT; however, since then, MT has become more widely available, although access remains disparate in some populations.[8,20-22] If MTs were to be limited to facilities that were certified (including meeting a certain minimum volume threshold), geographic access to MT may be reduced, although extent of these potential impacts is unknown. By contrast, restricting MT to only high-volume centers with more experience and practice processes could potentially lead to better outcomes. To understand how the geographic access to MT-capable centers could change by applying a threshold volume requirement of 15 per center annually, we used hospital discharge data from Florida in 2019 to analyze differences in geographic access to MT-capable centers that did not meet such volume threshold (low-volume centers) and to centers that met the volume threshold in 2019 (high-volume centers).

Methods

Study Design

We conducted a spatial analysis using street-level geographic data linked to hospital-level and patient-level clinical information.

Standard Protocol Approvals, Registrations, and Patient Consents

This study was deemed exempt by the University of California, San Francisco Institutional Review Board (IRB).

Data Sources

All nonfederal hospitals licensed in Florida are required to submit data on every hospital discharge to the Florida Agency for Health Care Administration; these data are compiled into the Florida Hospital Discharge Data Confidential Information and are available as the Florida State

Inpatient Database (SID) through the Healthcare Cost and Utilization Project (HCUP). We obtained additional hospital-level characteristics from the 2019 American Hospital Association (AHA) Hospital Statistics data set which includes hospitals that are both registered and not registered with the AHA and includes either hospital-reported data or estimations from prior years or similar hospitals.[23]

Determination of MT Volumes by Hospital

First, we identified all hospital discharges with a primary diagnosis of AIS at each nonfederal acute care hospital in Florida in 2019 using International Classification of Disease, Clinical Modification, 10th revision (ICD-10-CM) core codes I63.x.[24,25] Then we applied a previously described algorithm to identify when an MT was performed using procedure codes (International Classification of Disease, Procedure Coding System, 10th revision (ICD-10-PCS) codes 03CG3ZZ, 03CH3ZZ, 03CJ3ZZ, 03CK3ZZ, 03CL3ZZ, 03CM3ZZ, 03CN3ZZ, 03CP3ZZ, 03CQ3ZZ) or Medicare Severity Diagnosis Related Group (MS-DRG) code 023 or 024, excluding hospitalizations with an ICD-10-PCS code for craniectomy, craniotomy, or ventriculostomy.[24] This was based on a previously proposed and validated strategy that found that excluding these cases leaves out a nominal number of patients with thrombectomy but would not be expected to materially affect our overall results.

We then applied 2 MT volume thresholds to identify hospitals that had performed at least 1 MT and those that had performed 15 or more MTs annually, a threshold that was based on the Joint Commission criteria for Thrombectomy-Capable Stroke Center Certification, which, in turn, was based on recommendations from professional organizations. A hospital meeting this threshold was deemed a "high-volume center." Previous studies have demonstrated decreased odds of patient mortality and progressively greater odds of a good outcome beginning at a 15 case per proceduralist threshold.[26] We applied hospital-level minimum procedural volume thresholds instead of individual proceduralist levels because of the lack of available proceduralist annual volumes data and as some proceduralists may practice at multiple centers.

Acute Stroke Patient Geocoding

We identified all hospitalizations with a primary discharge diagnosis of stroke. We then captured the patient's zip code of residence and used US Census Bureau, IRS, and American Community Survey data to determine the geographic coordinates of each patient's residence using zip code centroids.[27] We excluded hospitalizations where the patient's zip code was located outside of Florida or in nonresidential areas, including post office boxes, zip codes with centroids that were located in water bodies, and zip codes in areas lacking road access. The identified geographic coordinates were then plotted on a map of Florida.

Additional Hospital Characteristics

We obtained hospital characteristics from the AHA Hospital Statistics data set and derived additional hospital-level measurements from SID data. AHA data included hospital-reported information on the availability of MRI and CT as well as whether the hospital was a certified trauma center, had a critical access hospital designation, or had a teaching hospital designation. Critical access designation was based on data from the Centers for Medicare and Medicaid (June 2020). Urban status was based on the US Census Bureau Core-Based Statistical Area Type. An area is defined as "metropolitan" if it contains at least one urbanized area of 50,000 or more people, as "micropolitan" statistical area if there is at least one urban cluster of between 10,000 and 50,000 people, and as "rural" otherwise.[28]

Teaching hospital designation was based on any of the following criteria: (1) membership in the Council of Teaching Hospitals of Association of American Medical Colleges, (2) presence of medical or dental residents, (3) accreditation by the Accreditation Council for Graduate Medical Education, or (4) medical school affiliation reported to the American Medical Association. The availability of intensive care unit (ICU) services was based on self-reported medical, surgical, or cardiac ICU availability.

Using Florida SID data, we determined the total annual volume of discharges, the proportion of patients with Medicare as a primary payer, the proportion of patients experiencing homelessness, and the proportion of patients having advanced neurologic procedures, including cerebral angiograms and craniotomies. Craniotomies and cerebral angiogram volumes were determined using submitted ICD-10-PCS codes (eTable 1). The capability to perform diagnostic cerebral angiograms in the inpatient setting was used as a proxy for the availability of an angiography suite necessary to perform MT.

Hospital Geocoding

Hospital location was determined using the specific geographic coordinates of the hospital listed in the AHA database. For hospitals that did not have geographic coordinates available in the database, hospital location was defined as the centroid of the zip code where the hospital was located.

Ground Transportation Distances and Service Area Maps

Using the mapped geographic coordinates of each hospital, we used network analysis software to develop service area maps that encompassed accessible routes for emergency vehicles within a specified transport distance from each hospital. We used ground transportation transport distance thresholds of 20, 65, 115, 165, and 200 miles, which have been shown to correspond to ground transport times of 1, 2, 3, 4, and 5 hours, respectively.[20,29,30] Ground transportation estimates were based on an emergency vehicle that avoids gates, private roads, roads under construction, and roads

where through-traffic is prohibited. We created combined service maps of all transport distances for the hospitals that performed at least 1 MT in 2019 and for the subset of hospitals that performed at least 15 MTs in 2019.

We then combined the maps of each stroke patient's residence with the service maps. We calculated the proportion of adults hospitalized for AIS who lived within each transport distance threshold. We also calculated the proportion of patients hospitalized with AIS that were treated with MT who lived within each transport distance threshold. ArcGIS Pro (Version 2.9; Esri, Redlands, CA) was used for all geospatial analyses.

Statistical Analysis

We summarized the baseline characteristics and proportions of low and high-volume centers using frequency counts and percentages, classified by MT volume. Statistical analyses were performed with Stata 17 (StataCorp LP, College Station, TX).

Data Availability

Data not provided in the article because of space limitations may be shared with approval from appropriate data collection bodies at the request of any qualified investigator for purposes on replication procedures and results. Detailed study protocol and programming code are available upon request.

Results

MT Volumes per Hospital

In 2019, 192 of 297 nonfederal hospitals in Florida (64%) did not perform any MTs, 51 (17%) hospitals performed between 1 and 14 MTs, and 54 hospitals (18%) performed 15 or more MTs (Figure 1). A total of 3,733 MTs were performed statewide; only 158 MTs (4%) of these were performed at the 51 low-volume hospitals.

Low-Volume and High-Volume MT Hospitals

Among low-volume hospitals that performed at least 1 but less than 15 MTs in 2019, the median (IQR) MT case volume was 2 cases per hospital (1, 5). However, among the high-volume hospitals that performed 15 or more MTs, the median (IQR) MT case load was 59.5 (41–87) cases.

Hospitals that did not perform any MTs saw fewer stroke patients annually with a median (IQR) of 3 (0–68) annual stroke patient discharges. This was substantially lower than both low-volume MT hospitals (median [IQR] 167 [120–239)] and high-volume MT hospitals (median [IQR] 417 [350–592]). Of the 10 hospitals that were designated as critical access hospitals, none performed MT.

The percentage of hospital discharges with Medicare as the expected primary payer was similar in low- and high-volume MT hospitals (53% vs 47%) and many of the available resources at these hospitals were also similar. Only 6 (17%) low-volume MT hospitals were trauma centers compared with 21 (49%) high-volume MT hospitals. Not all low-volume MT hospitals performed cerebral angiograms (80%) or craniotomies/craniectomies (63%), whereas all high-volume MT hospitals offered these services. Additional hospital-level characteristics are summarized in Table 1.

Patient Demographics at Select Low and High-Volume MT Hospitals

Patient demographics were assessed for adult patients with AIS on a hospital level. They were then aggregated within corresponding volume categories. The median age of patients treated at no MT, low-volume, and high-volume centers was 72, 70, and 71 years, respectively. Most demographics were within similar ranges. The median percentage of patients with Medicare as a primary payer was somewhat higher at centers that performed no MT (72%, vs 67% at low-volume and high-volume centers). Racial differences in patient composition were also seen with high-volume MT centers having a lower median percentage of patients identified as White (62% vs 75% at no MT and 74% at low-volume MT centers) and a higher median percentage of patients identified as Black (21% vs 9% at no-MT and 15% at low-volume MT centers). Additional patient characteristics are summarized on at the hospital level in Table 2.

Geographic Access to MT

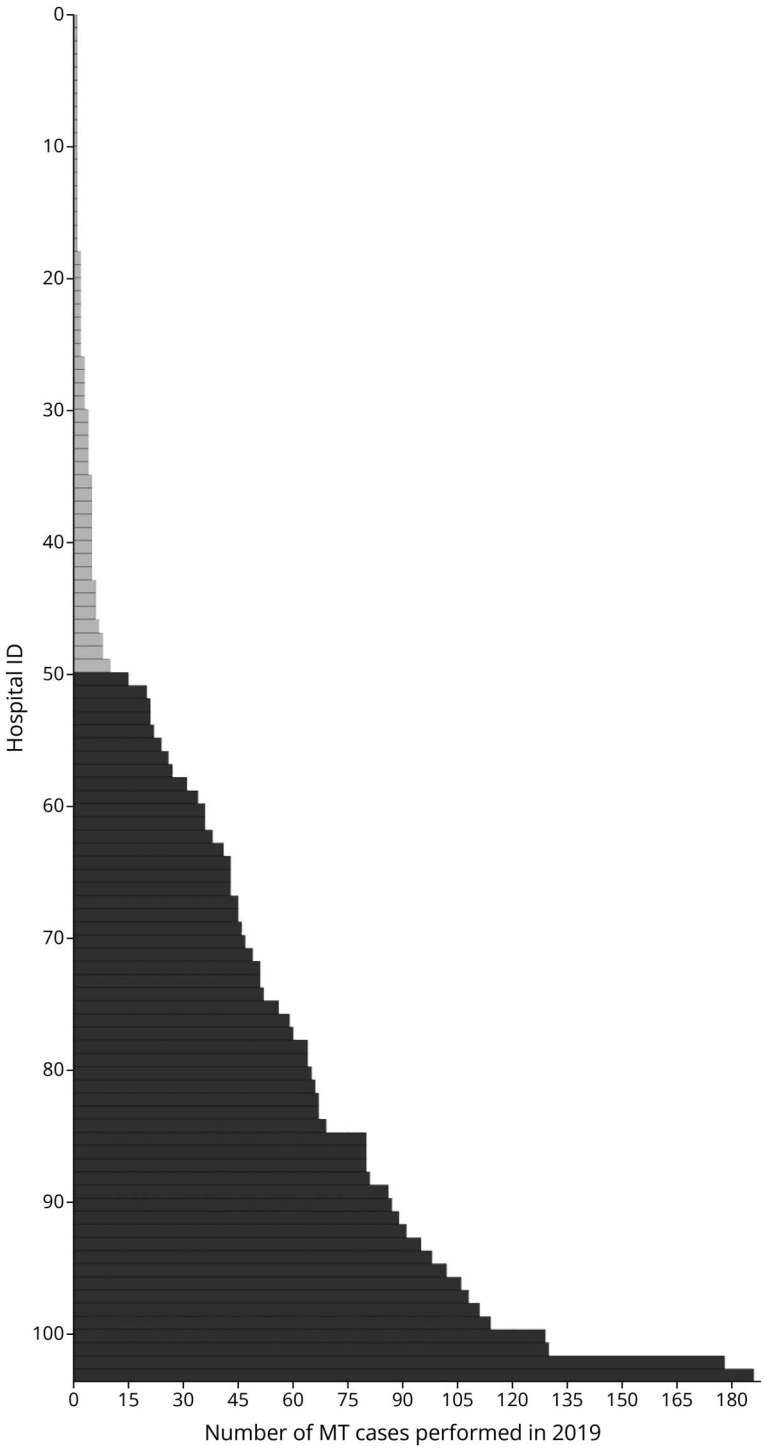
Hospital location was available for 285 (96%) of the 297 hospitals. The remaining 12 hospitals without available location information did not perform any MTs in 2019. Service area maps based on estimated emergency vehicle driving routes using driving thresholds of 20, 65, 115, 165, and 200 miles are shown in Figure 2. Drivable areas of Florida consisted of any route that an emergency vehicle could drive, excluding areas that have zip codes assigned but are not drivable, such as the Everglades. Every drivable area of Florida was within 115 miles of a facility that performed MT.

Among the 38,657 patients who were hospitalized for AIS, 33,593 (87%) lived within 20 miles or a 1-hour driving time of a hospital that performed at least 1 MT in 2019. All patients hospitalized with AIS lived within 115 miles or 3-hour driving time of a facility performing at least 1 MT. Less than 1% of patients with AIS lived between 65 and 115 miles of a hospital performing at least 1 MT.

Restricting MT to centers that performed at least 15 MTs decreased the geographic access to an MT center within a 1-hour driving time for patients hospitalized with AIS by 10% (from 87% to 77%); all patients hospitalized with AIS still resided within 115 miles of a high-volume MT center (Figures 2 and 3).

Among the 2,740 patients who were hospitalized for AIS and underwent MT, 2,492 (90%) lived within 20 miles of a hospital that performed at least 1 MT and 2,276 (83%) who lived within 20 miles of a hospital that performed at least 15 MTs. In total, 2,731 (nearly 100%) patients who received MT lived within 65 miles of a center that performed at least 1 MT and 2,740 (100%) lived within 115 miles.

Figure 1 Mechanical Thrombectomy (MT) Volume per Center in Florida, 2019



Note: Only Hospitals that performed at least one MT in 2019 are shown. Light gray shading represents centers with low MT volumes (<15 annually) and dark gray shading represents centers with high MT volumes (≥15 annually).

Discussion

In 2019, 87% of patients hospitalized with AIS in Florida lived within 20 miles or 1-hour driving time of a hospital that performed at least 1 MT annually. Setting a minimum procedural volume threshold of 15 MTs per center per year would lower the proportion of patients who have access to MT within 1-hour driving time by nearly 10%. Nearly all patients hospitalized with AIS live within 65 miles of a center that performed at least 1 MT and 98% of those patients live within 65 miles of a center that would meet a 15-MT case threshold. In fact, 96% of MTs were performed at hospitals that were already performing more than 15 MT procedures annually.

Table 1 Characteristics of Florida Hospitals by Volume of Mechanical Thrombectomies (MTs) Performed, 2019

	All hospitals	No MTs (low volume)	1–14 MTs	15 or more MTs (high volume)
Number of facilities, n (%)	297 (100)	192 (65)	51 (17)	54 (18)
Total licensed beds, median (IQR)	250 (106–521)	125 (65–309)	310 (207–473)	536 (400–772)
Annual volume per hospital, median (IQR)				
Total inpatient discharges	6097 (1631–14799)	2766 (655–6185)	13407 (8791–18151)	21922 (17262–31021)
Ischemic stroke discharges	68 (0–194)	3 (0–68)	167 (120–239)	417 (350–592)
Percentage of discharges with Medicare as expected primary payer	53% (41%–65%)	54% (38%–69%)	53% (44%–64%)	47% (39%–56%)
Percentage of discharges with patient experiencing homelessness	0.10% (0.0%–0.6%)	0.01% (0.0%–0.4%)	0.20% (0.1%–0.6%)	0.40% (0.1%–1.0%)
Hospital characteristics, n (%)				
Hospital location[a,b]				
Metro	267 (94)	162 (90)	51 (100)	54 (100)
Micro	10 (4)	10 (6)	0 (0)	0 (0)
Rural	8 (3)	8 (4)	0 (0)	0 (0)
Trauma center[c]	42 (22)	15 (13)	6 (17)	21 (49)
Teaching hospital[a,d]	195 (68)	99 (55)	44 (86)	52 (96)
Critical access[a,e]	10 (4)	10 (6)	0 (0)	0 (0)
Available services, n (%)				
Cerebral angiograms	129 (43)	34 (18)	41 (80)	54 (100)
Craniotomies/craniectomies	106 (36)	20 (10)	32 (63)	54 (100)
ICU services[c,f]	161 (83)	83 (73)	35 (97)	43 (100)
MRI on site[c,g]	156 (81)	78 (68)	36 (100)	42 (98)
CT on site[c]	174 (90)	95 (83)	36 (100)	43 (100)

[a] Data missing for 12 hospitals (4%). These hospitals did not perform any MTs.
[b] As defined by the US Census Bureau. A metropolitan statistical area has ≥1 urbanized area of ≥50,000 people; a micropolitan statistical area has ≥1 urban cluster of ≥10,000 but <50,000 people; and remaining areas are otherwise deemed a rural statistical area.
[c] Data missing for 104 hospitals (35%) of which 96 hospitals performed 1 or more MTs and 11 performed 15 or more MTs.
[d] Identified as a teaching hospital with any of the following: (1) Member of Council of Teaching Hospital of Association of American Medical Colleges (AAMC), (2) presence of medical or dental residents, (3) recognition by an Accreditation Council for Graduate Medical Education (ACGME) program, or (4) medical school affiliation reported to the American Medical Association (AMA).
[e] Critical Access Hospital designation based on Centers of Medicare and Medicaid (June 2020) data.
[f] Intensive care unit (ICU) services (medical, surgical, or cardiac ICU).
[g] One hospital that performed ≥15 MTs reported no MRI available.

Although 87% of all patients with AIS lived within a 1-hour driving time of a center that performed at least 1 MT, 90% of patients with AIS who received MT lived within 1-hour driving time of a center that performed at least 1 MT. Since finer clinical details about eligibility for MT are not available in administrative data, we chose to evaluate geographic access to MT centers for the entire population of patients with AIS.

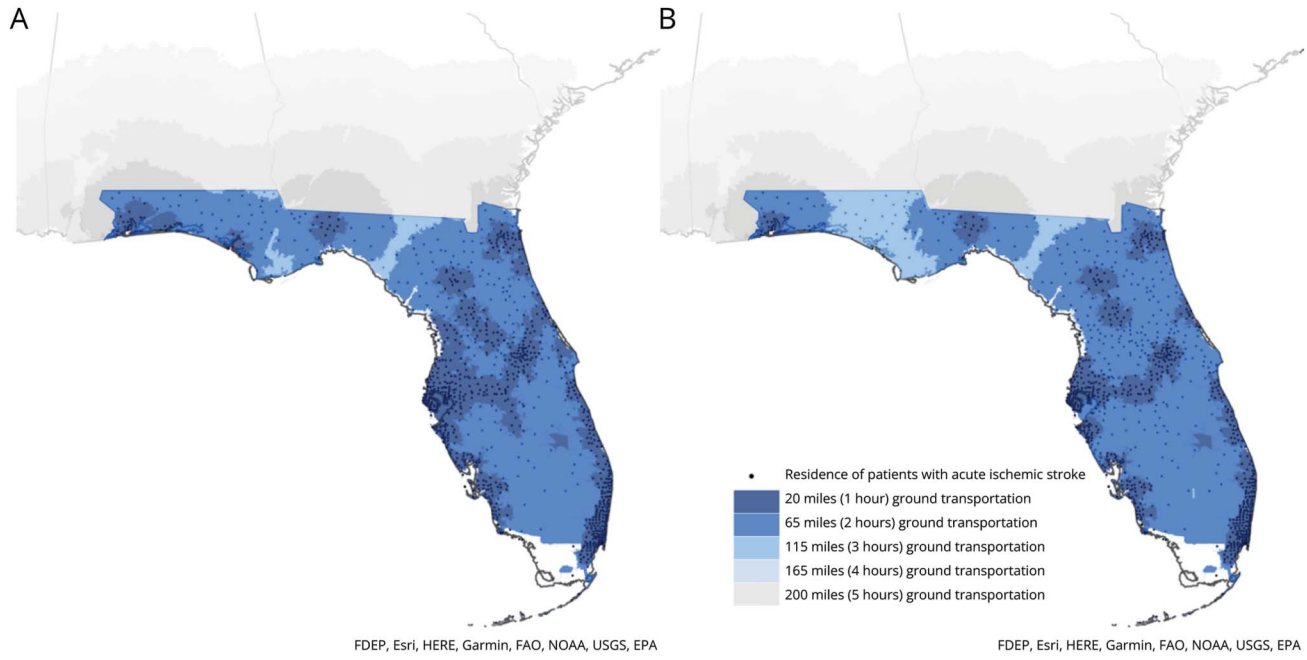
Previous studies based on neurointerventionalist practice locations and geographic data for patients and hospitals have suggested that most of the US population had access to a hospital that performs MT within approximately 2 hours of ground transport time, but this included hospitals with very low annual MT volumes.[20,29,31] Our findings suggest that applying a minimum procedural volume threshold may affect geographic access to MT in Florida. The eligibility requirements for Thrombectomy-Capable Stroke Center certification and Comprehensive Stroke Centers include a minimum procedural volume threshold of 15 MTs annually, both per center and per interventionalist. Although TSC or CSC certification is not required for a center to offer MT, our data suggest that if the minimum procedural volume per center was enforced statewide, geographic access to MT within 1-hour driving time would decrease. The result would be that 77% of patients with stroke could reach a qualifying hospital within 1-hour driving time, although nearly everyone could reach a hospital within 3-hour driving time.

Table 2 Characteristics of Patients Hospitalized With AIS by Center Volume of Mechanical Thrombectomies (MTs) Performed, 2019

	0 MT (no MT)	1–14 MTs (low-volume)	15 or more MTs (high-volume)
Patients with AIS as primary diagnosis, n	7,513	8,697	23,510
Facilities included[a], n	135	21	53
Age, median (IQR)	72 (68–74)	70 (69–73)	71 (69–73)
Female Sex, mean (SD)	0.5 (0.2)	0.5 (0.1)	0.5 (0)
Percentage experiencing homelessness, mean (SD)	0% (0%)	0% (0%)	0% (0%)
Percentage with Medicare as expected primary payer, median (IQR)	72% (66%–79%)	67% (61%–74%)	67% (62%–73%)
Race and ethnicity, median (IQR)			
White	75% (54%–89%)	74% (45%–84%)	62% (43%–78%)
Black	9% (3%–20%)	15% (8%–30%)	21% (11%–30%)
Hispanic	6% (1%–15%)	9% (2%–14%)	8% (4%–17%)
Asian	0% (0%–1%)	1% (1%–2%)	1% (0%–1%)
Native American	0% (0%–0%)	0% (0%–0%)	0% (0%–0%)
Other	0% (0%–2%)	1% (1%–3%)	1% (1%–2%)
Missing	0% (0%–1%)	1% (0%–1%)	1% (0%–2%)

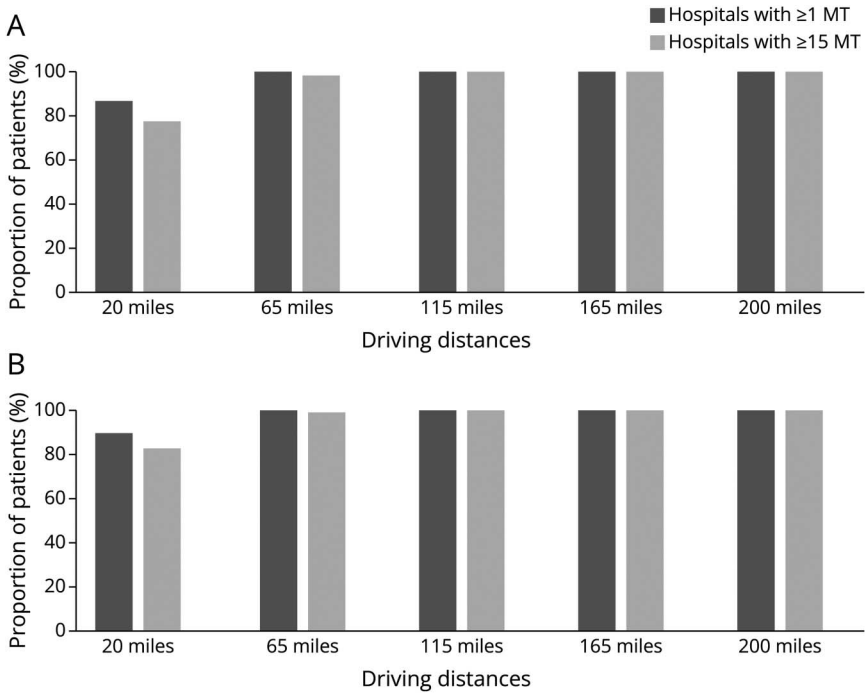
[a] Only adult patients with a primary diagnosis of AIS and a residential Florida zip code were included in this analysis. In our overall analysis, any patient who received MT contributed to a center's total MT count. As a result, the total number of centers in the demographic analysis is decreased from the overall number of centers considered for the geographic analysis.

Figure 2 Ground Transport Service Area Map of Hospitals That Performed at Least 1 or at Least 15 Mechanical Thrombectomy (MT) in Florida, 2019



Service area maps by ground transport distance time (A) to any hospital that performed at least one MT in 2019 and (B) to only hospitals that performed at least 15 MT procedures in Florida, 2019. Colored shading indicates areas reachable by emergency vehicle driving routes using driving distance thresholds of 20, 65, 115, 165, and 200 miles, with darker shading indicating areas with shorter driving distance thresholds to MT centers, and lighter shading indicating areas with longer driving distance thresholds to MT centers. Grey shading indicates areas that are outside of Florida state lines.

Figure 3 Proportion of Patients Hospitalized With Acute Ischemic Stroke (AIS) or Receiving Mechanical Thrombectomy (MT) That Live Within Different Driving Distances of Any MT Capable Center and High-MT Volume Centers



Proportion of (A) all patients with AIS and (B) patients who received MT that live within different driving distances of any MT capable center and high-MT volume centers.

A drop in access within a 1-hour driving time for nearly 10% of the population is important to consider. These patients are likely located in rural areas and experiencing other disparities of access to health care, which might be worsened by enforcing this threshold. Enforcing a minimum volume threshold per center universally could result in longer transport times, air transport notwithstanding, and contribute to delays of care for this population. However, it is also important to consider whether delays in care are offset by potential improvements in quality associated with treatment at high-volume centers.[17]

Restricting low-volume centers from offering MT could result in a more regionalized MT treatment system and concentration of MTs at fewer high-volume centers at the expense of transport delays and potential impacts on treatment times. These data provide important information about the geographic availability of MT because MT has been established as a standard-of-care treatment for eligible patients with AIS of LVOs.[32,33] However, timely access must also be considered. A consensus statement by multiple stakeholders, including the American Academy of Neurology and American Health Association, recommended that patients have access to advanced-level stroke centers, such as CSCs and TSCs, within 60 minutes travel time for rural location, 45 minutes for suburban areas, and 30 minutes for urban areas.[34] In fact, they state that if a CSC or TSC is not available within 60 minutes, then patients should be directed to a hospital that may or may not have MT available preferentially.[34] This recommendation highlights the importance of access within a 1-hour transport time and emphasizes that enforcing a minimum volume threshold that decreases access for nearly 10% of the population could result in a suboptimal stroke system of care.

A previous study using data from California in 2009–2010 showed that only 39% of patients hospitalized with AIS lived within 1-hour driving time of a hospital performing at least 10 MTs and only 70% lived within 2-hour driving time of such a center.[20] Since that time, there has likely been a substantial increase in the total number of MTs performed as well as the total number of centers performing MT. On the basis of more recent data in Florida, setting a minimum procedural volume threshold of 15 would half the number of hospitals performing MT in Florida.

In our analysis, nearly 35% of hospitals performed MT. Fewer than 10 years ago, national and state averages for hospitals performing MTs were below 10%. The increase in the total number of MTs performed and the total number of hospitals performing MTs demonstrates that MT has become more established, and access has likely increased as well.[20,35] A previous study found that nearly 50% of US residents and nearly 75% of Florida residents live within a 1-hour ground transportation time to a TSC or CSC.[36] Our analysis provides updated estimates about the actual number of MT procedures that a hospital performed, independent of whether a hospital has TSC or CSC certification.

Our results should be interpreted within the context of certain limitations. Patients were assigned a geographic location using the centroid of their residence zip code that does not account for strokes that occur away from home. Furthermore, for the geographic analyses, we excluded all patients without valid Florida residential zip codes, excluding information about MT access for patients with a post office box as their address, patients experiencing homelessness, or those who do not live in Florida. People reporting nonresidential zip codes might be medically underserved with health care disparities, so it is important to acknowledge that we could not capture and assess geographic access for all patients hospitalized with AIS. It is critical to consider what access to MT looks like for all patients to prevent widening health care disparities.

Our analysis is limited to Florida, which has 45 CSCs and 1 TSC; there is an average of 5.8 CSCs per state in the United States with Florida having more CSCs than any other state.[37] As a result, our findings may not be generalizable to other states with different stroke systems of care. Because our data are limited to Florida hospitals, we are unable to account for stroke patients transferred across state lines. Also, our analysis of service areas is based on ground transport times only and does not account for the possibility of fixed or rotary wing transports for patients with AIS. This form of transportation could have the potential to decrease travel times but depends on a coordinated system of care that efficiently identifies and transports eligible patients by air travel. We assessed procedural volumes by center only; we are not able to apply separate minimum procedural volume thresholds for individual proceduralists who may maintain procedural experience by performing procedures at multiple centers. Finally, we used administrative databases that introduce a potential for misclassification bias based on hospital billing practices. However, the HCUP database we used has other advantages, such as the large amount of data it contains and the inclusion of the uninsured population, which has led to the widespread use of these data for research.[38]

Ultimately, an effective stroke system of care will optimize both access and quality of care to improve patient outcomes. Geographic access is affected by minimum volume thresholds. We found that when minimum volume thresholds are applied, most patients could access MT within 2-hour driving time. Optimizing patient outcomes is a balance between improving timely access and the notion that high-volume centers might lead to improved patient outcomes, the origin of the proposed thresholds. Time to intervention should be further minimized as any delay in access to revascularization can worsen neurologic status. Yet this must be weighed against the impact of procedural volume on patient outcomes and whether low-volume centers can provide the same level of care as high-volume centers. Unfortunately, detailed information on patient outcomes was not available in our data, so we opted to focus on access. It is critical that the next step in this research addresses the interplay between access and patient outcomes in high vs low-volume centers.

In conclusion, applying a minimum procedural volume threshold for MT in Florida of 15 cases per year would restrict geographic access to these high-volume MT centers for stroke patients across the state. These data, in combination with future studies that will evaluate the precise relationship between procedural volume and patient outcomes, will help inform efforts to optimize the regionalization of MT care as part of a well-integrated system of care for patients hospitalized with AIS.

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TAKE-HOME POINTS

- Various certification bodies have recommended a minimum volume threshold of 15 mechanical thrombectomies per center annually. Enforcing that threshold would decrease the proportion of patients hospitalized with acute ischemic stroke in Florida who live within 20 miles, or an estimated 1-hour driving time, of a hospital that performs mechanical thrombectomy by 10%.
- All patients hospitalized with AIS lived within 115 miles, or an estimated 3-hour driving time, of a hospital that performed MT, regardless of whether the minimum volume threshold was applied.
- Information on geographic and timely access to mechanical thrombectomy must be paired with future studies aimed at evaluating the relationship between procedural volumes and patient outcomes to determine optimal stroke systems of care.

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Yu-Chu Shen, PhD	Naval Postgraduate School, Monterey, CA; National Bureau of Economic Research, Cambridge, MA	Drafting/revision of the manuscript for content, including medical writing for content; analysis or interpretation of data
Elan L. Guterman, MD	UCSF Weill Institute for Neurosciences, Department of Neurology; Philip R. Lee Institute for Health Policy Studies, University of California, San Francisco	Drafting/revision of the manuscript for content, including medical writing for content; analysis or interpretation of data
Jay Chol Choi, MD, PhD	Department of Neurology, School of Medicine, Jeju National University, Korea	Drafting/revision of the manuscript for content, including medical writing for content; analysis or interpretation of data
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