

Real-World Treatment Trends in Endovascular Stroke Therapy

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Background and Purpose—Recent landmark trials provided overwhelming evidence for effectiveness of endovascular stroke therapy (EST). Yet, the impact of these trials on clinical practice and effectiveness of EST among lower volume centers remains poorly characterized. Here, we determine population-level patterns in EST performance in US hospitals and compare EST outcomes from higher versus lower volume centers.

Methods—Using validated diagnosis codes from data on all discharges from hospitals and Emergency Rooms in Florida (2006–2016) and the National Inpatient Sample (2012–2016) we identified patients with acute ischemic stroke treated with EST. The primary end point was good discharge outcome defined as discharge to home or acute rehabilitation facility. Multivariate regressions adjusted for medical comorbidities, intravenous tPA (tissue-type plasminogen activator) usage and annual hospital stroke volume were used to evaluate the likelihood of good outcome over time and by annual hospital EST volume.

Results—A total of 3890 patients (median age, 73 [61–82] years, 51% female) with EST were identified in the Florida cohort and 42505 (median age, 69 [58–79], 50% female) in the National Inpatient Sample. In both Florida and the National Inpatient Sample, the number of hospitals performing EST increased continuously. Increasing numbers of EST procedures were performed at lower annual EST volume hospitals over the studied time period. In adjusted multivariate regression, there was a continuous increase in the likelihood of good outcomes among patients treated in hospitals with increasing annual EST procedures per year (odds ratio, 1.1; 95% CI, 1.1–1.2 in Florida and odds ratio, 1.3; 95% CI, 1.2–1.4 in National Inpatient Sample).

Conclusions—Analysis of population-level datasets of patients treated with EST from 2006 to 2016 demonstrated an increase in the number of centers performing EST, resulting in a greater number of procedures performed at lower volume centers. There was a positive association between EST volume and favorable discharge outcomes in EST-performing hospitals. (*Stroke*. 2019;50:683–689. DOI: 10.1161/STROKEAHA.118.023967.)

Key Words: endovascular procedures ■ population health ■ procedures and techniques utilization ■ stroke ■ thrombectomy

After the landmark clinical trials published in 2015, endovascular stroke therapy (EST) has been established as a key component of acute ischemic stroke (AIS) care.^{1–5} These studies demonstrated that EST leads to dramatic improvements in patient outcomes in combination with medical management versus medical management alone. However, in the wake of these results, stroke systems of care around the globe are now faced with the daunting task of ensuring that patients with AIS have access to appropriate screening and therapy.

The evidence of benefit for EST that emerged from these trials was derived from treatments rendered almost

exclusively at high volume stroke centers. However, since the publication and adoption of these findings into guidelines, it has become well-established that the likelihood of good neurological outcome for these patients remains dependent on minimizing delays in treatment.⁶ Even 15-minute delays in endovascular reperfusion have been associated with quantifiable decrements in clinical outcomes. As such, there has been an increase in demand for the procedure as well as calls for the dissemination of the treatment away from tertiary-care referral centers into the community, to avoid the costly delays associated with transferring patients.^{7,8} However, transferring

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EST patients to higher volume centers has also been associated with reduced mortality.⁹

Given the need to structure stroke systems of care in the modern EST era, as well as the potential expansion of the procedure away from tertiary-care referral centers and into lower volume centers, understanding the trends in treatment patterns as well as outcomes in relation to treatment volumes is of vital importance. To date, little is known about real-world practice and outcomes of EST. In this study, we examined practice patterns of EST over a 10-year period in a large cohort and evaluated the association between clinical outcomes and hospital treatment volumes.

Methods

This article adheres to the American Heart Association Journals implementation of the Transparency and Openness Promotion Guidelines. The data that support the findings of this study are available from the corresponding author on reasonable request.

Study Design

We performed a retrospective cross-sectional study using data from 2 complementary cohorts. The first cohort consisted of all Emergency Department visits and inpatient discharges from nonfederal acute care hospitals in Florida from 2006 to 2016. The Florida Agency for Health Care Administration provides these data to the Agency for Healthcare Research and Quality for its Healthcare Cost and Utilization Project. Florida was chosen because it is a large, demographically and socioeconomically diverse state, with a mixture of urban and rural populations. In addition, Florida's data allow for deidentified tracking of individual patients by a unique linkage variable across the Emergency Department and inpatient encounters. Of note, in 2004 the Florida state legislature defined 2 types of stroke centers (primary and comprehensive) according to criteria set by the Joint Commission and required all EMS providers to use triage assessment tools to evaluate, treat, and transport stroke patients to the most appropriate hospitals.¹⁰

To assess the generalizability of the findings from this state-wide cohort, we also examined a nationwide cohort. The National Inpatient Sample (NIS) is the largest publicly available inpatient health care database in the United States. Beginning in 2012, the NIS approximates a 20% stratified sample of all discharges from US hospitals, including data on all patients, regardless of payer, and the uninsured. At present 46 states plus the District of Columbia are included.¹¹ In this study, NIS data from 2012 to 2016 were used. Although the Florida state cohort allows for tracking of individual patients and as such, additional granularity, the NIS data are weighed to provide nationwide estimates. All analyses were conducted as per Healthcare Cost and Utilization Project data use agreements. Analyses of deidentified and publicly available data did not warrant an institutional review of this study.

Study Population

To identify the study population, we used diagnosis and procedure codes from the *International Classification of Diseases (ICD)* system. For data from 2006 to the third quarter of 2015, data were classified using the *Ninth Revision-Clinical Modification (ICD-9-CM)* codes, while data from the fourth quarter of 2015 and all of 2016 were classified using the *Tenth Revision-Clinical Modification (ICD-10-CM)* codes. Codes were derived from prior relevant literature for consistency and comparison.¹²

In both Florida and the NIS, our study population consisted of all patients aged 18 years or older with a diagnosis of AIS who were treated with EST. AIS was defined using previously validated *ICD-9* and *ICD-10* coding algorithms.¹³ For patients identified using *ICD-9* coding, we used 433.x1, 434.x1, or 436 in any hospital discharge diagnosis code position without a primary hospital discharge diagnosis

code for rehabilitation (V57) or any accompanying codes for trauma (800–804 or 850–854), intracerebral hemorrhage (431), or subarachnoid hemorrhage (430). For patients identified using *ICD-10* coding, we used I61, I63, and I64. EST was defined using specific cerebral thrombectomy procedural codes (39.74 and 03CG3ZZ, *ICD-9* and *ICD-10*, respectively), as was intravenous tPA (tissue-type plasminogen activator) administration (99.10 and 3E03317, *ICD-9* and *ICD-10*, respectively).

In the Florida cohort, we then cross-referenced each patient in our cohort that was treated with EST to identify any Emergency Department encounters within 1 day before the EST treatment. By doing so, we were able to identify patients that were treated with intravenous tPA at centers other than the EST-performing hospital and then transferred for the procedure, in a drip and ship paradigm. We also then tabulated the total number of patients transferred to receive EST at a different center. Note that this analysis was performed in the Florida cohort but not the NIS, as the NIS datasets do not allow for tracking of individual patients across multiple encounters.

Exposure, Outcome, and Covariates

Total numbers of EST treatments were tabulated for each hospital in both cohorts during the study period. A hospital was considered EST-performing if it performed one or more EST procedures within that calendar year. Annual thrombectomy volume was also analyzed by year of initiation of EST procedures. A composite score of comorbidities using the Charlson comorbidity index was calculated. This index is a validated approach widely used by health researchers to measure a patient's overall burden of disease.^{14,15} Other medical comorbidities, including hypertension and diabetes mellitus, were defined using Healthcare Cost and Utilization Project standardized definitions.¹⁶

The primary clinical outcome was patients' discharge destination (ie, disposition), which previous studies have shown to correlate with functional status in patients with stroke.¹⁷ These data were derived from the Healthcare Cost and Utilization Project meta-label DISPUNIFORM (Disposition of patient, uniform coding), which provides discharge disposition information on all patients included in the dataset. Good outcome was defined as discharge to home or acute rehabilitation hospital and poor outcome as discharge to skilled nursing facility, hospice, or in-hospital mortality. Secondary end points included hospital length of stay and in-hospital mortality. In the Florida cohort, we also examined these end points in patients treated at EST-performing hospitals who did not receive EST, to evaluate the effect of hospital-specific factors on these outcomes. This analysis could not be performed in the NIS as only a sample of admissions per hospital is tracked.

Because there are multiple other factors that influence patient outcomes after stroke that are not captured in population-level clinical databases, including availability of specialized stroke rehabilitation, nursing, neurosurgery, neuroimaging, and many other features, we also adjusted these analyses by hospital annual stroke volume, as higher annual volume centers are more likely to benefit from these advantages, and because this parameter has been shown to correspond with discharge outcomes.¹⁸

Statistical Analysis

Univariate analysis of categorical variables was performed using the Fisher exact test. Analyses using the NIS data were performed using survey design methods, accounting for sampling weights.¹¹ Multivariate logistic regression analyses adjusting for age (in quartiles), sex, race, Charlson index, and intravenous tPA usage were used to evaluate the association between year of treatment and annual EST volume on the primary and secondary clinical outcomes. Higher versus lower volume hospitals were defined in several ways. First, higher volume centers were defined as centers performing greater than or equal to the median number of procedures annually and lower volume centers as those performing fewer. Then, yearly EST treatment volume was examined as an ordinal variable by 10s (1–10, 11–20, 21–30, 31–40, 41–50, and >50). The Hosmer-Lemeshow

test of goodness of fit was used in these regression models. Data from 2008 onwards were used in the logistic regression models because annual hospital EST volumes were low before this year. Results are presented as odds ratio (OR) with associated 95% CI or median (interquartile range [IQR]). Analyses were performed using StataMP 14 (StataCorp LLC, College Station, TX) and Prism 7 (GraphPad, La Jolla, CA) statistical software.

Results

Our study comprised 3890 patients who underwent EST in our state-wide cohort and 42 505 in the NIS. Basic demographics between the 2 cohorts were comparable (Table I in the [online-only Data Supplement](#)), though the Florida cohort was slightly older and had a greater percentage of Hispanic patients. Data from 56 hospitals performing EST between 2006 and 2016 in Florida were included and 2260 hospitals from 2012 to 2016 in the nationwide cohort.

In the Florida cohort as shown in the Table, median age was 73 (61–82) years, 51% were women and 61% were white. Across the entire cohort, 47% had hypertension, 27% had diabetes mellitus, and the median Charlson comorbidity index was 3. Nearly half the patients were treated with intravenous tPA before EST. The median number of EST procedures per hospital per year was 24 (IQR, 12–45). Patients treated at higher volume centers (ie, hospitals that performed greater than or equal to the median number of EST procedures annually) received intravenous tPA before EST less often (38% versus 50%, $P \leq 0.001$ Fisher exact test) than patients treated at lower volume centers (ie, hospitals that performed fewer than the median number of EST procedures annually). The Charlson comorbidity index was similar between the 2 groups.

Table. Patient Demographics

	All Patients (n=3890)	Patients Treated at Lower Annual Volume Centers (>24) (n=1974)	Patients Treated at Higher Annual Volume Centers (≤24) (n=1916)
Age, median (IQR)	73 (61–82)	72 (60–81)	73 (62–82)
Female Sex	1997 (51%)	984 (50%)	1013 (53%)
Race			
White	2311 (61%)	1290 (66%)	1021 (55%)
Black	612 (16%)	305 (16%)	307 (17%)
Hispanic	749 (20%)	298 (15%)	451 (24%)
IV tPA	1704 (44%)	983 (50%)	721 (38%)
Comorbidities			
Hypertension	1815 (47%)	925 (47%)	890 (47%)
Smoking	359 (9%)	196 (10%)	163 (9%)
Dyslipidemia	1017 (26%)	487 (25%)	530 (28%)
Renal failure	318 (8%)	159 (8%)	159 (8%)
Diabetes mellitus	1056 (27%)	521 (26%)	535 (28%)
Charlson index	3 (3–4)	3 (3–4)	3 (2–4)

Data represented as median (IQR) or n (%). IQR indicates interquartile range; and IV tPA, intravenous tissue-type plasminogen activator.

Trends in Hospital Volumes and EST–State-Level Cohort

In Florida, there was a continuous increase in the number of EST procedures performed annually from 2006 to 2016, aside from a large jump in 2015 (Figure 1A), which was followed by a plateau. We observed a corresponding increase in the number of hospitals performing EST over this time period, as shown in Figure 1B, with a 4-fold increase in number over the study period and an average increase of ≈4 hospitals per year. Although the number of procedures plateaued between 2015 and 2016, the number of hospitals performing the procedure continued to increase. The median annual EST volume per EST-performing center increased over this time period, with 2 (IQR, 1–3) in 2006 to 5 (IQR, 4–10) in 2011 to 9 (IQR, 3–14) in 2013 to 14 (IQR, 6–31) in 2016. There was also a steady increase in the number of patients transferred for EST, as shown in Figure 1C. The rate of change of patient transfers largely mirrored the rate of change of EST procedures. Most patients who were transferred for EST did not receive intravenous tPA before transfer (87%).

As shown in Figure 2, earlier in the Florida cohort the majority of EST procedures were concentrated in a handful of hospitals, with 49% (51/105) of the procedures performed in 3 hospitals and 87% (91/105) performed across the top 8 hospitals in 2008. This figure presents the percentage of total annual EST procedures against the number of EST-performing hospitals in histogram bins, ordered by decreasing annual volume. By 2016, the number of hospitals performing EST increased and the distribution had shifted. In comparison, the top 3 hospitals performed 21% (197/943) of all EST procedures, and the top 8 hospitals 45% (425/943), in 2016. EST procedures were more evenly distributed across this larger number of EST-performing centers.

Because many of the centers performing EST later in the cohort were non-EST-performing centers earlier in the cohort, we studied the rate of growth of annual EST volume for centers that had been performing the procedure from the onset of the cohort versus those that began performing the treatment later in the cohort. As shown in Figure 3, in the Florida cohort for both centers that started before 2012, as well as those that began in 2012 or later, the annual EST procedure volume increased. The rate of growth of annual EST volume was greater in centers that started more recently, and the difference in annual volume between these 2 types of EST-performing centers was no longer significant in 2015 and 2016. Of note, despite the overall increase in annual EST volume for EST-performing hospitals over the time course of the cohort, a substantial proportion of treatments continued to occur in lower volume centers. As shown in Figure I in the [online-only Data Supplement](#), for the Florida cohort in 2016, 26% of procedures were performed at centers with fewer than 20 EST treatments per year. Of note, a small percentage of patients that were transferred from one hospital to another came from a center that was also an EST-performing center (<1%).

Trends in Hospital Volumes and EST–NIS

To assess the generalizability of the state-level cohort findings, we studied trends in EST procedures across a nationwide sample. As shown in Figure 4, we observed a comparable

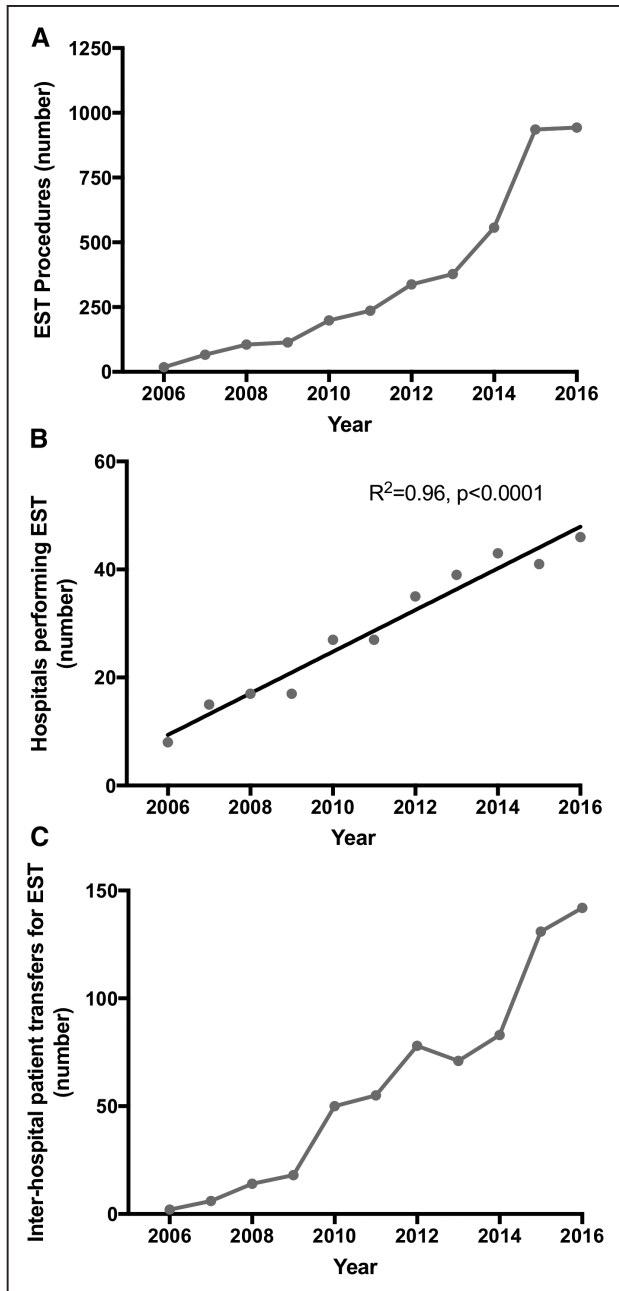


Figure 1. Annual trends in endovascular stroke therapy (EST) procedures performed in Florida (2006–2016). **A**, Total EST procedures performed by year. **B**, Total number of hospitals performing at least 1 EST procedure by year. On average, the number of EST-capable hospitals increased by 4 per year. **C**, Total number of patient transfers from one Emergency Department to another hospital for EST.

linear increase in the number of EST procedures performed, with a large jump in 2015 followed by a leveling off. Similarly, there was an increase in the number of hospitals performing EST, with an average increase of ≈ 188 hospitals per year. In addition, while the number of procedures leveled off between 2015 and 2016, the number of hospitals performing the procedure continued to increase. Along with the increase in number of EST procedures was an increase in the number of procedures performed at hospitals with fewer than 20 annual treatments (Figure 4C).

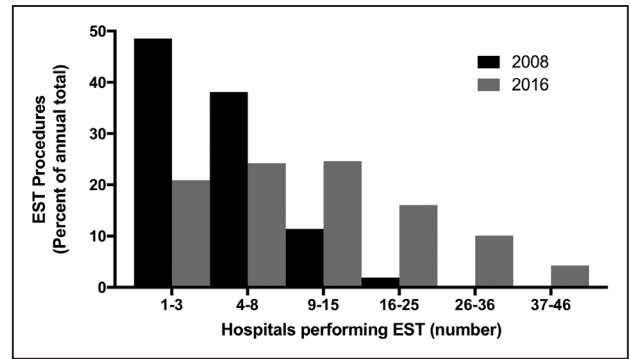


Figure 2. Distribution of endovascular stroke therapy (EST) procedures in hospitals performing EST in Florida. Histogram depicting the percentage of annual total EST procedures vs total number of hospital divided into bins for 2008 and 2016. Hospitals were divided into bins by ranking of total number of annual EST procedures.

Outcomes Following EST

In multivariate regression analysis adjusted for intravenous tPA administration, age, sex, race, Charlson index, and annual hospital stroke volume, we observed a significant increase in the likelihood of good discharge outcomes over the 10-year period of our cohort. The likelihood of discharge to home or acute rehabilitation facility improved over time for patients treated with EST (OR, 1.2; 95% CI, 1.1–1.2) in Florida and in the NIS (OR, 1.2; 95% CI, 1.1–1.2). The likelihood of good clinical outcome was greater in patients who had been treated with intravenous tPA (OR, 1.3; 95% CI, 1.1–1.6) in Florida and in the nationwide cohort (OR, 1.3; 95% CI, 1.2–1.5). In addition, the likelihood of good discharge outcomes also improved with increasing annual EST procedural volume. As shown in Figure II in the [online-only Data Supplement](#), there was a continuous increase in the likelihood of good discharge outcomes among patients treated in hospitals with increasing annual procedures per year (OR, 1.1; 95% CI, 1.1–1.2) in Florida, after adjusting for intravenous tPA administration, age, sex, race, Charlson index, and annual hospital stroke volume. These findings were maintained in the nationwide cohort (OR, 1.3; 95% CI, 1.2–1.4). For AIS patients evaluated at EST-capable centers who were not treated with EST in the Florida cohort, there was no effect on discharge outcomes by annual hospital EST volume (OR, 0.93; 95% CI, 0.83–1.1).

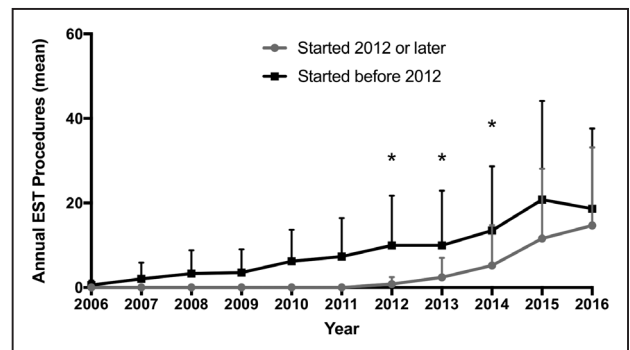


Figure 3. Growth of annual endovascular stroke therapy (EST) procedures by time of initial EST procedure. Mean (\pm SD) annual EST procedures for hospitals that began performing EST procedures before 2012 and those that began in 2012 or later vs time.

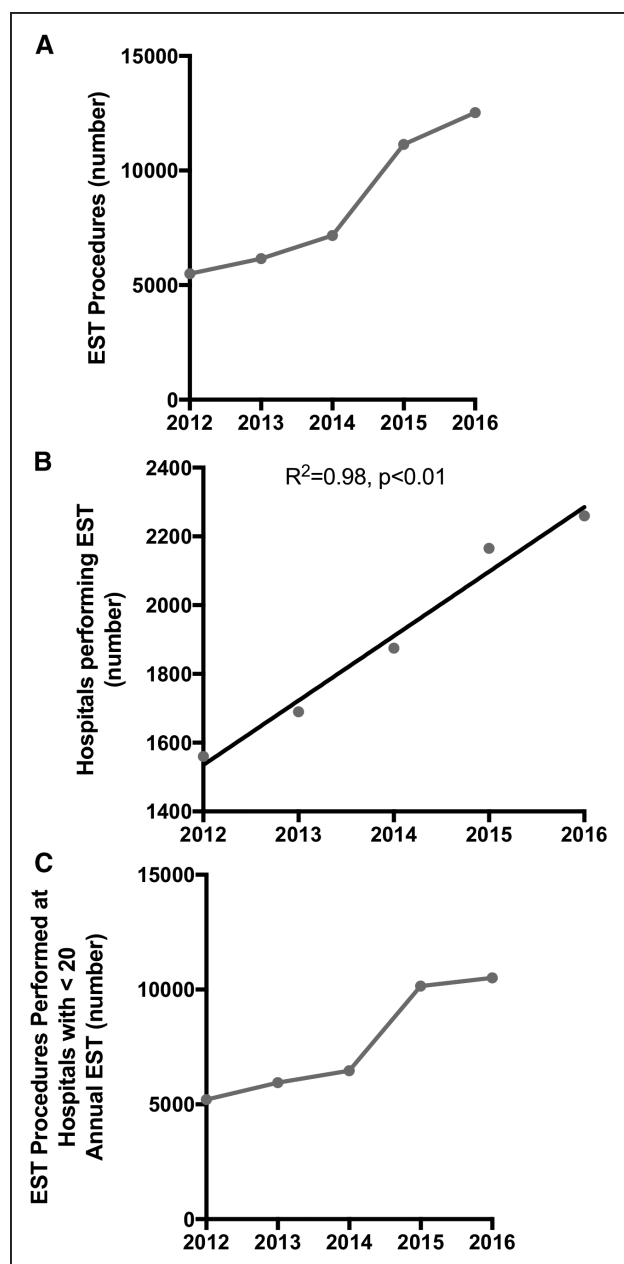


Figure 4. Annual trends in endovascular stroke therapy (EST) procedures performed in Nationwide cohort (2012–2016). **A**, Total EST procedures performed by year. **B**, Total number of hospitals performing at least 1 EST procedure by year. On average, the number of EST-capable hospitals increased by 188 per year. **C**, Total number of EST procedures performed at hospitals performing fewer than 20 procedures per year.

In secondary outcome analysis, the likelihood of in-hospital mortality also decreased with increasing annual EST volume. In adjusted multivariate logistic regression, greater annual EST volume was associated with decreased likelihood of inpatient mortality for patients treated with EST in Florida (OR, 0.9; 95% CI, 0.8–0.9) and in the nationwide cohort (OR, 0.8; 95% CI, 0.7–0.9). For AIS patients who were not treated with EST, there was no significant effect on the likelihood of inpatient mortality by annual EST volume in Florida (OR, 0.80; 95% CI, 0.62–1.03). In adjusted linear regression, there was no effect of annual EST volume on total length of

inpatient stay for patients treated with EST (coefficient 0.09; 95% CI, 0.3–0.5 in Florida and coefficient –0.4; 95% CI, –0.8 to 0.2 in nationwide cohort).

Discussion

In this large population-level study of patients treated with EST from 2006 to 2016, we observed a linear increase in annual treatment rates over time, with a large jump in 2015 corresponding to the release of multiple, positive randomized clinical trials. This increase in procedural volume was matched by an increase in the number of centers performing EST, with a resulting shift in distribution of procedures across a substantially greater number of hospitals. Hospitals that began performing EST midway through the cohort in 2012 saw a rapid growth of procedural volume and had comparable annual treatment numbers to those that had been performing EST in 2006 by 2015. Procedural outcomes improved over time as well, which may have been related to improvements in EST devices and techniques. We also found improved outcomes for treatments performed at hospitals with increasing annual volume.

Stroke systems of care across the globe are currently faced with the challenge of developing the best methods to triage patients with large vessel occlusions to ensure that eligible patients have access to EST.^{19–21} A wide range of solutions has been proposed, with some supporting a massive expansion in the number of EST-capable hospitals and providers to increase the number of local and community centers that can provide these services.²² Others have developed plans to concentrate procedural expertise in providers, but expand the number of centers supporting EST, by transporting the EST-capable physicians to the community hospitals, as opposed to transferring the patient.²³ Mobile stroke units have been suggested as another potential means of bringing the physician to the patient and avoiding excess drip and ship time. Finally, some have argued for continuing to concentrate both hospital and proceduralist expertise in tertiary referral centers and transferring patients from the community to these hub hospitals or directly routing patients from the prehospital setting.²⁴ This argument is supported by data demonstrating reduced mortality in EST patients transferred to higher volume centers, relative to lower volume centers.⁹ Determining which system of care works best may ultimately depend in a large part on local geographies and medical resource availability. However, data on real-world treatment trends such as those presented here are important to inform these decisions.

It should also be noted that the data supporting improved clinical outcomes in patients treated with EST have almost exclusively been derived from higher volume centers with comprehensive AIS care.^{1–5} While the distribution of EST to smaller centers may reduce time from onset to treatment, these centers frequently cannot match the Neuroimaging, Vascular Neurology, Neurosurgery, Neuro Nursing, and Rehabilitation capabilities of larger referral centers. As such, the efficacy of EST in lower volume or resource-restricted centers remains undetermined. Prior attempts at real-world data have relied primarily on EST registries, which fail to address this key issue in AIS care for several

reasons.⁸ First, these data do not capture all EST procedures performed in a hospital, as enrolling centers are free to pick and choose the patients they enroll. This selection bias limits the generalizability of these clinical outcomes. In addition, frequently only high volume centers are given the opportunity to participate in these registries. Thus, outcomes from lower volume centers are not represented. This limitation has led to some healthcare systems, including the Ministry of Health of Brazil, to require a recapitulation of prior clinical trial findings in their specific settings before acceptance of their results.²⁵ Our findings corroborate the concept that the findings seen in the randomized EST trials may not be generalizable to every setting. Indeed, given our study's findings of OR, 1.1 (Florida) and 1.3 (Nationwide) for good outcome per 10 additional annual EST procedures, the question of whether EST is effective at lower volume centers can be raised. However, while the likelihood of good outcome at lower volume centers in our study was lower than those of higher volume centers, would these patients who were treated at lower volume centers have done better or worse had they been transferred to another hospital, and had their treatment delayed or not performed at all?

It should also be noted that over the time course of this study, newer EST devices, which allowed for more effective and safer thrombectomy were released, a change which would render treatments before 2012 poorly representative of modern practice. To date, there have been few prior studies to evaluate volume-outcome relationships for EST in the modern era of EST. Previous studies include a retrospective review of 9 centers (442 consecutive patients with EST) that showed faster time to treatment, higher reperfusion rates, and better functional outcomes at follow-up for patients treated in higher volume centers.²⁶ In another study using the NIS in 2008, annual EST was correlated with inpatient mortality.²⁷ However, in another analysis using NIS from 2008 to 2011, patients treated at lower EST volume hospitals were not associated with greater odds of inpatient mortality after adjusting for multiple confounders.²⁸ In addition, similar trends of increased mortality have been observed for outcomes following intravenous tPA administration, as well as in patients with aneurysmal subarachnoid hemorrhage.^{29,30} In this study, we observed a continuous improvement in the rate of good outcomes with increasing annual EST hospital volume. This finding suggests improvements in patient selection, technical performance of EST, and postprocedure care with neurocritical care and neuroscience nurses may justify concentrating EST care at specialized centers, and also demonstrates that prior studies examining older cohorts may not be relevant in current practice paradigms.

In this study, we found lower rates of intravenous tPA usage among EST-treated patients at higher volume centers relative to lower volume centers. It should be noted that our data does not allow for adjustment by time to treatment. As such, this finding may be because of the fact that greater number of tPA-ineligible patients were evaluated and treated at higher volume centers, perhaps because of time of presentation relative to last known well time, or increased medical complexity. Our analysis demonstrated a significantly lower

risk of poor outcomes following EST in patients who received intravenous tPA as compared with EST alone, though better outcomes with intravenous tPA administration may partly be derived from a shorter time to treatment, and thus a potentially lower core infarct size at baseline. Data on this topic have been mixed in the literature, and it is the subject of ongoing randomized clinical studies.

While improved EST outcomes at higher volume centers are logical and consistent with prior studies as discussed above, these findings should not be extrapolated to imply that all stroke systems of care should focus on concentrating EST treatments at only a few high volume centers rather than disseminating EST treatments more widely. In some regions, distance, cost, and time make such transfers impractical. Further, although our analyses attempted to control for important variables affecting outcome, patients receiving EST at lower volume community hospitals may differ in important ways from those at higher volume centers, and in ways for which we are unable to adjust. As such, further data are needed to address this issue.

Our study has several limitations. As mentioned above, beyond annual EST volume, there are a number of other hospital characteristics including quality of Neuroimaging, critical care, and nursing that affect outcomes following large vessel occlusion stroke. Here we attempt to partially adjust for these differences by controlling for annual stroke volume as larger stroke centers are more likely to benefit from these additional resources. However, because these factors are not directly measurable, we are not able to quantify the reasons behind the improved outcomes observed in patients treated in higher volume centers. In addition, the clinical benefit conferred by EST has been shown to be dependent on several factors including time from onset to recanalization, as well as occlusion location, degree of reperfusion, and extent of preprocedural infarct to name a few. In this analysis, we are not able to account for these features. However, because the characteristics of patients with stroke presenting over the time course of our study are unlikely to have changed significantly, our finding of continuously improved outcomes over time would not be affected by this limitation, and could reflect improvements across a number of different areas, including patient selection, treatment, and postprocedure care. Further, additional outcomes measures, including long-term disability, as well as quality of life indicators, are needed to provide a richer description of the patients' poststroke experience. While our analysis focused on discharge outcomes, these outcomes have been shown to correlate well with longer-term functional outcomes.¹⁷

An evaluation of existing trends using population-based aggregate data is of paramount importance for designing future networks and policies for stroke care to develop optimal infrastructures to accommodate the demand created by novel endovascular therapeutics. We think our study is the first to provide a long-term analysis of treatment trends in EST that extends to the modern EST era and suggests that patients treated with EST at higher volume centers have better outcomes than those treated at lower volume centers. Further exploration of this relationship and the role of patient transfers with additional studies will be needed.

Disclosures

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