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ORIGINAL RESEARCH

Patterns and Outcomes of Endovascular Thrombectomy Among Patients Over Age 80 Years: The Florida Stroke Registry

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BACKGROUND: Older patients (≥80 years of age) were under-represented in randomized trials of endovascular thrombectomy (EVT). In the large Florida Stroke Registry (FSR), we aimed to evaluate the characteristics of the older patients receiving EVT in routine practice and to study the impact of age on EVT outcomes.

METHODS AND RESULTS: Data prospectively collected from Get With The Guidelines-Stroke hospitals in the FSR from January 2010 to December 2022 were analyzed for EVT outcomes. Among patients receiving EVT, characteristics associated with age ≥80 years and the impact of age on EVT outcomes of discharge directly to home or acute inpatient rehabilitation, and independent ambulation at discharge were studied using multivariable analysis with generalized estimating equations. Among 20 004 EVT FSR patients (mean age 71±15, 50% women), 29% were ≥80 years of age. In multivariable analysis, older patients with EVT had a similar rate of symptomatic intracerebral hemorrhage and in hospital mortality but were less likely to achieve independent ambulation at discharge (odds ratio [OR]: 0.44 [95% CI, 0.39–0.49]), be discharged directly home (OR: 0.46 [95% CI, 0.42–0.51]) or to a rehabilitation facility (OR: 0.68 [95% CI, 0.61–0.75]).

CONCLUSIONS: In routine practice, close to 30% of EVT treated stroke patients are over the age of 80 years. Our data shows that EVT is safe in this population; however, age remains an independent predictor of poor discharge outcomes post EVT.

Key Words: ambulation ■ discharge disposition ■ elderly ■ endovascular therapy ■ ischemic stroke ■ large vessel occlusion

The rising life expectancy in many developed countries is a noteworthy trend that holds significant implications for both individuals and societies.[1] Aging increases the lifetime probability of having a stroke, with the rates of stroke doubling for each decade after the age of 50.[2,3] In addition, the prevalence of other medical conditions such as vascular risk factors, non-vascular chronic illnesses, certain malignancies and psychological disorders increase over time and are disproportionately higher in the older population. Over the past 2 decades, despite a decrease in the global incidence rate of stroke, the absolute number of people who annually suffer a stroke is increasing.[4] The anticipated increase in the number of older patients affected by stroke combined with their increased frailty because of other comorbidities is expected to significantly impact the global burden of stroke.

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CLINICAL PERSPECTIVE

What Is New?

- One in 3 patients receiving endovascular thrombectomy (EVT) in clinical practice are over the age of 80 years. This study reveals significant differences in race, sex, and socioeconomic status of older patients who receive EVT as compared with their younger counterparts.
- Age is an important negative predictor of outcomes; however our findings emphasize the reassuring conclusion that EVT maintains its safety across the spectrum of age in routine clinical practice.

What Are the Clinical Implications?

- Recognizing demographic differences in EVT-treated older patients is vital for tailored treatment strategies and equitable access to care.
- The rising life expectancy and aging population contribute to a significant increase in the burden of stroke, given the higher lifetime probability of stroke with advancing age.
- As the older population grows and becomes increasingly frail because of comorbidities, the demand for effective stroke interventions like EVT will continue to rise; recognizing the efficacy of EVT in the growing population of older patients is crucial for optimizing stroke care and mitigating the impact of stroke on individuals and health care systems in aging societies.

Nonstandard Abbreviations and Acronyms

CSC	Comprehensive Stroke Center
CTTP	CT to puncture time
DTC	door to CT
DTN	door-to-needle
DTP	door-to-puncture
EVT	endovascular thrombectomy
FL-PR CReSD	Florida-Puerto Rico Collaboration to Reduce Stroke Disparities
FSR	Florida Stroke Registry
GWTG-S	Get With The Guideline-Stroke
mRS	modified Rankin Scale
NINDS	National Institute of Neurological Disorders
PSC	Primary Stroke Center
OTD	onset-to-door time
OTP	symptom onset to puncture time
TSC	thrombectomy-capable stroke center

Endovascular thrombectomy (EVT) has become the standard of care for treatment of select patients with large vessel occlusion.[5–9] Older patients (age ≥80 years) were under-represented in pivotal randomized controlled studies of EVT in the early and late treatment time windows.[10–12] Several observational studies have described EVT outcomes in the older patients.[13] However, many of these studies were limited due to small sample size, with data reflecting treatment completed before the latest guideline updates[14] that expanded the EVT treatment time window. Consequently, these findings might not be generalizable to the present-day practice.[15–18]

In the large FSR (Florida Stroke Registry), we evaluated patients who received EVT over the past decade and compared clinical characteristics, temporal trends, and discharge outcomes of older patients (age ≥80 years) to their younger EVT-treated counterparts.

METHODS

Data Availability Statement

The FSR uses data from Get With The Guideline-Stroke (GWTG-S). GWTG-S is collected primarily for quality improvement, and data-sharing agreements require an application process for other researchers to access data. Research proposal can be submitted at www.heart.org/qualityresearch and will be considered by the GWTG-S and the FSR publications committees upon reasonable request.

Study Population

From January 1, 2010 to December 31, 2022 a total of 348 609 patients were enrolled in the registry with a final diagnosis of ischemic stroke from 166 hospitals across the state of Florida. All patients who received EVT for an emergent target vessel occlusion were included in this analysis. EVT was defined as the use of any mechanical thrombectomy devices for the treatment of an acute visible intracranial occlusion. The device was selected at the discretion of the treating physician. Among 20 004 patients who underwent EVT, 5809 were ≥80 years of age (29%) (Figure 1).

Registry Data and Case Identification

Originally funded by the National Institute of Neurological Disorders, the registry includes data from Get With The Guidelines- Stroke (GWTG-S) participating hospitals and was referred to as the FL-PR CRESD (Florida-Puerto Rico Collaboration to Reduce Stroke Disparities) from 2010 to 2017. The goal of FL-PR CRESD registry was to identify disparities in stroke care among a multi-ethnic population with a high Hispanic representation.[19] Since 2017 the registry is

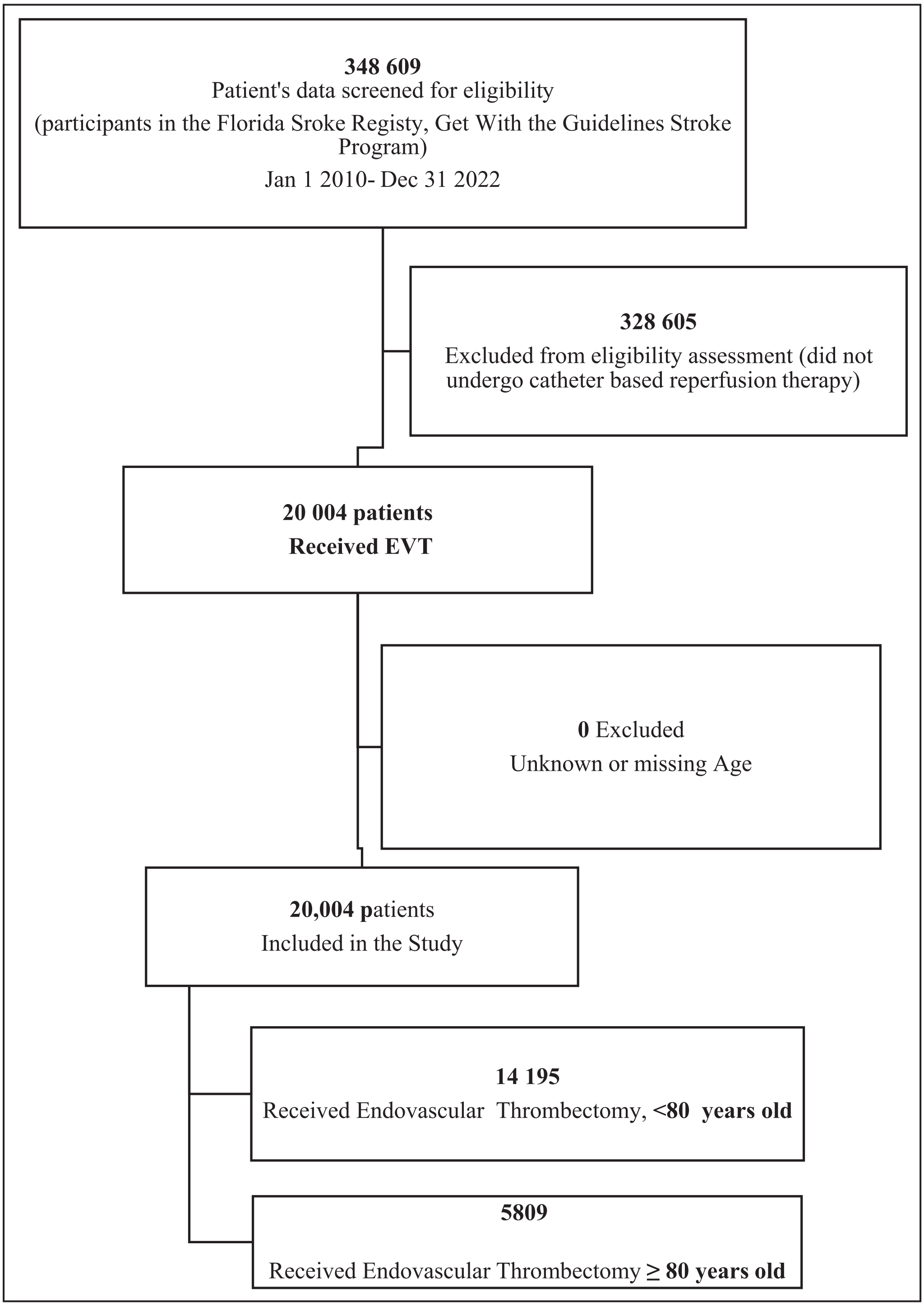

Figure 1. Flowchart of patients included in the study.
EVT indicates endovascular thrombectomy.

supported by the Florida Department of Health, including participating hospitals in Florida and is referred to as the FSR (Florida Stroke Registry). Briefly, deidentified retrospective and prospective data from hospitalized patients with the primary diagnosis of ischemic stroke, transient ischemic attack, subarachnoid hemorrhage, intracerebral hemorrhage, and stroke not otherwise specified are included in the registry as previously described.[20]

The study was approved by the University of Miami's Institutional Review Board. Each participating hospital received institutional approval to enroll patients in the registry without requiring individual patient consent under the common rule or a waiver of authorization and exemption from subsequent review by their institutional review board.

The following information was collected: patient demographics, clinical characteristics (vascular risk factors and relevant medical history), mode of arrival (via emergency medical services from home/scene, private transport, transfer from other hospital, unknown), premorbid independent ambulation, premorbid functional status (based on the modified Rankin Scale [mRS]), presenting National Institutes of Health Stroke Scale (NIHSS), the onset-to-door time (time from stroke onset to arrival in the emergency department, OTD), assessment characteristics (time from arrival to the initial head computed tomography) (door to CT, DTC), time from hospital arrival to initiation of intravenous alteplase (door-to-needle, DTN time), hospital arrival to the initiation of EVT (door-to-puncture time), CT to puncture time and symptom onset to the initiation of EVT (onset to puncture time and hospital-level characteristics) (number of beds, academic status, annual stroke volume and number of years in GWTG-S). Low-volume centers were characterized as those conducting fewer than 20 EVT cases annually, while high-volume centers encompassed those conducting 20 or more cases per year. Hospital certifications were collected as follows: comprehensive stroke centers, thrombectomy-capable stroke centers and primary stroke centers as previously described.[21]

The main study outcomes include favorable functional status as measured by discharge destination (discharged home or acute rehabilitation center) and ability to walk independently at the time of discharge (independent ambulation). Treatment complications including symptomatic intracerebral hemorrhage (sICH) and life-threatening or serious systemic hemorrhage, and in-hospital mortality. sICH was defined as clinical deterioration by 4 points in the NIHSS attributed to CT-evident intracranial hemorrhage within 36 hours of treatment; and life-threatening, or serious systemic hemorrhage defined as bleeding within 36 hours of EVT requiring transfusion of >3 units of blood. For the outcome of independent ambulation, the sample size was restricted to only those who were independently ambulating at baseline (Table 1).

Statistical Analysis

First, we compared the characteristics of EVT patients who were age ≥80 versus <80 years in univariable analyses. Continuous variables were reported as median with interquartile range and categorical variables were summarized as frequencies with percentages. For continuous variables, differences were assessed using the Student *t*-test (mean comparison) if normally distributed, or Wilcoxon–Mann–Whitney test (median comparison). For categorical variables, the Pearson Chi-square test was used to compare the distributions between groups.

Next, for assessment of discharge outcomes, multivariable analysis with generalized estimating equations to account for clustering effect within each hospital was used to compare favorable discharge outcomes and treatment complications between EVT patients <80 years of age and ≥80 years of age. The following variables were selected a priori based on clinical relevance to the outcomes of interest and adjusted for in the model: race and ethnicity, sex, insurance status, vascular risk factors, previous history of heart disease (atrial fibrillation, coronary artery disease/prior MI), intravenous thrombolysis (IVT), transient ischemic attack/stroke, presenting NIHSS, mode of arrival (emergency medical services, private transport, or transfer from another hospital), time to puncture hospital size, academic hospital status, and region. Results were considered statistically significant where $P<0.05$. All statistical analyses were performed using SAS Version 9.3 software (SAS Institute).

Most variables had missing values in <5% of cases, except for door to CT time (19.2% missing), symptom onset to hospital arrival time (17.3%), door to puncture (24.9%), onset to puncture (31.9%), CT to puncture (38.3%) and location of large vessel occlusion (LVO) (27%). The multiple imputation approach was used when accounting for these variables with high missingness. The multiple imputation was performed based on all variables in Table 1. The 2 variables of door to needle time (72.2%) and premorbid mRS (59.89%) had >50% missingness and as such these variables were not included in the multivariable analysis.

To construct the continuous age-predicted probability curves, the relationship between age, measured as a continuous variable, and 2 outcomes, independent ambulation and discharge home rates, were assessed using logistic regression using restrictive cubic splines.

We analyze time trends in the share of older patients with EVT using univariate t tests as well as ordinary least square regressions.

RESULTS

Among 20 004 EVT cases, the mean age was 71±15. Females constituted 50% and those aged ≥80 accounted for 29%. Ethnic breakdown revealed 19% Hispanic, 18% Non-Hispanic Black (NH-Black), and 63% non-Hispanic White (NH-White) individuals. A total of 84% were insured and 16% were either self-paid or had no insurance; 73% arrived at the hospital via emergency medical services. Among those with a known time of onset, the median time from symptom

Table 1. Clinical and Hospital Characteristics of Endovascular Thrombectomy Patients

Clinical characteristics	<80y old N=14195	≥80y old N=5809	*P* Value
Age, mean±SD	64.42±11.96	86.86±4.42	<0.001
Sex, %			
Male	7987 (56.27%)	2011 (34.62%)	<0.001
Ethnicity, %			
NH-White	8051 (60.49%)	3822 (69.26%)	<0.001
NH-Black	2869 (21.56%)	490 (8.88%)	
FL-Hispanic	2389 (17.95%)	1206 (21.86%)	
Medical insurance, %			
Private	4178 (29.43%)	1259 (21.67%)	<0.001
Medicare	6272 (44.18%)	4135 (71.18%)	
Medicaid	971 (6.84%)	96 (1.65%)	
Self-pay/no insurance	2669 (18.80%)	268 (4.61%)	
Missing	105 (0.74%)	51 (0.88%)	
Comorbidities, %			
Current smoker, %	2716 (19.13%)	175 (3.01%)	<0.001
Hypertension, %	9452 (66.59%)	4585 (78.93%)	<0.001
Diabetes, %	3686 (25.97%)	1346 (23.17%)	<0.001
Dyslipidemia, %	5463 (38.49%)	2736 (47.10%)	<0.001
CAD/prior MI, %	2665 (18.77%)	1473 (25.36%)	<0.001
Previous stroke/TIA, %	2868 (20.20%)	1374 (23.65%)	<0.001
Atrial fibrillation, %	3430 (24.16%)	2977 (51.25%)	<0.001
Pre-morbid ambulation, %			
Independent, %	8124 (57.23%)	3106 (53.47%)	<0.001
Dependent, %	372 (2.62%)	457 (7.87%)	
Missing	5699 (40.15%)	2246 (38.66%)	
Pre-morbid mRS, %			
0–2, %	5334 (37.58%)	1831 (31.53%)	<0.001
3–5, %	390 (2.75%)	468 (8.06%)	
Missing	8470 (59.67%)	3508 (60.41%)	
Location of target vessel occlusion, %			
>1 recoded locations	1310 (9.23%)	451 (7.76%)	<0.001
Basilar artery	527 (3.71%)	126 (2.17%)	
Internal carotid artery	955 (6.73%)	351 (6.04%)	
Middle cerebral artery	7085 (49.91%)	3199 (55.07%)	
Other cerebral artery branch	321 (2.26%)	116 (2.00%)	
Vertebral artery	80 (0.56%)	16 (0.28%)	
Missing	3917 (27.59%)	1550 (26.68%)	
Admission NIHSS, median (IQR)	14 (8–20)	17 (11–22)	<0.001
NIHSS 0–5, %	2075 (14.62%)	570 (9.81%)	
NIHSS 5 and above, %	11378 (80.15%)	4969 (85.54%)	
Mode of arrival, %			
EMS from home/scene	9967 (70.23%)	4586 (79.01%)	<0.001
Private transport/taxi/other from home/scene	995 (7.01%)	215 (3.70%)	
Transfer from other hospital	3098 (21.83%)	956 (16.47%)	
Not documented or unknown	51 (0.36%)	23 (0.40%)	
Intravenous thrombolysis, %	4520 (31.84%)	1722 (29.64%)	0.008

(*Continued*)

Table 1. Continued

Clinical characteristics	<80y old N=14 195	≥80y old N=5809	*P* Value
Time based metrics			
Symptom Onset to hospital arrival time (min), median (IQR)	146.00 (54–448)	128.00 (51–436)	0.008
Door to CT Time (min), median (IQR)	12 (7–20)	11 (7–17)	<0.001
Door to CT Time <25 min, %	9296 (82.04%)	4169 (86.28%)	<0.001
Door to Needle Time (min), median (IQR)	32 (23–44)	32 (24–45)	0.059
Door to Puncture Time (min), median (IQR)	83 (55–118)	80 (54–113)	0.002
Onset to Puncture Time (min), median (IQR)	276.00 (153–686)	253.5 (145–682)	0.004
CT to Puncture Time (min), median (IQR)	75 (51–107)	71 (49–103)	<0.001
Time from onset to treatment			0.075
0–6 h	5550 (58.14%)	2431 (59.79%)	
6–24 h	3313 (34.71%)	1381 (33.96%)	
>24 h	683 (7.15%)	254 (6.25%)	
Unknown time of onset	4649 (32%)	1743 (30%)	
Hospital characteristics			
Hospital size, median (IQR)	514.00 (404–772)	489.00 (368–728)	<0.001
Hospital size, %			
Large	9030 (63.61%)	3377 (58.13%)	<0.001
Mid	4272 (30.10%)	2138 (36.80%)	
Small	893 (6.29%)	294 (5.06%)	
Academic hospital, %	5304 (37.37%)	1782 (30.68%)	<0.001
No. of EVT treated patients per year, median	44.5 (34.38, 65.08)	47.2 (35, 65.08)	0.005
Endovascular treatment volume, %			
Low volume center (<20 per y)	1725 (12.15%)	707 (12.17%)	0.971
High volume center (≥20 per y)	12 470 (87.85%)	5102 (87.83%)	
Stroke center type, %			
Comprehensive stroke center	10 119 (71.29%)	4123 (70.98%)	0.468
Primary stroke center	2919 (20.56%)	1177 (20.26%)	
Thrombectomy-capable stroke center	1156 (8.14%)	509 (8.76%)	
Region of Florida, %			
East Central	2624 (18.49%)	973 (16.75%)	<0.001
North and Panhandle	2559 (18.03%)	700 (12.05%)	
South	6090 (42.90%)	2851 (49.08%)	
West Central	2922 (20.58%)	1285 (22.12%)	

CAD indicates coronary artery disease; EMS, emergency medical services; EVT, endovascular thrombectomy; FL-Hispanic, Florida Hispanic; IQR, interquartile range; MI, myocardial infarction; mRS, modified Rankin Scale; NH-Black, Non- Hispanic Black; NH-White, Non-Hispanic White; NIHSS, National Institutes of Health Stroke Scale; and TIA, transient ischemic attack.

onset to hospital arrival was 140 minutes (IQR, 392), median presenting NIHSS was 15 (IQR, 12), 31% underwent IVT. A total of 96.2% of EVT treatments were completed in the 0 to 6 hours from symptoms onset time window. Overall, 87.8% of EVT were conducted at high volume centers, comprising 71.2% at comprehensive stroke centers, 20.5% at primary stroke centers, and 8.3% at thrombectomy-capable stroke centers designated centers.

Table 1 summarizes the clinical and hospital characteristics of EVT patients categorized based on age equal/greater or younger than 80 years. Briefly, EVT-treated patients ≥80 years were more likely to be women (65.4% versus 43.7%), White (69.2% versus 60.4%), with a history of hypertension (78.9% versus 66.5%), atrial fibrillation (51.2% versus 24.2%), coronary artery disease/myocardial infarction (25.3% versus 18.8%), and dyslipidemia (47.1% versus 38.4%) and less likely to be Black (8.8% versus 21.6%), smokers (3% versus 19%) as compared with those <80 years of age. Patients ≥80 years had faster arrival time from onset (128 versus 146 minutes), higher NIHSS (17) (IQR, 11) versus 15 (IQR, 11) as compared with their younger counterparts and were less likely transferred from another hospital for EVT treatment (16.4% versus 21.8%). However, the percentage of patients treated under 6 hours, between

6 and 24 hours and >24 hours from onset was not significantly different between age categories (Table 1). Moreover, older patients who received EVT were less likely treated in North and Panhandle regions as compared with EVT treated patients <80 years of age.

Regarding in hospital time-based treatment metrics, DTC, DTN (when applicable), door-to-puncture and CT to puncture time (CTTP) times were shorter in EVT treated patients ≥80 years of age than those younger than 80 (Table 1). In multivariable analyses adjusting for sex, race and ethnicity, mode of hospital arrival, NIHSS, stroke center type and region, patients aged ≥80 years receiving EVT had similar assessment and treatment times to the younger counterparts (Table S1).

Discharge Outcomes and Treatment Complications

In total, 1059 (5.3%) of patients in this study suffered an sICH post EVT, 148 (0.7%) had life-threatening or serious systemic hemorrhage, and 1888 (9.5%) died in hospital. sICH after EVT occurred in 5.9% aged 80 years or older (6.5% with IVT, [n=112]) and in 5.1% under 80 (5.9% with IVT [n=267]). A total of 6553 (32.8%) were discharged home, 4611 (23.1%) discharged to an inpatient rehabilitation facility and 5785 (36.5%) were independently ambulating at the time of discharge.

Table 2 summarizes the odds of favorable discharge outcomes and treatment complications based on age younger or older than 80 years at the time of EVT in the unadjusted and adjusted models. In fully adjusted models, in-hospital mortality, sICH, and the risk of life-threatening or serious systemic hemorrhage were similar between older patients and those under the age of 80. In the adjusted models, the rate of favorable outcomes of discharge home, discharge to an inpatient rehabilitation center, and independent ambulation were significantly lower in the older patients with EVT compared with the younger EVT patients. A total of 6392 received EVT with an unknown time of onset (32% aged <80 years and 30% >80 years); 80% of the EVT population were >60 years, inclusion of aged <60 years patients in the continuous age-predicted probability curves resulted in substantial dilution of the effect of age on outcomes as younger age (less than 60 years) is strongly associated with positive outcomes of discharge home and independent ambulation.

The relationships between age and the binary outcomes of independent ambulation and discharge home are shown in Figure 2. Continuous age-predicted probability curves (for ages 60 and above) showed an inverse relationship between increase in age and the odds of favorable clinical outcomes (Figure 2). In the fully adjusted model, for every year increase in age between 60 and 80 years, the odds of independent ambulation after EVT decreases by 2% (odds ratio [OR]: 0.98 [0.97–0.98], *P*<0.001) and for every year increase in age after the age of 80 the odds of independent ambulation post EVT at discharge decreased by 7% (OR: 0.93 [0.91–0.94], *P*<0.001) (Figure 2A). Similarly, the odds of being discharged home reduced by 2% for every year increase in age (OR: 0.98 [0.98–0.98], *P*<0.001) between the ages of 60 to 80, and reduced by 8% (OR: 0.93 [0.92–0.95], *P*<0.001) after the age of 80 years (Figure 2B).

Temporal Trends of Endovascular Treatment Stratified by Age

The absolute number of EVT treated patients treated in FSR increased substantially over the study period, from 175 patients in 2010 to 3470 patients in 2022, *P* value for trend <0.00001 (Figure 3). This increase is largely due to the general increase in the application of EVT during the time period, although the relative proportion of older EVT treated patients increases slightly during this decade from 26.2% in 2010 to 29% in (*P* value=0.02). A univariate ordinary least squares regression of the fraction of older patients in each sample year on the passage of time, measured as the number of years since the start of our sample, finds a

Table 2. In-Hospital and Discharge Outcomes of EVT Patients Stratified by Age, in the Unadjusted and Adjusted Models

	EVT Outcomes				Adjusted Model 2 (OR 95% CI)
	Aged <80 y	Aged ≥80 y	Unadjusted (OR 95% CI)	Adjusted Model 1 (OR 95% CI)	
Discharge home, %	38.32	19.16	0.37 [0.34–0.40]	0.46 [0.42–0.51]	0.39 [0.36–0.42]
Discharge to acute inpatient rehabilitation center, %	24.69	19.04	0.72 [0.66– 0.79]	0.68 [0.61–0.75]	0.70 [0.64–0.77]
Independent ambulation at discharge*, %	42.37	21.71	0.38 [0.34–0.43]	0.44 [0.39–0.49]	0.40 [0.37–0.43]
Symptomatic ICH, %	5.07	5.85	1.17 [1.03–1.33]	1.10 [0.95–1.26]	1.13 [0.99–1.28]
Life-threatening or serious systemic hemorrhage, %	0.73	0.76	1.02 [0.73–1.42]	0.93 [0.64–1.37]	0.97 [0.69–1.34]
In-hospital death, %	8.89	10.88	1.32 [1.2–1.44]	1.3 [1.19–1.43]	1.32 [1.22–1.44]

Model 1: Adjusted for sex, race, insurance, smoking, hypertension, diabetes, dyslipidemia, coronary artery disease, stroke/TIA, atrial fibrillation, arrival mode, NIHSS, hospital size, hospital type, region, site of LVO, symptom onset to puncture time. Model 2: Model 1+year of treatment. EVT indicates endovascular thrombectomy; and ICH, intracranial hemorrhage.

*Restricted to those ambulating independently before admission.

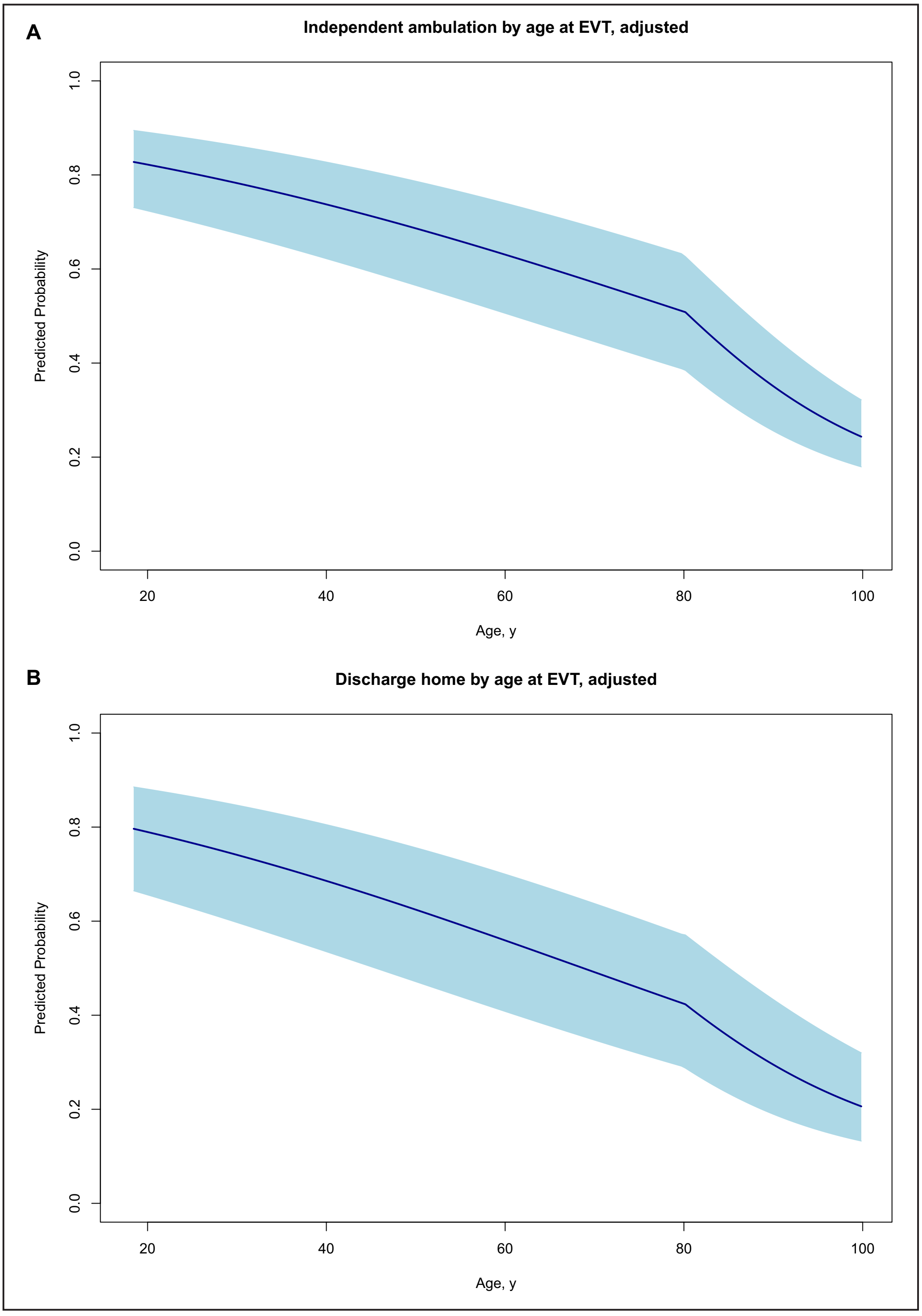

Figure 2. Relationship between increase in age and the binary outcomes of (A) independent ambulation and (B) discharge home in multivariable logistic regression models with generalized estimating equations to account for clustering effect within each hospital.

Curves (blue shading indicates 95% CIs) show the adjusted predicted outcome rate for a hypothetical patient with mean values for baseline characteristics as compared with the same patients characteristics at the age of 60 years. EVT indicates endovascular thrombectomy.

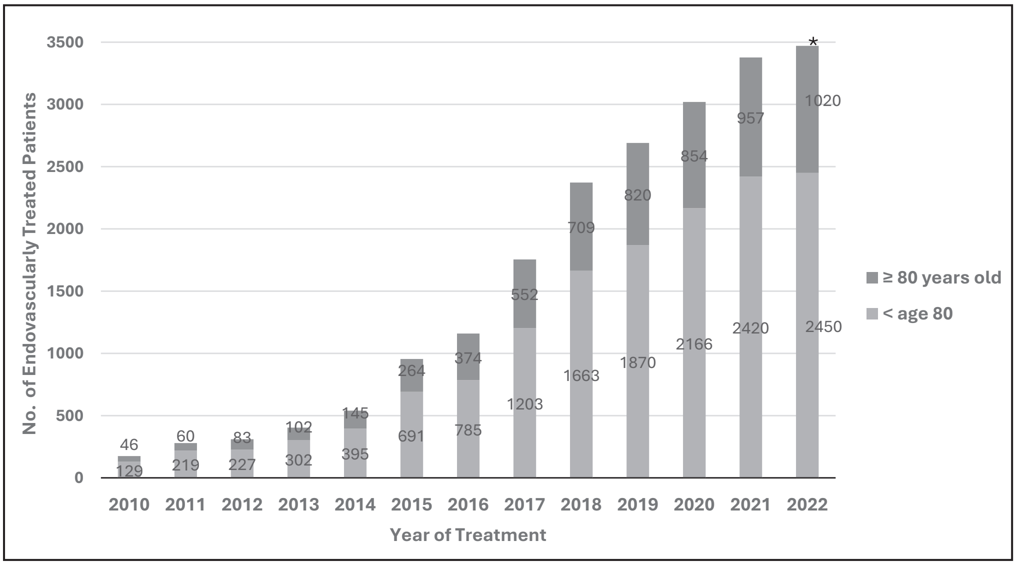

Figure 3. Temporal trends of endovascular therapy (EVT) in the Florida Stroke registry based on age of the patient at the time of treatment.
*Projected values for 2022.

statistically significant coefficient estimate of 0.004, implying a relative increase in the share off octogenarian patients of 0.4 percentage points each year (*P*=0.02).

DISCUSSION

In this large multicenter registry, nearly 30% of endovascularly treated patients are older than 80 years of age. We found significant differences in sex, race and ethnicity, clinical, socioeconomic, and regional characteristics of older patients treated with EVT as compared with those who are younger than age 80.

The majority of EVT patients over the age of 80 in our study were women. Female patients with stroke are on average 4 to 5 years older than male patients with stroke and more likely to present with severe neurological symptoms.[22,23] However, women did not comprise a higher proportion of patients enrolled in randomized trials of EVT.[10] The higher proportion of women among EVT patients over the age of 80 in our study, implies that older patients included in the trials may not be representative of the older patients that receive this treatment in routine practice.

Multiple previous studies have demonstrated significant race/ethnic disparities in access to acute stroke therapies.[24,25] Even though reasons behind these disparities were not clearly apparent in those studies, they demonstrated that Black, and low-income patients are less likely to receive EVT. In our study, the proportion of NH-Black patients and those without medical insurance significantly decreased among thrombectomy patients over the age of 80 years. The reasons behind these findings are likely multifactorial; some factors may include that NH-Black patients are generally younger at the time of their first stroke, and health insurance (Medicare) is more available in the older population in the United States. Regardless, these data suggest that age is an important modifier of race and socioeconomic factors to access thrombectomy.

In our study, the rate of death, sICH or life-threatening complications were similar in the older population and was not affected by increase in age. These data confirm that in routine practice, EVT has comparable safety outcome profile across a wide range of age. Older patients with EVT in our study had overall poorer discharge outcomes as compared with EVT patients under the age of 80 years. Accounting for baseline differences, older patients were less likely to be discharged directly home or to an acute rehabilitation center after EVT. Between 60 and 80 years of age for 1000 endovascularly treated patients, every year increase in age resulted in 20 fewer patients discharged home or ambulating independently. Over the age of 80 years, for 1000 endovascularly treated patients, every year increase in age resulted in 60 fewer patients ambulating independently and 80 fewer patients discharged home.

Older patients were underrepresented in prior large, randomized trials of EVT. In the pooled meta-analysis of 1287 patients enrolled in the 5 randomized trials of EVT, the median age was 68 years with total of 198 patients included over the age of 80 years.[10] Two of these trials excluded patients >80 years old.[5,7] Older age and higher baseline NIHSS score were associated with higher mRS score at 90 days.[10] In octogenarians, favorable outcome was observed in

13.9% in the control group compared with 29.8% in the endovascular arm (OR: 3.68 [95% CI, 1.95–6.92]). However, within the endovascular group, the rate of favorable outcome decreased from 50.0% in the 50 to 59 years age group to 29.8% in individuals over 80 years old, as measured by favorable mRS scores (0–2) at 90 days. Notably, among octogenarians, mortality was observed in 45% of patients randomized to best medical care in contrast to 28% in the intervention arm.[10] Overall, the benefit of EVT over medical management persisted across the spectrum of age with no increased risk of development of post EVT parenchymal hematoma and sICH between populations.[10] Importantly, while discharge outcomes may decline with age, other randomized controlled trials have demonstrated the effectiveness of EVT compared with no treatment, and our observational study does not directly assess this comparison.

Our findings are in keeping with prior retrospective studies that evaluated outcomes in older patients treated with EVT.[15–18,26,27] In a systematic review and meta-analysis of 17 studies reporting on 860 patients,[28] outcomes in the older patients were inferior to those described in the younger patients, however recovery of independent function was observed in ~1 in 4 cases.

The most feared complication of reperfusion therapies, sICH, occurred in 5.3% of our study population but was not significantly different in the older patients in our study. Our findings are in keeping with prior reported rate of sICH of EVT patients from randomized studies.[10,29] In a systematic review and meta-analysis of 1499 patients receiving EVT, the incidence of sICH in patients who underwent EVT was about 6%.[30] Our study observed comparable rates of sICH in line with existing literature and did not exhibit substantial differences between the 2 age groups.

We observed a substantial and consistent increase in the total number of patients undergoing EVT throughout the study period (Figure 3). Over the course of 12 years, there was a remarkable nearly 20-fold increase in the number of EVT-treated patients. The observed increase may be attributed to technological advancements, pivotal positive studies, and guidelines, as well as geographic expansion of EVT and increase in the number of hospitals enrolling in FSR, which is consistent with trends reported in other studies.[31,32] While there was substantial growth in the geographic reach of EVT, the age distribution of patients and the ratio of older versus young patients with EVT remained relatively stable. Though speculative, this stable ratio maybe an indicator that older patients are continuously underrepresented in the overall EVT population.

Our study has multiple limitations inherent to registry studies. First, our study did not analyze all patients in FSR who may have been eligible to receive EVT but did not receive this therapy. The indications to pursue treatment was determined by the treating physicians in each facility which may be a source for selection bias. Reluctance in offering aggressive reperfusion therapies to the older population may have reduced the total number of older patients to receive EVT and as such limited the overall generalizability of our results. Second, our registry does not have data on imaging characteristics and technical factors related to thrombectomy, such as device selection, device preference, technical expertise, and number of thrombectomy passes. These factors are important determinants of EVT outcomes and could therefore modify our results.[33,34] Third, premorbid mRS had >50% missingness in our data set and as such the effect of preexisting disability on our study outcomes were not studied. Fourth, data on 90-day mRS, the conventional outcome metric used in stroke trials, were not available in FSR, hence a direct comparison of outcomes between our study and those of randomized trials was not possible in the current analysis. Despite these limitations, the current analysis provides one of the largest studies of EVT patterns and outcomes in the older population in routine practice.

CONCLUSIONS

In this large multicenter registry, encompassing the largest sample size to date on this topic, we observed that nearly 30% of EVT-treated patients were aged >80 years. We found significant race, ethnic, sex, socioeconomic, and geographic difference between EVT-treated patients who were younger or older than 80 years of age. The probability of favorable outcomes upon discharge post EVT decreased with advancing age. However, our analysis did not reveal a significant association between older age and higher occurrences of sICH or post-EVT mortality. Overall, these findings underscore the reassuring notion that EVT maintains its safety across a wide range of ages in routine clinical practice.

ARTICLE INFORMATION

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Supplemental Material

Data S1
Table S1

REFERENCES

1. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. *Lancet*. 2009;374:1196–1208. doi: 10.1016/S0140-6736(09)61460-4
2. Wolf PA, Abbott RD, Kannel WB. Atrial fibrillation as an independent risk factor for stroke: the Framingham study. *Stroke*. 1991;22:983–988. doi: 10.1161/01.STR.22.8.983
3. Béjot Y, Bailly H, Durier J, Giroud M. Epidemiology of stroke in Europe and trends for the 21st century. *Presse Med*. 2016;45:e391–e398. doi: 10.1016/j.lpm.2016.10.003
4. Krishnamurthi RV, Feigin VL, Forouzanfar MH, Mensah GA, Connor M, Bennett DA, Moran AE, Sacco RL, Anderson LM, Truelsen T, et al. Global and regional burden of first-ever ischaemic and haemorrhagic stroke during 1990-2010: findings from the global burden of disease study 2010. *Lancet Glob Health*. 2013;1:e259–e281. doi: 10.1016/S2214-109X(13)70089-5
5. Jovin TG, Chamorro A, Cobo E, Miquel MA, Molina CA, Rovira A, Roman LS, Serena J, Abilleira S, Ribo M, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med*. 2015;372:2296–2306. doi: 10.1056/NEJMoa1503780
6. Campbell BC, Mitchell PJ, Kleinig TJ, Dewey HM, Churilov L, Yassi N, Yan B, Dowling RJ, Parsons MW, Oxley TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med*. 2015;372:1009–1018. doi: 10.1056/NEJMoa1414792
7. Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, Albers GW, Cognard C, Cohen DJ, Hacke W, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med*. 2015;372:2285–2295. doi: 10.1056/NEJMoa1415061
8. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, Roy D, Jovin TG, Willinsky RA, Sapkota BL, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med*. 2015;372:1019–1030. doi: 10.1056/NEJMoa1414905
9. Berkhemer OA, Fransen PS, Beumer D, Van den Berg LA, Lingsma HF, Yoo AJ, Schonewille WJ, Vos JA, Nederkoorn PJ, Wermer MJH, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med*. 2015;372:11–20. doi: 10.1056/NEJMoa1411587
10. Goyal M, Menon BK, van Zwam WH, Dippel DWJ, Mitchell PJ, Demchuk AM, Davalos A, Majoie CBLM, van der Lugt A, de Miquel MA, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet*. 2016;387:1723–1731. doi: 10.1016/S0140-6736(16)00163-X
11. Nogueira RG, Jadhav AP, Haussen DC, Bonafe A, Budzik RF, Bhuva P, Yavagal DR, Ribo M, Cognard C, Hanel RA, et al. Thrombectomy 6 to 24 hours after stroke with a mismatch between deficit and infarct. *N Engl J Med*. 2018;378:11–21. doi: 10.1056/NEJMoa1706442
12. Albers GW, Marks MP, Kemp S, Christensen S, Tsai JP, Ortega-Gutierrez S, McTaggart RA, Torbey MT, Kim-Tenser M, Leslie-Mazwi T, et al. Thrombectomy for stroke at 6 to 16 hours with selection by perfusion imaging. *N Engl J Med*. 2018;378:708–718. doi: 10.1056/NEJMoa1713973
13. Zhao W, Ma P, Zhang P, Yue X. Mechanical thrombectomy for acute ischemic stroke in octogenarians: a systematic review and meta-analysis. *Front Neurol*. 2019;10:1355. doi: 10.3389/fneur.2019.01355
14. Kleindorfer DO, Towfighi A, Chaturvedi S, Cockroft KM, Gutierrez J, Lombardi-Hill D, Kamel H, Kernan WN, Kittner SJ, Leira EC, et al. 2021 guideline for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline from the American Heart Association/American Stroke Association. *Stroke*. 2021;52:e364–e467. doi: 10.1161/STR.0000000000000375
15. Sallustio F, Koch G, Motta C, Diomedi M, Alemseged F, D'Agostino VC, Napolitano S, Sama D, Davoli A, Konda D, et al. Efficacy and safety of mechanical thrombectomy in older adults with acute ischemic stoke. *J Am Geriatr Soc*. 2017;65:1816–1820. doi: 10.1111/jgs.14909
16. Kleine JF, Boeckh-Behrens T, Prothmann S, Zimmer C, Liebig T. Discrepancy between early neurological course and mid-term outcome in older stroke patients after mechanical thrombectomy. *J Neurointerv Surg*. 2016;8:671–676. doi: 10.1136/neurintsurg-2015-011702
17. Imahori T, Tanaka K, Arai A, Shiomi R, Fujiwara D, Mori T, Yokote A, Matsushima K, Matsui D, Kobayashi M, et al. Mechanical Thrombectomy for acute ischemic stroke patients aged 80 years or older. *J Stroke Cerebrovasc Dis*. 2017;26:2793–2799. doi: 10.1016/j.jstrokecerebrovasdis.2017.06.060
18. Sharobeam A, Cordato DJ, Manning N, Cheung A, Wenderoth J, Cappelen-Smith C. Functional outcomes at 90 days in octogenarians undergoing thrombectomy for acute ischemic stroke: a prospective cohort study and meta-analysis. *Front Neurol*. 2019;10:254. doi: 10.3389/fneur.2019.00254
19. Asdaghi N, Romano JG, Wang K, Ciliberti-Vargas MA, Koch S, Gardener H, Dong C, Rose DZ, Waddy SP, Robichaux M, et al. Sex disparities in ischemic stroke care: FL-PR CReSD study (Florida-Puerto Rico collaboration to reduce stroke disparities). *Stroke*. 2016;47:2618–2626. doi: 10.1161/STROKEAHA.116.013059
20. Sacco RL, Gardener H, Wang K, Dong C, Ciliberti-Vargas MA, Gutierrez CM, Asdaghi N, Burgin S, Carrasquillo O, Garcia-Rivera EJ, et al. Racial-ethnic disparities in acute stroke Care in the Florida-Puerto Rico Collaboration to reduce stroke disparities study. *J Am Heart Assoc*. 2017;6:2.
21. Alberts MJ, Latchaw RE, Selman WR, Shephard T, Hadley MN, Brass LM, Koroshetz W, Marler JR, Booss J, Zorowitz RD, et al. Recommendations for comprehensive stroke centers: a consensus statement from the brain attack coalition. *Stroke*. 2005;36:1597–1616. doi: 10.1161/01.STR.0000170622.07210.b4
22. Uchida K, Yoshimura S, Sakai N, Yamagami H, Morimoto T. Sex differences in management and outcomes of acute ischemic stroke with large vessel occlusion. *Stroke*. 2019;50:1915–1918. doi: 10.1161/STROKEAHA.119.025344
23. Mainz J, Andersen G, Valentin JB, Gude MF, Johnsen SP. Disentangling sex differences in use of reperfusion therapy in patients with acute ischemic stroke. *Stroke*. 2020;51:2332–2338. doi: 10.1161/STROKEAHA.119.028589
24. Sheriff F, Xu H, Maud A, Gupta V, Vellipuram A, Fonarow GC, Matsouaka RA, Xian Y, Reeves M, Smith EE, et al. Temporal trends in racial and ethnic disparities in endovascular therapy in acute ischemic stroke. *J Am Heart Assoc*. 2022;11:e023212. doi: 10.1161/JAHA.121.023212
25. Mehta AM, Fifi JT, Shoirah H, Shigematsu T, Oxley TJ, Kellner CP, Leacy RD, Mocco J, Majidi S. Racial and socioeconomic disparities in the use and outcomes of endovascular thrombectomy for acute ischemic stroke. *AJNR Am J Neuroradiol*. 2021;42:1576–1583. doi: 10.3174/ajnr.A7217
26. Cohen JE, Gomori JM, Leker RR. Stent retriever-based thrombectomy in octogenarians. *Interv Neurol*. 2016;5:111–117. doi: 10.1159/000446795
27. Groot AE, Treurniet KM, Jansen IGH, Lingsma HF, Hinsenveld W, van de Graaf RA, Roozenbeek B, Willems HC, Schonewille WJ, Marquering HA, et al. Endovascular treatment in older adults with acute ischemic stroke in the MR CLEAN registry. *Neurology*. 2020;95:e131–e139. doi: 10.1212/WNL.0000000000009764
28. Hilditch CA, Nicholson P, Murad MH, Rabinstein A, Schaafsma J, Pikula A, Krings T, Pereira VM, Agid R, Brinjikji W. Endovascular management

of acute stroke in the elderly: a systematic review and meta-analysis. *AJNR Am J Neuroradiol*. 2018;39:887–891. doi: 10.3174/ajnr.A5598
29. McDonough RV, Ospel JM, Campbell BCV, Hill MD, Saver JL, Dippel DWJ, Demchuk AM, Majoie CBLM, Brown SB, Mitchell PJ, et al. Functional outcomes of patients ≥85 years with acute ischemic stroke following EVT: a HERMES substudy. *Stroke*. 2022;53:2220–2226. doi: 10.1161/STROKEAHA.121.037770
30. Hao Y, Zhang Z, Zhang H, Xu L, Ye Z, Dai Q, Liu X, Xu G. Risk of intracranial hemorrhage after endovascular treatment for acute ischemic stroke: systematic review and meta-analysis. *Interv Neurol*. 2017;6:57–64. doi: 10.1159/000454721
31. Adcock AK, Schwamm LH, Smith EE, Fonarow GC, Reeves MJ, Xu H, Matsouaka RA, Xian Y, Saver JL. Trends in use, outcomes, and disparities in endovascular Thrombectomy in US patients with stroke aged 80 years and older compared with younger patients. *JAMA Netw Open*. 2022;5:e2215869. doi: 10.1001/jamanetworkopen.2022.15869
32. Saber H, Navi BB, Grotta JC, Kamel H, Bambhroliya A, Vahidy FS, Chen PR, Blackburn S, Savitz SI, McCullough L, et al. Real-world treatment trends in endovascular stroke therapy. *Stroke*. 2019;50:683–689. doi: 10.1161/STROKEAHA.118.023967
33. Kobeissi H, Adusumilli G, Ghozy S, Dmytriw AA, Senol YC, Orscelik A, Bilgin C, Kadirvel R, Brinjikji W, Kallmes DF. First-pass effect in posterior acute ischemic stroke undergoing endovascular thrombectomy: a systematic review and meta-analysis. *J Stroke Cerebrovasc Dis*. 2023;32:107304. doi: 10.1016/j.jstrokecerebrovasdis.2023.107304
34. Karamchandani RR, Satyanarayana S, Yang H, Rhoten JB, Strong D, Singh S, Clemente JD, Defilipp G, Hazim M, patel NM, et al. The charlotte large artery occlusion endovascular therapy outcome score compares favorably to the critical area perfusion score for prognostication before basilar thrombectomy. *J Stroke Cerebrovasc Dis*. 2023;32:107147. doi: 10.1016/j.jstrokecerebrovasdis.2023.107147