Endovascular Stroke Therapy Trends From 2011 to 2017 Show Significant Improvement in Clinical and Economic Outcomes

Ansaar T. Rai, MD, MBA; Concetta Crivera, PharmD, MPH; Iftekhar Kalsekar, PhD; Rashmi Kumari, BS; Nataly Patino, MPH; Farid Chekani, PhD; Rahul Khanna, PhD

***Background and Purpose*—**The purpose of this study was to evaluate trends in length of stay, discharge status, and costs among patients with acute ischemic stroke who underwent endovascular therapy (ET) between 2011 and 2017.

***Methods*—**Using a retrospective observational study design, acute ischemic stroke patients undergoing ET from 2011 to 2017 were identified in the Premier Healthcare Database. The Mann-Kendall trend test was performed to examine clinical and economic outcomes trends.

***Results*—**Among the 505 824 acute ischemic stroke patients, 11 811(2.3%) were treated with ET. Patients receiving ET had a significant increase in home discharge and a significant decrease in mortality (17.7% to 29.6%, $P<0.01$; 21.6% to 12.8%, $P<0.01$). There was a significant decline in length of stay from 11.7 days to 8.7 days ($P<0.01$). Total index admission costs declined ≈17% from 2011 to 2017 ($50 516.5–$42 026.9, $P<0.01$).

***Conclusions*—**Clinical and economic indicators significantly improved for acute ischemic stroke patients undergoing ET from 2011 to 2017. **(*Stroke*. 2019;50:1902-1906. DOI: 10.1161/STROKEAHA.119.025112.)**

Kew Words: length of stay ■ morbidity ■ mortality ■ patients ■ thrombectomy

Acute ischemic stroke (AIS) is associated with significant morbidity, mortality, and economic burden to patients, caregivers, and the healthcare system.[1–3] An estimated 31/100 000 people/y in the United States have a large vessel stroke (internal carotid artery terminus, middle cerebral artery main stem, or the bifurcation branches and the basilar artery).[4,5] In the light of recent clinical trials showing superior efficacy of endovascular therapy (ET) for treatment of large vessel strokes,[6–9] the American Heart Association/American Stroke Association updated their guidelines in 2018 recommending ET up to 24 hours in appropriately selected patients.[5]

ET for large vessels strokes has been associated with better cost savings than intravenous thrombolysis.[10,11] A database analysis by Hassan et al[12] showed a 6-fold increase in patients with AIS who underwent endovascular treatment from 2004 to 2009, with the lowest thrombectomy utilization (0.2%) among patients ≥85 years of age. The current study is one of the first to evaluate trends in healthcare utilization and costs related to ET of large vessel strokes. As ET devices, hospital practice patterns, and physician experience have evolved, it is important to understand if these improvements have translated in improving outcomes among AIS patients. The objective of the current retrospective cohort study was to evaluate trends in discharge status (discharge to home, discharge to long-term care, death), healthcare use (operating room time, length of stay [LOS] for index AIS, all-cause 365-day readmission), and costs (index admission) among AIS patients who underwent ET between 2011 and 2017 in a real-world setting.

Methods

All supporting data has been made available within the article.

Data Source

A retrospective analysis of hospital billing records from January 1, 2011 to June 30, 2017 (Q3) of the Premier Healthcare Database was performed. The database represents a nationally representative set of >700 hospitals based on bed size, geographic region, location (urban/rural), and teaching status. The study data were extracted from hospital records of inpatient discharges. The study did not require institutional review board approval.

Study Sample

Patients (≥18 years) with a first primary diagnosis of AIS (*International Classification of Diseases, Ninth Revision* codes 433.xx, 434.xx, and 436.xx and equivalent *International Classification of Diseases, Tenth Revision* codes) between January 1, 2011 to June 30, 2017 were identified. Patients with a primary or secondary diagnosis of AIS within 12 months before the index data were excluded. Patients were also excluded if their LOS was ≤1 day to accurately capture true inpatient admissions. The final sample included patients who underwent ET, as

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Correspondence to Ansaar T. Rai, MD, MBA, Neurosciences, W Virginia University, Room 2278, HSCS, PO Box 9235, Morgantown, WV 26505. Email ansaar.rai@gmail.com

defined by *International Classification of Diseases, Ninth Revision* procedure code 39.74 and equivalent *International Classification of Diseases, Tenth Revision* codes; Current Procedural Terminology codes 61645, 61650, and 61651; and Diagnosis-Related Group codes 023 and 024.

Statistical Analysis

All study variables were analyzed descriptively. The Mann-Kendall trend test, which is a nonparametric statistical test to assess monotonic upward or downward trends, was used to examine trends in the study outcomes. For sensitivity analysis, generalized estimating equations approach was used to account for baseline covariates including demographics, clinical, and hospital characteristics to examine the relationship between index admission year and study outcomes. All analyses were conducted using SAS for Windows, Version 9.4 (SAS Institute, Inc, Cary, NC).

Results

Patient attrition is presented in Table 1. Among 505 824 patients with the first diagnosis of AIS, 11 811 (2.34%) patients were treated with ET. Patient and hospital characteristics are presented in Table 2. The mean age of all patients was 66.47 (±14.75) years. The majority of the patients were white (69.42%), male (51.97%), and had a Charlson Comorbidity Index >2 (81.30%). ET patients in recent years were older (63.59±14.84 years in 2011; 67.90±14.66 years in 2017; $P<0.01$) and sicker (as per Charlson Comorbidity Index score >2; 78.69% in 2011 and 86.60% in 2017; $P<0.01$). Most hospitals were urban (98.33%), had bed size >500 (64.55%), and were teaching hospitals (60.36%). Most providers were located in the southern US region (49.06%).

Among patients undergoing ET, discharge to home significantly increased from 17.7% in 2011 to 29.6% in 2017 (P=0.004). Mortality significantly decreased from 21.6% to 12.8% (P=0.002). Although discharge to long-term care decreased from 2011 to 2017, the trend was not significant (53.5% to 49.7%, P=0.0985). The decrease in the mean operating room time from 2011 to 2017 was not significant (201 to 170 minutes, P=0.1). The overall LOS decreased significantly from 11.7 days to 8.7 days between 2011 and 2017. Although all-cause 365-day readmission decreased from 2011 to 2016 (24.2% to 19.8%; P=0.35), the trend was not significant. The index admission costs decreased significantly from 2011 to 2017 (overall, $50 516.5 to $42 026.9; P=0.004; Figure [A1 through A3, B, C, and D]).

Table 1. Cohort Selection

Step	Criteria	n
1	Inpatient episodes with discharge between 2011 to 2017Q3	39 405 973
2	All episodes with primary diagnosis of AIS	706 340
3	Select index occurrence of the AIS	643 061
4	Exclude patients <18 y	642 570
5	Exclude patients with the diagnosis (primary or secondary) of AIS in inpatient setting in the baseline period of 12 mo	625 871
6	Patients with LOS >1 day	505 824
7	Patients who underwent thrombectomy (final study sample)	11 811

AIS indicates acute ischemic stroke; LOS, length of stay; and Q, quarter.

Sensitivity Analysis

The generalized estimating equations approach for examining the relationship between the main independent variable of admission year and outcomes controlling for study covariates depicted similar results. The odds ratio (OR) for discharge to home was 2.37 (95% CI, 1.86–3.03), whereas mortality was ≈44% (OR, 0.56; 95% CI, 0.44–0.72) lower for ET patients admitted in 2017 compared with 2011. Patients admitted in 2017 versus 2011 had significantly lower LOS (OR, 0.77; 95% CI, 0.71–0.84); lower all-cause 365-day readmission (OR, 0.79; 95% CI, 0.61–1.01); and lower index admission cost (OR, 0.81; 95% CI, 0.75–0.88).

Discussion

Better techniques and patient selection may have improved clinical and economic outcomes for ET. Few studies have evaluated these outcomes in a real-world setting. Despite the fact that ET patients in recent years were older and sicker, we found that outcomes still improved. There was a significant increase in patients discharged to home and in improved survival, with a significant decline in overall LOS. These findings were consistent with a previous study in which mortality decreased over time among AIS patients who received thrombectomy.[12] These improvements may explain the significant decline in total index admission costs from 2011 to 2017. The sensitivity analysis using adjusted models demonstrated a similar relationship between time and outcomes as compared with unadjusted analysis, with outcomes clearly favoring AIS patients receiving ET.

ET outcomes may continue to improve in clinical practice. Patient selection may lead to more patients being treated in the late time window. Evolving guidelines, medical therapies, individualized treatment, or improved patient compliance could have influenced trends in ET outcomes and needs to be further explored. Despite these improvements in clinical and economic outcomes among AIS patients treated with ET, there is still a significant morbidity and mortality burden associated with AIS among such patients. In 2017, inpatient mortality rate was >10%, and approximately half of the patients were discharged to long-term care facility. Final recanalization status has emerged as the strongest factor associated with clinical outcomes in AIS patients undergoing ET.[13] This necessitates utilization of newer thrombectomy devices with superior revascularization profile to further reduce the burden of AIS.

There are a few limitations to this study, but most are inherent to those associated with observational database analyses. The Premier hospital database contains information from >700 hospitals throughout the United States; therefore, it is conceivable that it may not include data records that are representative of all hospitals in the United States. The occurrence

Table 2. Patient Demographics, Clinical Characteristics, and Hospital Characteristics

Characteristic (%)	2011	2012	2013	2014	2015	2016	2017	
N	(1023)	(1320)	(1381)	(1625)	(2189)	(2154)	(2119)	*P* Value
Mean age, y (SD)	63.59 (14.84)	64.81 (14.55)	65.70 (14.75)	65.22 (14.91)	67.31 (14.49)	68.00 (14.67)	67.90 (14.66)	<0.01
Age group, y								<0.01
18–49	17.20	15.00	15.06	15.45	11.79	12.12	11.99	
50–59	21.99	20.08	18.10	19.82	17.59	15.13	15.76	
60–69	22.29	24.32	23.68	21.91	23.25	23.49	23.17	
70–79	22.87	22.20	21.58	22.34	23.30	23.40	23.27	
≥80	15.64	18.41	21.58	20.49	24.07	25.86	25.81	
Male	53.27	52.95	51.41	53.42	52.17	49.63	52.15	0.27
Race								<0.01
Black	13.59	13.48	12.45	14.28	12.75	12.02	12.22	
White	65.59	67.73	65.82	67.82	70.76	72.79	71.07	
Other	20.82	11.92	21.72	17.91	16.49	15.18	16.71	
Marital status								0.07
Married	48.00	45.23	43.88	45.54	46.83	44.20	42.99	
Not married	52.00	54.77	56.12	54.46	53.17	55.80	57.01	
Payer								<0.01
Commercial	29.42	26.59	24.69	26.09	25.08	22.56	21.76	
Medicaid	11.44	10.98	12.02	13.11	13.43	10.96	10.00	
Medicare	51.03	53.41	54.82	51.57	53.04	58.64	60.88	
Other	8.11	9.02	8.47	9.23	8.45	7.85	7.36	
Transfer admission	24.05	26.82	20.56	18.71	21.43	21.91	27.32	<0.01
Comorbidities								
AF	32.16	35.38	35.63	35.02	38.60	42.29	39.08	<0.01
CAD	27.96	26.36	25.49	26.83	28.19	28.51	27.47	0.46
CHF	20.04	17.88	18.83	18.95	20.33	23.63	22.32	<0.01
TIA	1.27	1.36	0.58	0.74	0.73	1.62	0.90	0.01
HS	9.38	9.55	9.99	10.77	10.51	9.05	8.54	0.22
DM	29.91	29.24	29.25	31.57	30.06	29.48	28.98	0.72
GIB	1.37	0.76	1.16	0.92	0.82	0.97	0.94	0.76
Hypertension	76.34	76.44	77.91	79.69	82.05	82.50	81.45	<0.01
Valve disease	11.73	13.11	13.76	12.31	14.07	14.53	12.74	0.21
Chronic renal failure	9.68	10.61	11.66	11.38	12.33	12.63	13.17	0.06
Dementia	0.59	1.14	1.38	1.54	3.03	5.39	6.32	<0.01
Cancer	3.42	3.18	4.78	4.43	4.43	3.85	4.01	0.31
COPD	17.30	16.89	16.36	18.34	19.28	16.11	16.80	0.10
CCI score								<0.01
0–2	21.31	20.45	21.22	20.62	19.60	17.64	13.40	
>2	78.69	79.55	78.78	79.38	80.40	82.36	86.60	
Provider region								<0.01
Midwest	17.60	17.80	17.23	15.26	14.62	21.36	17.93	
Northeast	25.81	26.89	21.43	15.63	17.09	14.81	14.91	
South	39.88	39.55	45.11	55.88	53.72	49.58	51.44	

(*Continued*)

Table 2. Continued

Characteristic (%)	2011	2012	2013	2014	2015	2016	2017	
N	(1023)	(1320)	(1381)	(1625)	(2189)	(2154)	(2119)	*P* Value
West	16.72	15.76	16.22	13.23	14.57	14.25	15.71	
Teaching hospital	64.71	65.61	60.61	53.78	57.97	59.01	63.71	<0.01
Hospital beds								<0.01
0–99	0	0.08	0.22	0.06	0.05	0.09	0	
100–199	9.19	4.17	4.49	2.83	3.61	5.62	2.55	
200–299	8.80	8.18	10.07	5.60	6.26	4.69	3.35	
300–399	8.31	11.29	12.96	12.74	13.07	11.65	11.70	
400–499	14.76	12.73	11.08	9.66	9.55	13.46	18.78	
≥500	58.94	63.56	61.19	69.11	67.47	64.48	63.61	
Hospital location								<0.01
Rural	2.44	1.14	1.23	0.98	1.32	2.55	1.89	
Urban	97.56	98.86	98.77	99.02	98.68	97.45	98.11	

AF indicates atrial fibrillation; CAD, coronary artery disease; CCI, Charlson Comorbidity Index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; GIB, gastrointestinal bleeding; HS, hemorrhagic stroke; and TIA, transient ischemic attack.

of billing and coding errors or missing data on database records may also have potentially affected the accuracy of study estimates. ET presents a critical treatment tool to reduce disability associated with AIS. As observed in our study, there were significant improvements in clinical and economic outcomes among AIS patients treated with ET from 2011 to 2017.

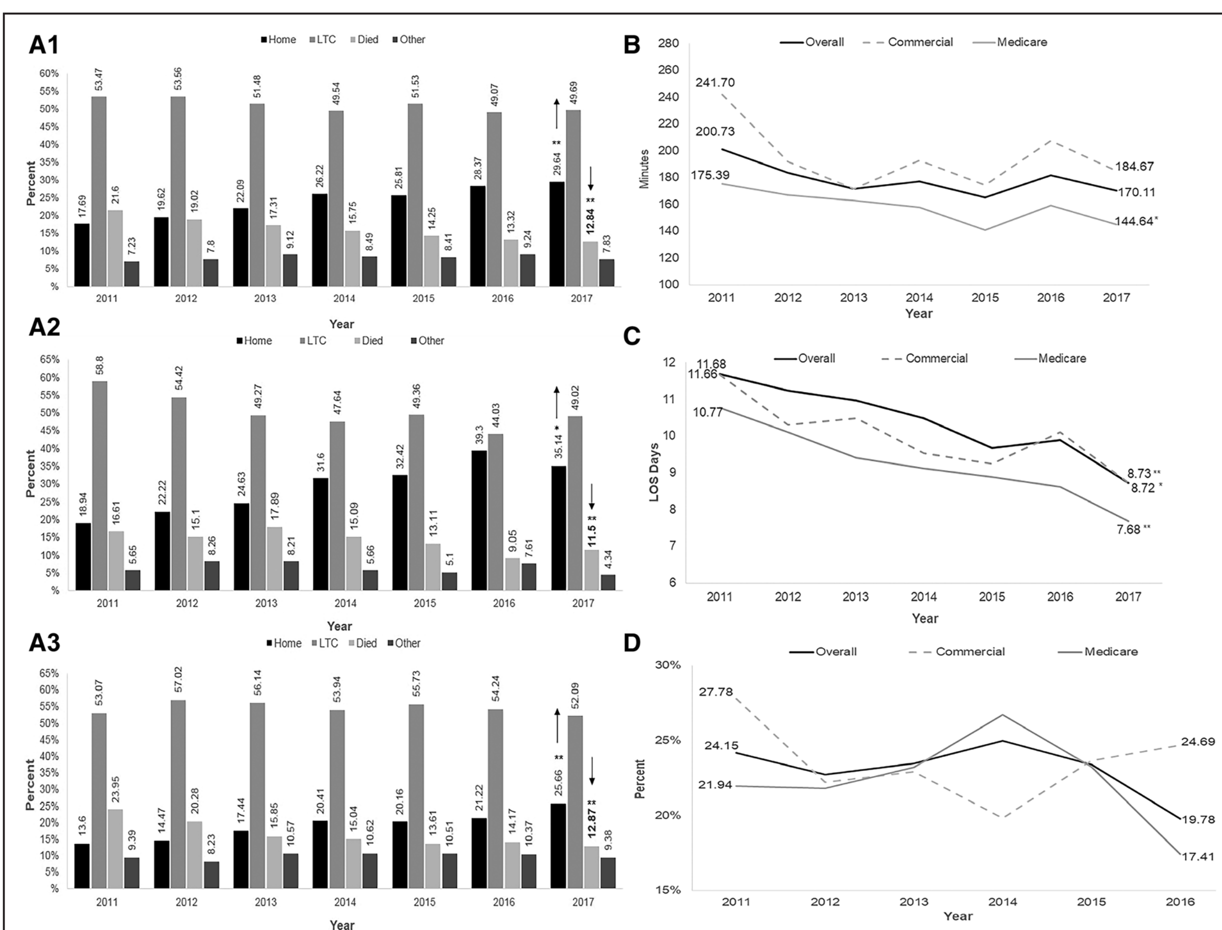

Figure. Outcomes in patients with acute ischemic stroke treated with endovascular therapy from 2011 to 2017. **A**, Discharge status for the (**A1**) overall, (**A2**) commercial, and (**A3**) Medicare cohorts. ***P*<0.01. **B**, Operating room time. **C**, Length of stay (LOS; **P*<0.01). **D**, All-cause 365-day readmission. LTC indicates long-term care.

Conclusions

There were significant improvements in clinical and economic outcomes among AIS patients treated with ET from 2011 to 2017; however, the burden of disease remains high in this patient population. As access to treatment improves, more stroke patients may benefit from ET, in turn, diminishing the burden on patients and society.

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Disclosures

C. Crivera, Dr Kalsekar, Dr Khanna, and N. Patino are Johnson & Johnson employees. Dr Chekani was a Johnson & Johnson employee at the time of the study. C. Crivera, Drs Kalsekar, and Khanna have stock ownership in Johnson and Johnson. R. Kumari works for MuSigma which has a consulting agreement with Johnson & Johnson. Johnson & Johnson manufactures devices for treatment of acute ischemic stroke. Dr Rai has consulting agreement with Stryker Neurovascular and Cerenovus (part of Johnson and Johnson family of companies). Stryker Neurovascular also manufactures devices for treatment of acute stroke.

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