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Trends in hospital procedure volumes for intra-arterial treatment of acute ischemic stroke: results from the paul coverdell national acute stroke program

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Abstract

Background—Rates of intra-arterial revascularization treatments (IAT) for acute ischemic stroke (AIS) are increasing in the USA. Using a multi-state stroke registry, we studied the trend in IAT use among patients with AIS over a period spanning 11 years. We examined the impact of IAT rates on hospital procedure volumes and patient outcome after stroke.

Methods—We used data from the Paul Coverdell National Acute Stroke Program (PCNASP) and explored trends in IAT between 2008 and 2018. Patient outcomes were examined by rates of IAT procedures across hospitals. Specifically, outcomes were compared across low-volume (>15 IAT per year), medium-volume (15–30 IAT per year), and high-volume hospitals (<30 IAT per year). Favorable outcome was defined as discharge to home.

Results—There were 612 958 patients admitted with AIS to 687 participating hospitals within the PCNASP during this study. Only 2.9% of patients (mean age 68.5 years, 49.3% women) received IAT. The percent of patients with AIS receiving IAT increased from 1% in 2008 to 5.3% in 2018 ($p>0.001$). The proportion of low-volume hospitals decreased over time ($p>0.001$), and the proportions of medium-volume ($p=0.007$) and high-volume hospitals ($p>0.001$) increased between 2008 and 2018. When compared with medium-volume hospitals, high-volume hospitals had a higher ($p>0.0001$) and low-volume hospitals had a lower ($p>0.0001$) percent of patients discharged to home.

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Conclusion—High-volume hospitals were associated with a higher rate of favorable outcome. With the increased use of IAT among patients with AIS, the proportion of low-volume hospitals performing IAT significantly decreased.

BACKGROUND

The benefits of intra-arterial revascularization treatments (IAT) for acute ischemic stroke (AIS) were established through five randomized controlled trials in 2015.[1] This evidence changed the standard of treatment for patients with AIS presenting with large vessel occlusions (LVO). Subsequently, two additional randomized trials showed the benefits of an expanded time window for IAT.[23] Based on the evidence from these trials, guidelines recommended the use of IAT among eligible patients (Class I, Level A recommendation).[4] Centralization of stroke care has been associated with improved patient outcomes. However, IAT is typically performed at higher level of care centers. This necessitates the transfer of patients with LVO from hospitals of initial presentation to thrombectomy-performing centers (TPCs). These hospital transfers may delay intervention, and prolonged travel times may obscure the benefit of IAT.[56]

One solution would be to increase the number of TPCs. This would lead to greater numbers of patients presenting initially to IAT-performing centers, thereby saving time to treatment. This may result in fewer procedures per TPC, and the lower procedure volumes per hospital may affect the outcomes of patients with LVO AIS. Previous studies have suggested that higher IAT volume centers yield higher proportions of favorable outcomes.[578] As national rates of IAT have increased among eligible patients,[9] we studied the impact on procedure volumes per TPC using data from the Paul Coverdell National Acute Stroke Program (PCNASP)[1011].

METHODS

Our study population included patients admitted with a clinical diagnosis of AIS from 2008 through 2018 within the PCNASP. The PCNASP is an ongoing acute stroke quality improvement program funded by the Centers for Disease Control and Prevention (CDC) and provides feedback to states on adherence to stroke care guidelines. The goal of the PCNASP is to improve care quality for patients hospitalized with stroke and transient ischemic attack (TIA). During the study period, hospitals across 12 states (Arkansas, California, Georgia, Iowa, Massachusetts, Michigan, Minnesota, New York, North Carolina, Ohio, Washington, and Wisconsin) participated in the PCNASP.[1011]

Hospital participation in the PCNASP within each state is voluntary. Trained abstractors collect detailed information on stroke and TIA admissions concurrent with or soon after hospitalization discharge using standard data definitions provided by the CDC.[1011] More information on PCNASP hospital metrics and data elements can be found on the CDC website (https://www.cdc.gov/dhdsp/programs/pcnasr_metrics.htm). This study was approved by the CDC Institutional Review Board (protocol #5373).

We examined the rates of IAT alone or in combination with intravenous thrombolysis (IVT +IAT) using the number of annual AIS admissions as the denominator. Trends were

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identified for IAT alone, IVT+IAT, and overall IAT. We then examined the annual volume trends of IAT performed at each participating TPC across the study years. We classified participating TPCs as low-volume (<15), medium-volume (15–30), and high-volume (>30) by year. Low-volume reporting hospitals were defined as those performing fewer than the minimum number of IAT procedures per year recommended by The Joint Commission.12 High-volume hospitals were defined as those performing greater than the minimum number of IAT procedures based on recommendations reported by the Committee for Advanced Subspecialty Training for training program accreditation (CAST).[13] Unfavorable outcome measures included rates of symptomatic intracranial hemor rhage (sICH), life-threatening complications, and in-hospital mortality. Favorable outcome was defined as discharge to home. Outcomes were then compared among low-volume, medium-volume, and high-volume centers.

Categorical variables were compared across groups using ctwo-tailed Fisher's exact or χ^2 tests. Continuous variables were compared using the Wilcoxon–Mann–Whitney rank test or the Kruskal–Wallis test. We examined the trends and obtained the p values based on the Cochran–Armitage test. To account for the clustering of patients within hospitals, generalized estimating equations (GEE) were used to assess the association between the outcomes (discharge destination to home, in-hospital mortality, and sICH) and volume hospitals. A two-sided p<0.05 was considered statistically significant. All analyses were performed using SAS software Version 9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

During the study period 612 958 patients were admitted with AIS to 687 participating PCNASP hospitals. Among them, 17 985 (2.9%) patients (mean age 68.5 years, 49.3% women) received IAT (table 1). The percent of AIS patients receiving IAT increased from 1% in 2008 to 5.3% in 2018 (p>0.001). The proportion of patients receiving IAT only in comparison to IVT+IAT did not significantly change during the study period. The number of hospitals providing IAT increased from 32 centers in 2008 to 90 centers in 2018. The median number of IATs performed at each hospital increased substantially between 2008 and 2018 from four procedures annually to 43 procedures annually (p<0.001). The proportion of low-volume hospitals decreased over time from 90.6% to 22.2% (p<0.001). The proportions of medium-volume (p=0.007) and high-volume (p<0.001) hospitals increased over time from 3.1% to 16.7% and 6.3% to 61.1%, respectively (table 2).

The rate of sICH was 4.8% among all patients receiving IAT (tables 3 and 4). Using medium-volume hospitals as a reference on univariate analysis, low-volume hospitals had a significantly lower rate of discharge to home and a significantly higher rate of sICH. After adjusting for age, sex, race, hospital arrival, and stroke severity on presentation on multi variate analysis, rates of discharge to home (OR 0.79 (95% CI .60 to 0.82), p<0.0001) and sICH (OR 1.32 (95% CI 1.02 to 1.70), p=0.034) remained significantly different for low-volume hospitals compared with medium-volume hospitals. While there were no differences in the rate of sICH (OR 0.97 (95% CI 0.80 to 1.18), p=0.78) or in-hospital mortality (OR 0.88 (95% CI 0.78 to 1.00), p=0.052), high-volume hospitals had a significantly higher rate of discharge to home than medium-volume hospitals (OR 1.25 (95% CI 1.13 to 1.39),

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p<0.0001) on multivariate analysis (table 5). Because of low rates of life-threatening complications, no comparisons were completed among groups.

DISCUSSION

Our study shows that, among PCNASP participants during 2008–2018, there was a significant trend towards a decreasing proportion of TPCs performing fewer than 15 IATs and a significantly increasing trend towards TPCs performing more than 30 IATs annually. Low-volume hospitals were associated with significantly higher rates of sICH and a significantly lower rate of discharge to home, while high-volume hospitals were associated with a significantly higher rate of discharge to home.

During the third quarter of 2018, The Joint Commission suspended individual physician training and volume requirements for IAT in AIS while maintaining minimal requirements for IAT among TPCs.[12] The suspension of individual procedure volume requirements prompted much discussion among many stroke specialists.[14] Only a few hospitals in the USA meet all neurointerventional procedural volume criteria, and analyses from the interventional cardiology literature confirm the presence of a learning curve in performing procedures and indicated that complication frequency was inversely proportional to increasing operator experience.[15] In addition, literature evaluating procedural outcomes from carotid artery, coronary artery, and cerebral aneurysm interventions confirms that experience with higher volumes is associated with fewer in-hospital complications.[16–19] For these reasons, multiple neurointerventional societies have agreed on a minimum individual volume requirement of at least 15 IATs for AIS annually.[20]

Success within the recent IAT studies was largely related to the fact that participating sites are high-volume stroke centers, which was a prerequisite for participation in the randomized controlled trials.[21] Lower volume centers may not achieve as high a rate of favorable outcomes. In fact, in a recent database analysis from 2013 and 2015 of patients receiving IAT, Qureshi and colleagues demonstrated that those participating in clinical trials had lower rates of in-hospital mortality than those outside clinical trials.[22] Based on the characteristics of participating clinical trial sites[21] and with this recent analysis,[22] strategies are essential to ensure appropriate adoption of IAT in order to replicate the results of clinical trials into general practice.

Our study confirms that high-volume IAT sites experience lower rates of unfavorable outcomes and higher rates of favorable outcome. This has been demonstrated in the past; however, the definition of a high-volume center varied considerably, ranging from >10 to >50 IATs annually per site.[578] We defined -high-volume as >30 procedures per year based on CAST requirements for accreditation of training programs.[13] Within the inter ventional cardiology literature we have learned that the number of high-volume physicians affects the high hospital volume to favorable outcome relationship.[23] Therefore, we selected to define high-volume sites as those performing IATs at the threshold required annually for training programs to adequately train neurointerventionists as opposed to recent IAT standards of care recommendations for volumes per site (>50).[24]

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Strengths of our study include the large number of patients within multi-state data from a variety of hospitals collected during regular delivery of stroke care. An important limitation of our study is the inability to assess selection criteria for those receiving IAT to determine adherence to or deviation from institutional guidelines.[425] We also had difficulties in ascertaining baseline disability in a proportion of patients (as defined by the National Institute of Health Stroke Scale score, 3.9%). A selection bias may exist since participation in PCNASP is voluntary and not all TPCs may be included in our analysis. We also do not have access to individual neurointerventionist procedure volume. These limitations should not affect the general observations of this study, however. Favorable outcome was defined by discharge to home rather than a formal outcome scale, although it has been shown that discharge destination can act as a highly predictive surrogate for standard outcome scales.[2627]

High-volume TPCs are associated with a significantly higher rate of favorable outcome. With the increased use of IAT for patients with AIS, there is an increased trend for higher procedure volumes per TPC and the proportion of low-volume TPCs continues to significantly decrease. Future studies could examine individual neurointerventionist IAT volume and its impact on associated outcomes.

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Table 1

Demographic and baseline characteristics of patients with acute ischemic stroke receiving intra-arterial treatment, 2008–2018

Overall AIS patients	612 958
Receipt of IAT (%)	17 985 (2.9)
Mean (SE) age in years	68.5 (0.1)
No of women (%)	8867 (49.3)
Race (n, %)	
Non-Hispanic White	12 850 (71.4)
Non-Hispanic Black	2687 (14.9)
Other race	2448 (13.6)
Median admission NIHSS score (IQR) *	16 (9–21)

* NIHSS score missing in 3.9% of patients.

AIS, acute ischemic stroke; IAT, intra-arterial treatment; NIHSS, National Institutes of Health Stroke Scale.

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Table 2

Trends in intra-arterial treatment by year, 2008–2018

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	P for trend
Overall IAT among AIS patients, n (%)		225 (1.0)	347 (1.2)	490 (1.4)	698 (1.7)	843 (2.1)	1012 (1.7)	1358 (2.0)	2358 (3.5)	2270 (3.2)	3189 (3.9)	5195 (5.3)	<0.001
	Method of IAT delivery, n (%)												
	IAT only	178 (79.1)	272 (78.4)	366 (74.7)	538 (77.1)	624 (74.0)	723 (71.4)	1002 (73.8)	1711 (72.6)	1689 (74.4)	2321 (72.8)	3966 (76.3)	0.82
	IVT+IAT	47 (20.9)	75 (21.6)	124 (25.3)	160 (22.9)	219 (26.0)	289 (28.6)	356 (26.2)	647 (27.4)	581 (25.6)	868 (27.2)	1229 (23.7)	0.82
Hospital level results													
	No of hospitals providing IAT	32	38	45	49	62	77	86	92	56	75	90	
	Distribution of hospitals by IAT volume, n (%)												
	<15	29 (90.6)	33 (86.8)	34 (75.6)	33 (67.3)	45 (72.6)	59 (76.6)	58 (67.4)	41 (44.6)	22 (39.3)	30 (40.0)	20 (22.2)	<0.001
	15–30	1 (3.1)	2 (5.3)	9 (20.0)	12 (24.5)	12 (19.4)	12 (15.6)	19 (22.1)	28 (30.4)	8 (14.3)	12 (16.0)	15 (16.7)	0.007
	>30	2 (6.3)	3 (7.9)	2 (4.4)	4 (8.2)	5 (8.1)	6 (7.8)	9 (10.5)	23 (25.0)	26 (46.4)	33 (44.0)	55 (61.1)	<0.001
Median (IQR) procedure per hospital		4 (2–11)	5.5 (2–11)	7 (4–12)	8 (3–17)	6.5 (3–15)	7 (2–14)	8 (4–20)	18 (7–31)	27.5 (7–47)	24 (6–47)	43 (17–66)	<0.001

p value for trend was based on Cochran-armitage test.

AIS, acute ischemic stroke; IAT, intra-arterial treatment; IVT, intravenous thrombolysis.

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Table 3

Outcomes among patients receiving intra-arterial treatment for stroke (Paul Coverdell National Acute Stroke Program, 2008–2018)

		N (%)
Symptomatic ICH	Overall	864 (4.8)
	IAT only	627 (4.7)
	IVT+IAT	237 (5.2)
Life-threatening complications	Overall	133 (0.7)
	IAT only	78 (0.6)
	IVT+IAT	55 (1.2)
In-hospital mortality	Overall	2321 (12.9)
	IAT only	1785 (13.3)
	IVT+IAT	536 (11.7)
Discharge home	Overall	4772 (26.5)
	IAT only	3276 (24.5)
	IVT+IAT	1496 (32.6)

IAT, intra-arterial treatment; ICH, intracranial hemorrhage; IVT, intravenous thrombolysis

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Table 4

Characteristics and outcomes of patients receiving intra-arterial treatment for stroke based on procedural volume per hospital (Paul Coverdell National Acute Stroke Program, 2008–2018)

		N (%) or statistics by volume per site		
	overall N (%) or statistics (n=17 985)	**<15 (n=2222)**	**15–30 (n=2860)**	**>30 (n=12 903)**
Mean age, years (SE)	68.5 (0.1)	66.4 (0.3)	67.6 (0.3)	69.0 (0.1)
No of women (%)	8867 (49.3)	1063 (47.8)	1380 (48.3)	6424 (49.8)
Race, n (%)				
Non-Hispanic White	12 850 (71.4)	1582 (71.2)	2150 (75.2)	9118 (70.7)
Non-Hispanic Black	2687 (14.9)	372 (16.7)	369 (12.9)	1946 (15.1)
Other race	2448 (13.6)	268 (12.1)	341 (11.9)	1839 (14.3)
Arrival by ambulance	8566 (47.6)	1344 (60.5)	1469 (51.4)	5753 (44.6)
NIHSS score recorded, n (%)	17 276 (96.1)	1982 (89.2)	2685 (93.9)	12 609 (97.7)
Median NIHSS score (IQR)	16 (9–21)	16 (10–21)	16 (10–21)	15 (9–21)
Discharge to home	4772 (26.5)	451 (20.3)	711 (24.9)	3610 (28.0)
In-hospital mortality	2321 (12.9)	347 (15.6)	391 (13.7)	1583 (12.3)
Symptomatic ICH	864 (4.8)	133 (6.0)	134 (4.7)	597 (4.6)
Life-threatening complications	133 (0.7)	24 (1.1)	25 (0.9)	84 (0.7)

ICH, intracranial hemorrhage; NIHSS, National Institutes of Health Stroke Scale.

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Table 5

Univariate and multivariate analyses of outcomes among patients receiving intra-arterial treatment for stroke based on procedural volume per hospital (Paul Coverdell National Acute Stroke Program, 2008–2018)

	Volume per site	OR (95% CI)	P value	AOR (95% CI)*	P value
Symptomatic intracranial hemorrhage	<15	1.30 (1.01 to 1.66)	0.04	1.32 (1.02 to 1.70)	0.033
	15–30	Ref		Ref	
	>30	0.99 (0.81 to 1.20)	0.89	0.97 (0.80 to 1.18)	0.78
In-hospital mortality	<15	1.17 (0.999 to 1.37)	0.051	1.15 (0.97 to 1.37)	0.11
	15–30	Ref		Ref	
	>30	0.88 (0.78 to 0.995)	0.04	0.88 (0.78 to 1.00)	0.052
Discharge to home	<15	0.77 (0.67 to 0.88)	0.0001	0.70 (0.60 to 0.82)	<0.0001
	15–30	Ref		Ref	
	>30	1.17 (1.07 to 1.29)	0.0007	1.25 (1.13 to 1.39)	<0.0001

GEE model was used to obtain the OR and AOR.

* Adjusted by age, sex, race, arrival by emergency medical services, and NIH Stroke Scale score.