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A Nationwide Inpatient Sample Study of Stroke Outcomes Based on Aggressiveness to Pursue Thrombectomy: The Thrombectomy/Thrombolysis Ratio

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Abstract

Background: Consensus guidelines to assist practitioners regarding patient selection for thrombectomy in acute ischemic stroke are absent. The purpose of this study is to use the Nationwide Inpatient Sample Database to evaluate the differences in patient outcomes between high-volume stroke centers that are more aggressive with using thrombectomy than those high-volume stroke center that are less aggressive.

Methods: High volume stroke centers were identified for the years 2009, 2010 and 2011 in the Nationwide Inpatient Sample Database based upon having treated at least 5 patient with thrombectomy, 20 with thrombolysis, and 300 total stroke patients. Hospitals were then categorized based on the ratio of thrombectomies/thrombolyses performed each year (T/T ratio). Outcomes and mortality after thrombectomy were compared based on T/T ratio.

Results: Between 2009 and 2011, 97 hospitals met inclusion criteria; there were 56,582 patients with stroke, 1,431 patients treated with thrombectomy, and 4,583 patients treated with intravenous thrombolysis at these hospitals during the study period. There were non-linear, significant associations between T/T ratio and both poor outcome (P=0.03) and mortality (P=0.01), where hospitals with the highest and lowest T/T ratios had worse outcomes and higher mortality after thrombectomy compared to moderately aggressive hospitals.

Conclusion: Hospitals with moderate T/T ratios had the best clinical outcomes after thrombectomy. This data suggest the importance of both adequate treatment volumes to maintain proficiency and the use of intelligent patient selection based upon generally accepted criteria in obtaining optimal stroke outcomes after thrombectomy.

Keywords: Acute ischemic stroke; Endovascular; Mortality; Thrombectomy; Thrombolysis

Introduction

Recently, the Multicenter Randomized CLinical trial of Endovascular treatment for Acute ischemic stroke in the Netherlands (MR CLEAN) [1], The Endovascular Treatment for Small Core and Anterior Circulation Proximal Occlusion with Emphasis on Minimizing CT to Recanalization Times (ESCAPE) [2], the Extending the Time for Thrombolysis in Emergency Neurological Deficits - Intra-Arterial (EXTEND-IA) [3] and SWIFT-PRIME studies have provided overwhelming evidence supporting the benefits of mechanical thrombectomy for acute ischemic stroke. These trials strongly suggest intra-arterial therapies (IAT) with intravenous tissue plasminogen activator (IV tPA) is the new standard of care treatment for patients presenting with large vessel occlusion (LVO) within 4.5 hours of symptom onset. These results are in stark contrast to previously published randomized controlled trials [4-6] that demonstrated no benefit from IAT towards primary outcomes but were noted to suffer from significant limitations [7]. Together, these studies suggest that patient outcomes with IAT are highly dependent on adequate patient selection and revascularization.

Consensus guidelines to assist practitioners regarding patient selection for thrombectomy are absent. While a National Institute of Health Stroke Severity score (NIHSS) of 8 or greater, the presence of large vessel occlusion, and presentation within 8 hours of stroke onset represent generally-accepted criteria, for the most part neurointerventionists in practice are making decisions regarding IAT based on their individual training and their inherited interpretation of selection criteria. The lack of consensus regarding selection has resulted in a spectrum of institutional practices, whereby some hospitals are more aggressive and lean towards IAT when the best option is unclear, while others are less aggressive and lean towards IV thrombolysis only in the same situation.

The purpose of this study is to use the Nationwide Inpatient Sample Database to evaluate the differences in patient outcomes between high-volume stroke centers that are more aggressive with using thrombectomy than those high-volume stroke center that are less aggressive. To do so, we created a novel metric for exploring the aggressiveness of individual centers based on a comparison between thrombectomy procedures performed and intravenous thrombolysis administered: the T/T ratio.

Materials and Methods

We obtained the NIS database from the Agency for Healthcare Quality and Research's (AHRQ) Healthcare Cost and Utilization Project (Rockville, Maryland). For each sampled hospital, all inpatient admissions for the year are contained in the NIS. The NIS includes data for approximately 8 million hospital admissions each year, or approximately one-fifth of all inpatient admissions to U.S. nonfederal hospitals. For more information regarding the NIS database, please

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see http://www.hcup-us.ahrq.gov/nisoverview.jsp. Institutional Review Board approval was obtained prior to accessing the NIS database for this study.

We searched the NIS for all hospitalizations for the years of 2002 through 2011 involving acute ischemic stroke. These hospitalizations were identified in the NIS using ICD-9 diagnosis codes: 433.XX, 434.XX, 436, 437.0 or 437.1. Patients having undergone mechanical thrombectomy were identified if the ICD-9 procedure code 39.74 appeared in the hospital record. Patients having received intravenous thrombolysis were identified if the ICD-9 procedure code 99.01 appeared in the hospital record. As the NIS lacks clinical outcome scoring systems such as modified Rankin score, we utilized previously published definitions [8] of good versus poor clinical outcome based on NIS discharge disposition. Clinical outcome was defined as "Good" if the patient was "discharged to home or self-care", "discharged to short-term hospital for inpatient care", "discharged to home under care of an organized home health service organization", "left against medical advice", "discharged to home IV provider", "discharged to another institution for outpatient services", "discharged to same institution for outpatient services", or "discharged alive, destination unknown." Clinical outcome was defined as "Poor" if the patient was "discharged to skilled nursing facility", "discharged to intermediate care facility", "discharged to hospice", "discharged to hospital-based Medicare-approved swing bed", "discharged to inpatient rehabilitation facility", "discharged to long-term care hospital", or "discharged to nursing facility certified by Medicaid, but not certified by Medicare." Finally, deceased patients were identified by: "expired", "expired at home", "expired in a medical facility", or "expired – place unknown." Patients with intracranial hemorrhage were identified by the appearance of the ICD-9 diagnosis codes 430, 431, 432, or 432.X in the hospital record, while gastrointestinal hemorrhage, those who received gastrostomy tubes, and those receiving tracheostomy were identified by ICD-9 diagnosis code 578 or 578.X, ICD-9 procedure code 43.11-43.19, and ICD-9 procedure code 31.1-31.29, respectively.

To be included in this study, a stroke center had to be considered high volume. High-volume stroke centers were identified for 2009, 2010 and 2011 as those with at least 20 patients treated with intravenous thrombolysis (ICD-9 procedure code 99.01 incidence of at least 20), at least 5 patients treated with mechanical thrombectomy (ICD-9 procedure code 39.74 incidence of at least 5), and at least 300 total stroke patients treated during the year in question. Twenty-two hospitals met these criteria in 2009, 36 in 2010, and 39 in 2011. Next, institutions were divided into categories of "aggressiveness to pursue thrombectomy" by creating a ratio of thrombectomy cases to intravenous thrombolysis cases, wherein those with higher thrombectomy/thrombolysis ratios (T/T ratio) were considered more aggressive to pursue thrombectomy. For each year, the hospitals with T/T ratios in the upper 20% (ratio > 0.60) were considered "most aggressive," those in the lowest 40% (ratio < 0.30) were categorized as "least aggressive," and those in the middle 40% (ratio 0.3-0.6) were considered "moderately aggressive." These delineations were created based upon an initial analysis suggesting improved mortality rates between T/T ratios of 0.3 and 0.6 (Figure 1).

Statistical Analysis

The SAS statistical software package (V.9.3) was used to extract data from the NIS and to calculate means, standard deviations and frequencies for all outcomes in the dataset. National incidences and rates were estimated using the procedure detailed by the Healthcare Cost and Utilization Project (HCUP) at http://www.hcup-us.ahrq.gov/tech_assist/nationalestimates/508_course/508 course.htm. We used mixed-effects, multivariate logistic regression models to evaluate the effect of T/T ratio on mortality and good outcome when controlling for patient characteristics. In these models, our fixed factors were T/T ratio (treated as continuous), patient age, gender, Charlson Comorbidity Index and socioeconomic status (median income in the patient's ZIP code). To account for the clustering of observations on hospitals, we considered hospital a random factor.

Results

A total of 1,184,988 patients with a diagnosis of stroke were identified between the years of 2002 and 2011. In-hospital mortality, discharge disposition, and mean lengths of stay based on year are displayed in Table 1. The number of patients undergoing mechanical thrombectomy, intravenous thrombolysis, or both for the years 2006-2011 is displayed in Table 2. While only accounting for a small minority of the patients carrying a diagnosis of stroke, the number of patients undergoing thrombectomy or thrombolysis increased steadily from 2006 to 2011. However, both the percentage of patients with good outcome and in-hospital mortality decreased slightly over time.

Table 3 provides an example of how hospitals were categorized into aggressiveness based on T/T ratio. The data shown in Table 3 is for the 39 representative hospitals for 2011. Note that those with T/T ratios greater than 0.6 are classified as "most aggressive," those with T/T ratios 0.3-0.6 are classified as "moderately aggressive," and those with the lowest T/T ratios (<0.3) are classified as "least aggressive." Similar stratifications were seen in 2009 and 2010 (not shown). Table 4 displays the mean number of stroke cases, thrombolyses, thrombectomies, and T/T ratios for 2009, 2010, 2011 and 2009-2011.

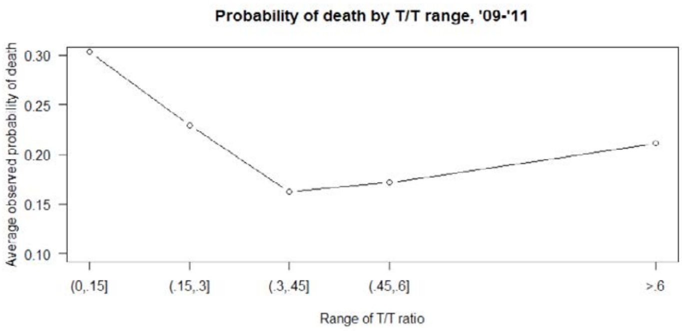

Figure 1: Data used to suggest hospital classification by T/T ratio. The points indicate the average observed mortality rate for hospitals in one of five classes of T/T ratio. The data suggest improved mortality rates for hospitals with moderately aggressive T/T ratios (roughly 0.3-0.6), and higher rates for least aggressive (T/T<0.3) and most aggressive (T/T>0.6) hospitals.

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Year	In-hospital mortality	Discharge disposition =Good	LOS Mean (SD); Median	Intracranial hemorrhage	GI bleeding	Underwent G-tube	Underwent Tracheotomy
2002 (n=128,343)	6.317 (5.0)	67.736 (67.4)	5.1 (5.8); 4	662 (0.52)	1.054 (0.82)	4.897 (3.8)	499 (0.39)
2003 (n=125,043)	5.946 (4.8)	67.595 (66.6)	5.0 (5.8); 4	692 (0.55)	1.125 (0.90)	4.779 (3.8)	599 (0.48)
2004 (n=118,069)	5.594 (4.7)	63.504 (62.8)	4.9 (5.8); 4	722 (0.61)	901 (0.76)	4.401 (3.7)	568 (0.48)
2005 (n=113,999)	5.111 (4.5)	58.344 (62.9)	4.8 (5.7); 3	648 (0.57)	822 (0.72)	3.963 (3.5)	505 (0.44)
2006 (n=115,543)	4.998 (4.3)	61.528 (63.3)	4.8 (5.7); 3	815 (0.71)	895 (0.77)	3.977 (3.4)	554 (0.48)
2007 (n=112,887)	4.558 (4.0)	58.021 (62.7)	4.7 (5.8); 3	812 (0.72)	834 (0.74)	3.847 (3.4)	529 (0.47)
2008 (n=120,056)	5.156 (4.3)	62.572 (61.8)	4.7 (5.8); 3	1.126 (0.94)	907 (0.76)	4.247 (3.5)	629 (0.52)
2009 (n=112,210)	4.416 (3.9)	60.288 (62.1)	4.5 (5.7); 3	1.050 (0.94)	783 (0.70)	4.014 (3.6)	578 (0.52)
2010 (n=114,852)	4.752 (4.1)	60.202 (59.9)	4.6 (5.8); 3	1.515 (1.3)	814 (0.71)	4.168 (3.6)	698 (0.61)
2011 (n=123,986)	4.490 (3.6)	63.551 (59.5)	4.4 (5.8); 3	2.984 (2.4)	823 (0.66)	4.288 (3.5)	676 (0.55)
All years (n=1,184,988)	51.388 (4.3)	62.3341 (62.9)	4.8 (5.8); 3	11.026 (0.93)	8.958 (0.76)	42.581 (3.6)	5.835 (0.49)

Table 1: Outcomes for all stroke patients identified in the NIS (n (%)) between 2002 and 2011.

Year	Any Thrombectomy	Any Thrombolysis	Only Thrombectomy	Only thrombolysis	Both
2006 (n=115,543)	42 (0.04)	2,280 (2.0)	20 (0.02)	2,258 (2.0)	22 (0.02)
2007 (n=112,887)	141 (0.12)	2.549 (2.6)	57 (0.05)	2.465 (2.2)	84 (0.07)
2008 (n=120,056)	507 (0.42)	3.160 (2.6)	247 (0.21)	2.900 (2.4)	260 (0.22)
2009 (n=112,210)	467 (0.42)	3.843 (3.4)	184 (0.16)	3.560 (3.2)	283 (0.25)
2010 (n=114,852)	691 (0.60)	5.025 (4.4)	278 (0.24)	4.612 (4.0)	413 (0.36)
2011 (n=123,986)	782 (0.63)	5.482 (4.4)	358 (0.29)	5.058 (4.1)	424 (0.34)
2006-2011 (n=699,534)	2.630 (0.38)	22.339 (3.2)	1.144 (0.16)	20.853 (3.0)	1.486 (0.21)

Table 2: Number stroke patients identified in the NIS (n (%)) carrying ICD-9 procedure codes for thrombectomy or thrombolysis from 2006-2011.

Hospital ID	Total Patients With Stroke	Total Patients Undergoing Thrombectomy	Total Patients Undergoing Thrombolysis	T/T Ratio	Aggressiveness
1	433	29	20	1.45	Most Aggressive
2	1424	87	81	1.07	
3	590	55	61	0.902	
4	380	21	24	0.875	
5	480	29	46	0.630	
6	421	37	66	0.561	Moderately Aggressive
7	442	34	65	0.523	
8	581	14	32	0.438	
9	674	16	41	0.390	
10	365	10	26	0.385	
11	599	13	34	0.382	
12	432	21	55	0.382	
13	391	11	29	0.379	
14	352	14	38	0.368	
15	694	17	49	0.347	
16	554	19	61	0.311	
17	382	9	29	0.310	

18	537	15	54	0.278	Least Aggressive
19	329	13	48	0.271	
20	592	14	58	0.241	
21	563	13	54	0.241	
22	384	7	30	0.233	
23	994	11	50	0.220	
24	433	8	37	0.216	
25	1265	23	107	0.215	
26	392	6	28	0.214	
27	632	12	57	0.211	
28	480	8	38	0.211	
29	514	8	38	0.211	
30	474	6	29	0.207	
31	517	6	31	0.194	
32	762	7	38	0.184	
33	765	7	39	0.179	
34	724	20	112	0.179	
35	518	9	53	0.170	
36	713	5	30	0.167	
37	489	5	35	0.143	
38	975	9	69	0.130	
39	552	5	52	0.096	

Table 3: Hospitals ranked by ratio of thrombectomy:thromboylsis (T/T ratio) for the year of 2011. Those hospitals with T/T ratios greater than 0.6 are considered "most aggressive," those with 0.3-0.6 "moderately aggressive", and hospitals with less than 0.3 as "least aggressive" towards performing thrombectomy.

Year	**Hospitals Included**	**Diagnosis of Stroke**		**Thrombectomy**		**Thrombolysis**		**T/T Ratio**
		Total	**Mean (SEM)**	**Total**	**Mean (SEM)**	**Total**	**Mean (SEM)**	**Mean (SEM)**
2009	22	13,359	607.2 (57.7)	286	13.0 (1.4)	1,013	46.0 (4.7)	0.312 (0.03)
2010	36	20,425	567.4 (32.5)	492	13.7 (1.6)	1,726	47.9 (3.3)	0.299 (0.03)
2011	39	22,798	584.6 (38.2)	653	16.7 (2.5)	1,844	47.3 (3.3)	0.362 (0.05)
2009-2011	97	56,582	583.3 (23.3)	1,431	14.8 (1.2)	4,583	47.2 (2.1)	0.328 (0.02)

Table 4: Mean number of stroke cases, thrombolyses, thrombectomies, and T/T ratios for 2009, 2010, 2011 and 2009-2011 for hospitals included in the analysis.

	Least aggressive (n=539)	**Moderately aggressive (n=569)**	**Most aggressive (n=323)**	***p*-value**
Age Mean (SD);	66.3 (15.0)	67.3 (15.2)	63.7 (15.8)	0.570
Median [IQR] (range)	68 [56, 79] (16, 94)	70 [58, 78] (17, 95)	69 [56, 78] (17, 110)	
Gender n, (% female)	261 (48.4)	299 (52.5)	158 (48.9)	0.342
Median income in patient's ZIP code n (%) (28 obs missing)				
Low	149 (28.2)	107 (19.2)	93 (29.2)	<0.001
Low-Mid	112 (21.2)	125 (22.4)	95 (29.9)	
Mid-High	123 (23.3)	170 (30.5)	67 (21.1)	
High	144 (27.3)	155 (27.8)	63 (19.8)	
Charlson Comorbidity Index				
Mean (SD);	2.4 (1.7)	2.5 (1.7)	2.4 (1.7)	0.709
Median [IQR] (range)	2 [2, 3] (0, 12)	2 [2, 3] (0, 13)	2 [2, 3] (0, 8)	
Outcomes				
Mortality n (% who died) (2 obs missing)	130 (24.2)	94 (16.5)	68 (21.1)	0.007
Discharge disposition n (% good) (147 obs missing)	80 (16.8)	112 (21.5)	43 (14.9)	0.037
Length of stay Mean (SD);	10.1 (10.4)	9.0 (9.6)	8.7 (7.6)	0.062
Median [IQR] (range)	7 [4, 13] (0, 93)	7 [4, 11] (0, 142)	6 [4, 11] (0, 62)	

Table 5: Thrombectomy patient characteristics and outcomes by hospital type, 2009-2011 combined.

Hospital mortality based on aggressiveness classification

Mortality comparisons between most, moderately, and least aggressive categories are displayed in Table 5. When controlled for age, gender, comorbidity index and socioeconomic status, the probability of death was significantly lower for patients treated at moderate hospitals than for patients treated at the least aggressive hospitals (OR=0.59, 95% CI=[0.42, 0.85], p=0.004). The probability of death was not significantly different for patients treated at low and most aggressive hospitals (p=0.52) or between moderate and the most aggressive hospitals (p=0.14).

Hospital mortality based on T/T ratio

There was a significant, non-linear association between T/T ratio and mortality (p=0.01). It is estimated that the risk of death is highest for patients treated in hospitals with low T/T ratios. Risk decreases exponentially, more rapidly for low T/T ratios, levels out and then increases for higher ratios (Figure 2).

Clinical outcome based on aggressiveness classification

Clinical outcome comparisons between most, moderately, and least aggressive hospitals are displayed in Table 5. When controlled for age, gender, comorbidity index and socioeconomic status, the probability of good outcome was marginally higher for patients treated at moderate hospitals than for patients treated at least aggressive hospitals (OR=1.5, 95% CI=[.969, 2.21], p=0.07). The probability of good outcome was not significantly different for patients treated at least and most aggressive hospitals (p=0.93) or different for patients treated at moderate hospitals than for patients treated at the most aggressive hospitals (p=0.18).

Clinical outcome based on T/T ratio

There was a significant non-linear association between T/T ratio and mortality (p=0.03). It is estimated that the probability of good outcome is lowest for patients treated in hospitals with low T/T ratios. Probability increases exponentially until about T/T ratio of 0.58, then decreases exponentially for higher ratios. Figure 3 characterizes the overall relationship.

Length of hospital stay

LOS comparisons between most, moderately, and least aggressive categories are displayed in Table 5. When controlled for age, gender, comorbidity index and socioeconomic status, there was no significant association between hospital type and LOS (p-values for all pairwise comparisons are >0.8). T/T ratio was not significantly associated with LOS (p=0.47).

Relationship between T/T ratio and outcome measures for all stroke patients

For all stroke patients treated at hospitals included in the analysis (including those patients treated with thrombectomy, thrombolysis or neither), there was no relationship between T/T ratio and poor outcome (Spearman correlation coefficient -0.07, p=0.53). Similarly, there was no association between mortality and T/T ratio (Spearman correlation coefficient 0.09, p=0.41) or between LOS and T/T ratio (Spearman correlation coefficient -0.02, p=0.86).

Relationship between T/T ratio and outcome measures for all thrombolysis patients

For all stroke patients treated with thrombolysis at hospitals

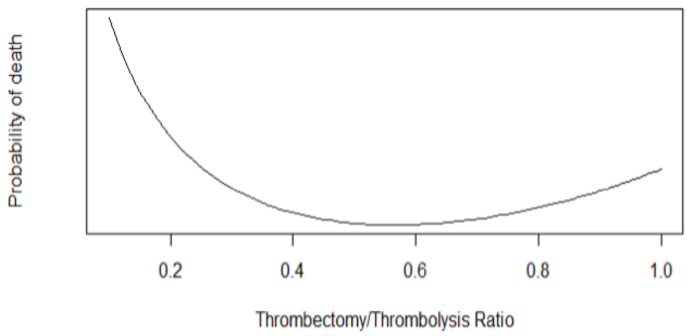

Figure 2: Estimated probability of death after thrombectomy and hospital T/T ratio. The curve is the line of best fit from a mixed-effects logistic regression model with T/T ratio, patient age, gender, Charlston Comorbidity Index and socioeconomic status as fixed factors, and hospital as a random factor. Exact probability estimates are omitted because these vary with values of the covariates.

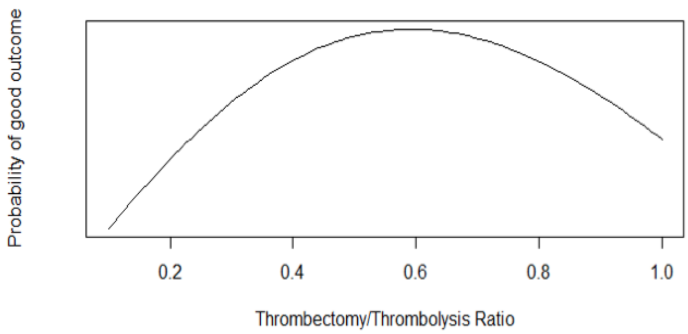

Figure 3: Estimated probability of good outcome after thrombectomy and hospital T/T ratio. The curve is the line of best fit from a mixed-effects logistic regression model with T/T ratio, patient age, gender, Charlston Comorbidity Index and socioeconomic status as fixed factors, and hospital as a random factor. Exact probability estimates are omitted because these vary with values of the covariates.

included in the analysis, there was no relationship between T/T ratio and poor outcome (Spearman correlation coefficient 0.05, p=0.70). Similarly, there was no association between mortality and T/T ratio (Spearman correlation coefficient 0.12, p=0.29) or between LOS and T/T ratio (Spearman correlation coefficient 0.08, p=0.50).

Discussion

From 2009 to 2011, the hospitals that were less aggressive in performing thrombectomy had higher mortality and worse clinical outcomes following thrombectomy. Interestingly, poor clinical outcome and mortality also increased at the upper extreme of aggressiveness. Furthermore, the effect of T/T ratio on thrombectomy outcomes was not seen in all stroke patients or in thrombolysis patients, indicating that the metric is not confounded by other hospital factors. This analysis suggests that an approach of moderate aggressiveness, with intelligent patient selection and a realistic approach to the risks and benefits of thrombectomy, offers the best chance of good outcome following thrombectomy. This finding is particularly important as the number of thrombectomies being performed in the United States annually continues to rise.

The most recent and effective thrombectomy devices, the stentriever technologies, have markedly improved our ability to recanalize large vessel occlusions compared to older technologies [9,10], a factor demonstrated to be consistently correlated with outcome after stroke [11-18]. The three negative randomized trials [4-6] demonstrated poor revascularization outcomes and used predominantly antiquated thrombectomy technologies. Furthermore, IMS III was limited by the use of CTA imaging in only a minority of patients prior to randomization. Interestingly, when patients with the index disease process for thrombectomy (large vessel occlusion) were actually identified by CTA prior to randomization, these patients had significantly better outcomes with thrombectomy compared to thrombolysis alone [7,19]. In the four recently presented positive trials, all patients had angiographic imaging prior to randomization and the vast majority of patients were treated with retrievable stent technology. These trials have demonstrated the importance of confirming large vessel occlusion as an important patient selection factor prior to offering intervention.

A number of studies have attempted to identify other important prognostication factors that help to predict outcome after IAT with the goal of enhancing patient selection for thrombectomy. A number of scoring systems have been created to simplify prognostication for improving the risk-benefit discussion with patients and family members [20-22]. These scores account for advanced age, hyperglycemia, comorbidities, and imaging findings to stratify patients based on potential benefit from treatment. Furthermore, physiologic imaging, such as CT perfusion, has altered our understanding of the role of time since symptom onset in making decisions to perform thrombectomy. There is increasing evidence suggesting that identification of salvageable tissue on perfusion imaging may actually be more important than the amount of time that has passed since stroke onset [23-25], although this argument remains controversial. Unfortunately, there are few guidelines for patient selection [26] and a wide range of practices regarding patient selection for stroke treatment in the community. Consider a recent survey of neurologists, where many respondents disagreed on the candidacy for intravenous thrombolysis [27], a treatment that has been available for nearly 20 years with Class 1 evidence supporting its use. It is therefore not surprising that the indications for thrombectomy vary considerably in the community, particularly given that IAT has no supportive Class 1 evidence, and in fact, just had three negative randomized clinical trials.

A second important consideration in this analysis is the concept of the T/T ratio as an independent factor, separate from the number of thrombectomy cases being performed at each center annually. The T/T ratio has never been described before as a means of evaluating stroke treatment practice patterns. In our analysis, centers with higher T/T ratios also had higher absolute numbers of patients treated with thrombectomy. The source for the effect of T/T ratio on outcome has two possibilities: physician volume and physician selection. In the low T/T group, the low thrombectomy volume may correlate to a center that is less skilled at IAT. It is well documented that the quality of care and outcomes after neurointerventional procedures are directly associated with proceduralist and hospital volume [28-33]. However, these facilities may also be inappropriately choosing patients for intervention, resulting in worse thrombectomy outcome. Erratic selection is more likely in low volume thrombectomy centers where coverage may be stressed or less consistent.

While our analysis shows a volume-dependent increase in good outcomes, there is a point where an increasing number of thrombectomies equates to worse clinical outcomes. Centers with high volume are likely to be the most experienced at IAT, so worsening outcomes are likely due to patient selection rather than physician volume. This finding supports the argument that good judgment, using widely-accepted indications for IAT and therefore practicing with a moderately aggressive T/T ratio, is the best plan of action when considering patient candidacy**.** This ratio is subject to change as the safety of endovascular therapy for stroke improves.

This analysis is dependent upon the assumption that hospitals included in the study were high-volume stroke centers with the capability of performing thrombectomy as well as having the necessary infrastructure and specialists to adequately care for stroke patients. It is assumed that hospitals treating more than 300 stroke patients, treating 20 or more patients with intravenous thrombolysis, and performing at least 5 mechanical thrombectomies per year have the basic requirements for optimal stroke care that are mandated for primary stroke center designation, as defined by the Brain Attack Coalition [34]. Furthermore, this analysis assumes that patients presenting at each hospital are roughly equivalent, such that a roughly uniform percentage of patients presenting to each individual center have large vessel occlusions and are candidates for thrombectomy. Unfortunately, NIHSS is not reported within the NIS, so we are unable to confirm that stroke severities at each center are equivalent. It is possible, although unlikely, that the centers deemed to be more aggressive are merely categorized as such because they experienced a higher number of patients presenting with large vessel occlusions and more severe strokes, necessitating more frequent thrombectomies. Patient outcomes in the thrombolysis only analysis and all stroke analysis were similar in these high volume centers, suggesting similar patient cohorts, in addition to the presenting patient characteristics that were evaluated.

There are other important limitations to this study. This study is retrospective and patient selection and biases were not controlled. Due to the retrospective nature, patient groups in hospitals and regions, as well as within treatment groups could be heterogenous and adversely affect the results. This is particularly apparent in that the NIS does not allow controlling for NIHSS or specific cormobidities. There is also inherent potential for selection bias while using the NIS and it is subject to coding errors and variability in coding. Since this retrospective study relied on ICD-9 coding for patient selection, errors in coding could affect result accuracy. Furthermore, the NIS comprises only about 20% of inpatient admissions to non-federal hospitals in the United States. Finally, this study only evaluates outcomes from thrombectomy between 2009 and 2011, during the beginning of the stentriever era. The reason for the 2011 endpoint is that 2012 data was not yet available for review at the time of analysis.

Conclusion

Mechanical thrombectomy for acute ischemic stroke now has supportive Class I evidence. We evaluated the role of individual institution aggressiveness to perform thrombectomy and its effect on patient outcomes through the development of a novel marker, the T/T ratio, defined as the ratio of thrombectomy to intravenous thrombolysis. When evaluating only high-volume centers, both less aggressive centers (low T/T ratio) and the most aggressive centers (highest T/T ratio) had higher mortality and worse clinical outcomes after thrombectomy compared to moderately aggressive centers. This data suggest the importance of both adequate treatment volumes to maintain proficiency and the use of intelligent patient selection based upon generally accepted criteria in obtaining optimal stroke outcomes after thrombectomy.

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