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BRIEF COMMUNICATION

Capturing Intravenous Thrombolysis for Acute Stroke at the *ICD-9* to *ICD-10* Transition: Case Volume Discontinuity in the United States National Inpatient Sample

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BACKGROUND: Transition from *International Classification of Diseases* (*ICD*) *Ninth* and *Tenth Revisions* (*ICD-9* and *ICD-10*) for hospital discharge data was mandated for US hospitals on October 1, 2015. We examined the volume of patients receiving thrombolysis in ischemic stroke (IS) identified using *ICD* codes within this transition period in the 2015 to 2016 National Inpatient Sample, a weighted 20% sample of all inpatient US hospital discharges.

METHODS AND RESULTS: During the *ICD-10* period, 2 case identification strategies were used. Codes for IS were combined with: (1) only the *ICD-10* code for thrombolytic given into a peripheral vein and (2) all new *ICD-10* codes mapped to the *ICD-9* code for all thrombolysis. On visual inspection there was an obvious discontinuity in the volume of patients with IS treated with IV thrombolysis corresponding to 3 time periods: *ICD-9* (study period 1), transition (period 2), and *ICD-10* (period 3). With Strategy 1, analysis using a linear spline with 2 knots shows that the volume of patients with IS treated with IV thrombolysis was significantly different between study periods 1 and 2 (slope difference –1880, 95% CI –2834 to –928, P=0.005), and periods 2 to 3 (slope difference 1980, 95% CI 1207–2754, P = 0.002). With Strategy 2, volumes did not change significantly between periods 1 to 2, though there was a significant difference between periods 2 and 3 (slope difference 719, 95% CI 91–1347, P=0.034).

CONCLUSIONS: The significant discontinuity in thrombolysis volumes for IS during the transition period for *ICD-9* to *ICD-10* coding suggests that more rigorous validation of US administrative data during this time period may be necessary for research, resource planning, and quality assurance.

Key Words: *ICD-9* ■ *ICD-10* ■ ischemic stroke ■ thrombolysis ■ tissue plasminogen activator ■ trends

On October 1, 2015, transition from the use of World Health Organization's *International Classification of Diseases*, *Ninth Revision* (*ICD-9*) to *Tenth Revision* (*ICD-10*) was mandated for all US hospitals covered by the Health Insurance Portability and Accountability Act.

ICD diagnosis and procedure codes are used for health services research, quality assurance, and remuneration. Previous studies have shown good evidence of validity for both *ICD-9* and *ICD-10* codes in identifying patients with ischemic stroke (IS) in administrative data.[1] A recent study including 17 US electronic databases demonstrated no significant changes to IS incidence at the *ICD-9* to *ICD-10* transition using a forward and backward mapping strategy.[2]

Intravenous thrombolysis (IVT) is the standard of care therapy for eligible patients with acute ischemic stroke. In comparison to codes for IS, *ICD* procedural codes for thrombolysis are not well validated. However, these codes have been used previously to examine changing trends in acute stroke treatment[3,4] and the associated impact of hospital characteristics.[5,6]

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Whereas *ICD-9* coding for thrombolysis did not specify by site or method of delivery of thrombolysis, *ICD-10* introduced 10 sub-codes for thrombolysis depending on site and route of administration. In this descriptive study, we examined the volume of patients with IS treated with IVT at the time of the US transition from *ICD-9* to *ICD-10*.

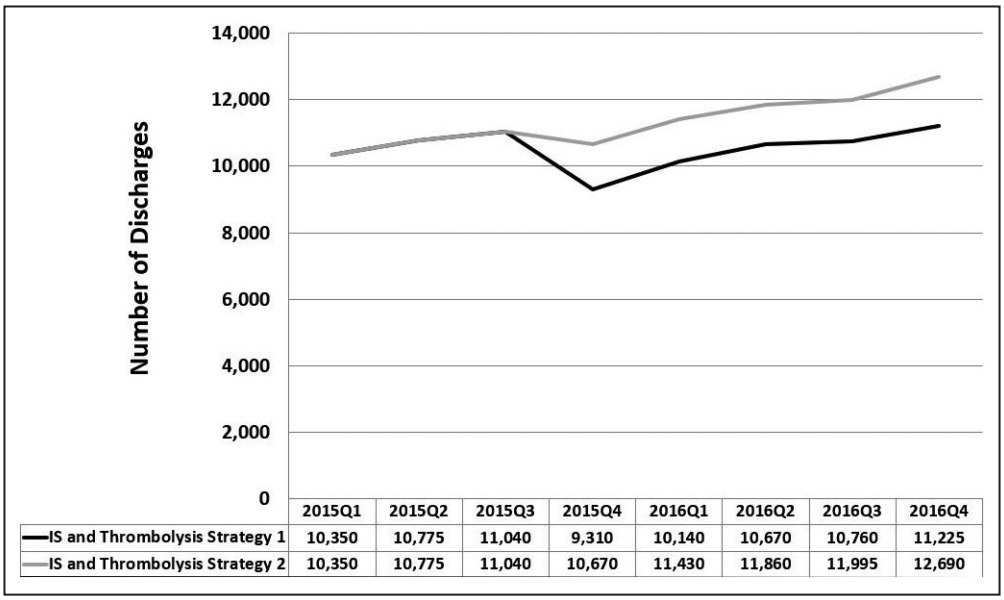
METHODS AND RESULTS

We utilized 2015 to 2016 data from the National Inpatient Sample (NIS), a publicly available data set sponsored by the Agency for Healthcare Research and Quality. It provides a weighted 20% sample of all-payer inpatient US hospital discharges.[7] A waiver of consent for use of this publicly available database was obtained from the University of British Columbia Institutional Review Board. Because of the sensitive nature of the data collected, requests to access the data set from qualified researchers trained in human subject confidentiality protocols may be sent to HCUP Central Distributor at hcup@ahrq.gov. Variable coding, national incidence estimation, and statistical analysis were performed using STATA/IC 15.1 (StataCorp LLC, College Station, TX).

All discharges from January 1, 2015 to December 31, 2016 were included. During the *ICD-9* period (January–September 2015), cases were identified using diagnostic codes for IS combined with the procedure code associated with thrombolysis (Table S1). During the *ICD-10* period (October 2015–December 2016), 2 case identification strategies were used: *ICD-10* codes for IS were combined with: (1) only the *ICD-10* code for thrombolytic given into a peripheral vein through a percutaneous approach (Strategy 1) and (2) all related *ICD-10* codes mapped to previous *ICD-9* code for thrombolysis using the Center for Medicare and Medicaid Services' General Equivalence Mappings, including injection of thrombolytic agent into a peripheral or central vein, artery, or the heart through percutaneous or open approaches (Strategy 2). The volume of patients receiving thrombolysis and then subsequently transferred to another facility ("drip and ship") was studied using 2 methods: (1) discharges identified using the strategies above and then documented to be transferred to another facility at the end of the admission (2) discharges with *ICD-9/ICD-10* codes for acute ischemic stroke and thrombolysis in a different facility within the last 24 hours prior to admission to current facility (Table S1). Method 1 represents the sending hospital and method 2 represents the receiving hospital and these volumes should be similar within sample variability.

In an exploratory analysis, the discharge disposition of patients with IS receiving thrombolysis identified using Strategy 1 and those only identified using Strategy 2 was examined. Similar, an exploratory analysis of the proportion of patients with IS receiving thrombolysis also underdoing mechanical thrombectomy on the same admission (using *ICD* codes listed in Table S2) was conducted.

National incidence estimates are calculated by applying discharge weights to the 20% sampled



	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3	2016Q4
IS and Thrombolysis Strategy 1	10,350	10,775	11,040	9,310	10,140	10,670	10,760	11,225
IS and Thrombolysis Strategy 2	10,350	10,775	11,040	10,670	11,430	11,860	11,995	12,690

Figure 1. US hospital discharges for patients with ischemic stroke treated with thrombolysis. The volume of hospital discharges for patients with ischemic stroke (IS) treated with thrombolysis identified using *International Classification of Diseases (ICD)* codes. Strategy 1 uses *ICD-10* codes for thrombolytic given in a peripheral vein; Strategy 2 uses all *ICD-10* codes mapped to previous *ICD-9* code.

Table 1. US Hospital Discharges for Patients With Ischemic Stroke 2015 to 2016

	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3	2016Q4
Total discharges	1 797 650 (8 988 249)	1 785 546 (8 927 729)	1 789 213 (8 946 064)*	1 774 617 (8 873 084)*	1 797 772 (8 988 853)	1 771 304 (8 856 513)	1 783 052 (8 915 253)	1 776 301 (8 881 498)
Thrombolysis Strategy 1†	6353 (31 765)	6356 (31 780)	6394 (31 970)*	3739 (18 695)*	3906 (19 530)	3981 (19 905)	4254 (21 270)	4286 (21 430)
Thrombolysis Strategy 2†	6353 (31 765)	6356 (31 780)	6394 (31 970)*	6066 (30 330)*	6174 (30 870)	6112 (30 560)	6391 (31 955)	6640 (33 200)
Ischemic stroke	29 569 (147 845)	29 827 (149 135)	29 748 (148 740)*	29 651 (148 255)*	30 388 (151 940)	30 279 (151 395)	30 131 (150 655)	30 756 (153 780)
IS and thrombolysis Strategy 1†	2070 (10 350)	2155 (10 775)	2208 (11 040)*	1862 (9310)	2028 (10 140)	2134 (10 670)	2152 (10 760)	2245 (11 225)
IS and thrombolysis Strategy 2†	2070 (10 350)	2155 (10 775)	2208 (11 040)*	2134 (10 670)*	2286 (11 430)	2372 (11 860)	2399 (11 995)	2538 (12 690)
Difference between strategies	N/A	N/A	N/A*	272 (1360)*	258 (1290)	238 (1190)	247 (1235)	293 (1465)
IS and thrombolysis Strategy 1† and transferred out	1016 (5080)	1005 (5025)	985 (4925)*	856 (4280)*	905 (4525)	893 (4465)	911 (4555)	947 (4735)
IS and thrombolysis Strategy 2† and transferred out	1016 (5080)	1005 (5025)	985 (4925)*	987 (4935)*	1038 (5190)	1009 (5045)	1046 (5230)	1093 (5465)
IS and received tPA at another facility <24 h ago	913 (4565)	1049 (5245)	1088 (5440)*	1059 (5295)*	1095 (5475)	1167 (5835)	1159 (5795)	1137 (5685)

Numbers reflect sampled discharges (national estimates are shown in bracket). IS indicates ischemic stroke; N/A, not applicable.

*Time of mandated transition from *ICD-9* to *ICD-10* in 2015 for US hospitals.

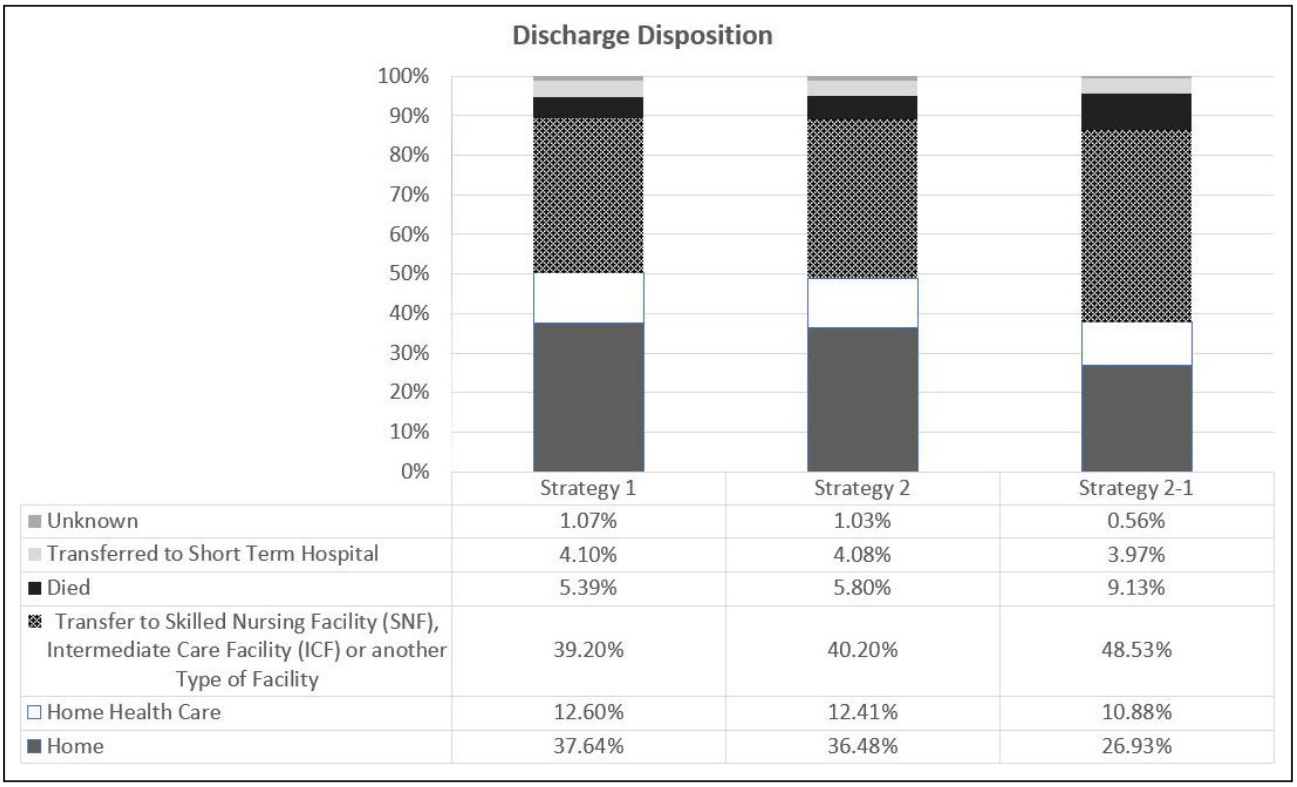
†Strategy 1 uses *International Classification of Diseases, Tenth Revision ICD-10* codes for thrombolytic given in a peripheral vein, Strategy 2 uses all *ICD-10* codes mapped to previous *ICD-9* code.

discharges adjusting for sampling technique. Trend analysis over time was plotted against discharge quarter.

The volume of patients with IS treated with IVT increased every quarter except at the time of the *ICD-9* to *ICD-10* transition. A clear visual discontinuity at the *ICD-9* to *ICD-10* transition was apparent. The 3 time periods identified with inspection corresponded to periods characterized by *ICD-9* coding, the *ICD-9* to *ICD-10* transition, and *ICD-10* coding, respectively (Figure 1). Linear regression using splines with 2 knots at the 3rd quarter of 2015 and 4th quarter of 2015 was used to demarcate 3 study periods: period 1 (Q1–3 of 2015), period 2 (Q3–4 of 2015), and period 3 (Q4 of 2015 to Q4 of 2016).

The effect of time on volume of patients with IS treated with IVT identified using Strategy 1 changed significantly from periods 1 to 2 (slope difference −1880, 95% CI −2834 to −928, P=0.005) and again from study period 2 to 3 (difference in slope 1980, 95% CI 1207–2754, P=0.002). Using Strategy 2, the change from periods 1 to 2 was not significant (slope difference −603, 95% CI −1378 to 170, P=0.096) but there was a significant change between periods 2 and 3 (slope difference 719, 95% CI 91–1347, P=0.034). A similar discontinuity was seen when "drip and ship" volumes were analyzed using Strategy 1 from period 1 to 2 (slope difference −531, 95% CI −865 to −197, P=0.012) and then again from study period 2 to 3 (difference in slope 703, 95% CI 431–974, P=0.002). Using Strategy 2, there was no significant discontinuity in "drip and ship" volumes at the time of the *ICD-9* to *ICD-10* transition. There was no discontinuity effect seen in the volume of IS or on the volume of thrombolysis patients documented as receiving thrombolysis at another facility within 24 hours during this period. The volume of discharges with diagnosis codes associated with IS, IVT using *ICD-9* and *ICD-10* procedural codes, and patients with IS transferred to another facility after IVT and those who received IVT at a prior facility within 24 hours can be found in Table. The volumes of "drip and ship" patients identified in the *ICD-10* period as receiving thrombolysis at another facility within 24 hours at the receiving hospital is consistently higher than the volume at the sending hospital using either Strategy 1 or 2 but the gap is lower using the more inclusive Strategy 2 than Strategy 1.

Within the *ICD-10* period, among patients with IS receiving thrombolysis who were only identified using Strategy 2 and not using Strategy 1, a higher proportion died during the admission (9.13% versus 5.39%, χ^2 [1, N=11 681]=28.7, $P<0.001$) and a lower proportion were discharged home (29.6 versus 37.6%, χ^2 [1, N=11 681]=55.86, $P<0.001$) (Figure 2). There was a higher proportion of patients who underwent mechanical thrombectomy during their admission among



	Strategy 1	Strategy 2	Strategy 2-1
Unknown	1.07%	1.03%	0.56%
Transferred to Short Term Hospital	4.10%	4.08%	3.97%
Died	5.39%	5.80%	9.13%
Transfer to Skilled Nursing Facility (SNF), Intermediate Care Facility (ICF) or another Type of Facility	39.20%	40.20%	48.53%
Home Health Care	12.60%	12.41%	10.88%
Home	37.64%	36.48%	26.93%

Figure 2. Discharge disposition of ischemic stroke patients identified using different *ICD* coding strategies.

patients with IS receiving thrombolysis who were only identified only using Strategy 2 (31.9% versus 8.1%, χ^2 [1, N=11 681]=666, P<0.001) (Table S3). Baseline demographics comparing patients identified using the 2 different strategies is included in Table S4.

DISCUSSION

We examined the volume of patients with IS undergoing IVT captured using *International Classification of Diseases (ICD)* coding within a 20% sample of all US discharges at the time of transition from *ICD-9* to *ICD-10*. The significant discontinuity in volumes of thrombolysis at the *ICD* transition in the context of steady volumes of IS suggest that there may be a significant proportion of cases of IS treated with IVT that were not captured when defined by only the new *ICD*-10 code specific to IVT. It is not possible to discern the validity of *ICD* diagnosis codes by examining trends in administrative data, but our findings highlight the need for further direct validation of *ICD-9* and *ICD-10* procedural codes for thrombolysis in acute ischemic stroke against pharmacy or order entry data. However, the relative preservation of thrombolysis volumes using the more inclusive *ICD-10* coding strategy and closer approximation of the "drip and ship" volumes suggest that other thrombolysis-related codes may have been inappropriately applied for IVT in patients with IS during this transition period.

Acute ischemic stroke patients coded using thrombolysis codes others than peripheral intravenous administration had worse outcomes with a higher proportion dying in hospital and a lower proportion being discharged home. There was also a higher proportion of patients who underwent mechanical thrombectomy in this group and the worse outcome likely reflects a higher proportion of patients with large vessel occlusions. An additional potential explanation for this worse outcome is the capture of thrombolysis use in another context for patients with acute ischemic stroke, such as true intra-arterial administration during endovascular therapy or possibly for other indications such as pulmonary embolism or myocardial infarction. The period of 2015 to 2016 immediately follows the 5 large landmark randomized control trials showing benefit of mechanical thrombectomy for large vessel occlusion.[8] Given that approximately one-third of all thrombolysis use in patient receiving mechanical thrombectomy was coded as receiving thrombolysis other than through percutaneous peripheral intravenous administration, (Table S3) this could reflect either (1) a much higher proportion of adjunct intra-arterial thrombolysis during this period of increased adoption of endovascular therapy,[9] or (2)

increased miscoding of the route of administration of thrombolysis in patients getting endovascular therapy.

Our study has limitations. Firstly, while more granular data by month or date of discharge would allow for better visualization and interrupted time series analysis, this information was not available within the NIS. Second, our analysis includes US hospital discharges only and may not be generalizable to other countries. Our findings suggest that future researchers should be cautious in using *ICD-10* codes to study patients with IS treated with IVT, particularly during the time of the transition between *ICD-9* to *ICD-10* coding in the US, and may wish to consider a more inclusive strategy when coding for thrombolysis exposure. Direct validation of *ICD* procedural codes for thrombolysis against pharmacy or order entry data is a needed future direction for this work.

ARTICLE INFORMATION

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Disclosures

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Supplementary Material

Tables S1–S4

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SUPPLEMENTAL MATERIAL

Table S1. ICD 9 and 10 codes used for Ischemic Stroke and IV Thrombolysis.

Ischemic Stroke	Using ICD-9 codes in the first 3 positions: • 433 (Occlusion and stenosis of precerebral arteries) OR • 434 (occlusion of cerebral arteries) OR • 436 (acute, but ill-defined, cerebrovascular disease) OR • 437.1 (Other generalized ischemic cerebrovascular disease)
	Using ICD-10 codes in the first 3 positions: • I63 (cerebral infarction) OR • I64 (stroke not specified as haemorrhage or infarction) OR • I67.81 (Acute cerebrovascular insufficiency) OR • I67.82 (Cerebral ischemia) OR • I67.89 (Other cerebrovascular disease)
Exposure to IV tPA	Using ICD-9 code in any position: 99.10 (Injection or infusion of thrombolytic agent)
	Strategy 1, using ICD-10 code in any position: • 3E03317 (Introduction of Other Thrombolytic into Peripheral Vein)
	Strategy 2, using ICD-10-PCS codes in any position: • 3E03317 (Introduction of Other Thrombolytic into Peripheral Vein, Percutaneous Approach) OR • 3E04317 (Introduction of Other Thrombolytic into Central Vein, Percutaneous Approach) OR • 3E05317 (Introduction of Other Thrombolytic into Peripheral Artery, Percutaneous Approach) OR • 3E06317 (Introduction of Other Thrombolytic into Central Artery) OR • 3E08317 (Introduction of Other Thrombolytic into Heart) OR • 3E03017 (Introduction of Thrombolytic into Peripheral Vein, Open Approach) OR • 3E04017 (Introduction of Other Thrombolytic into Central Vein, Open Approach) OR • 3E05017 (Introduction of Other Thrombolytic into Peripheral Artery, Open Approach) OR • 3E06017 (Introduction of Other Thrombolytic into Central Artery, Open Approach) OR • 3E08017 (Introduction of Other Thrombolytic into Heart, Open Approach
Receiving tPA at another hospital	Using ICD-9 code in any position: V45.88 (Status post administration of tPA (rtPA) in a different facility within the last 24 hours prior to admission to current facility)
	Using ICD-10 code in any position: Z92.82 (Status post administration of tPA (rtPA) in a different facility within the last 24 hours prior to admission to current facility)

Table S2. ICD 10 codes used for Mechanical Thrombectomy.

Mechanical thrombectomy	ICD 10 codes
	• 03CG3ZZ: Extirpation of Matter from Intracranial Artery, Percutaneous Approach • 03CG4Z6: Extirpation of Matter from Intracranial Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CG4ZZ: Extirpation of Matter from Intracranial Artery, Percutaneous Endoscopic Approach • 03CH3ZZ: Extirpation of Matter from Right Common Carotid Artery, Percutaneous Approach • 03CH4Z6: Extirpation of Matter from Right Common Carotid Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CH4ZZ: Extirpation of Matter from Right Common Carotid Artery, Percutaneous Endoscopic Approach • 03CJ3ZZ: Extirpation of Matter from Left Common Carotid Artery, Percutaneous Approach • 03CJ4Z6: Extirpation of Matter from Left Common Carotid Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CJ4ZZ: Extirpation of Matter from Left Common Carotid Artery, Percutaneous Endoscopic Approach • 03CK3ZZ: Extirpation of Matter from Right Internal Carotid Artery, Percutaneous Approach • 03CK4Z6: Extirpation of Matter from Right Internal Carotid Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CK4ZZ: Extirpation of Matter from Right Internal Carotid Artery, Percutaneous Endoscopic Approach • 03CL3ZZ: Extirpation of Matter from Left Internal Carotid Artery, Percutaneous Approach • 03CL4Z6: Extirpation of Matter from Left Internal Carotid Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CL4ZZ: Extirpation of Matter from Left Internal Carotid Artery, Percutaneous Endoscopic Approach • 03CM3ZZ: Extirpation of Matter from Right External Carotid Artery, Percutaneous Approach • 03CM4Z6: Extirpation of Matter from Right External Carotid Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CM4ZZ: Extirpation of Matter from R Ext Carotid, Perc Endo Approach • 03CN3ZZ: Extirpation of Matter from L Ext Carotid, Perc Approach • 03CN4Z6: Extirpation of Matter from Left External Carotid Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CN4ZZ: Extirpation of Matter from Left External Carotid Artery, Percutaneous Endoscopic Approach

	• 03CP3ZZ: Extirpation of Matter from Right Vertebral Artery, Percutaneous Approach • 03CP4Z6: Extirpation of Matter from Right Vertebral Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CP4ZZ: Extirpation of Matter from Right Vertebral Artery, Percutaneous Endoscopic Approach • 03CQ3ZZ: Extirpation of Matter from Left Vertebral Artery, Percutaneous Approach • 03CQ4Z6: Extirpation of Matter from Left Vertebral Artery, Bifurcation, Percutaneous Endoscopic Approach • 03CQ4ZZ: Extirpation of Matter from Left Vertebral Artery, Bifurcation, Percutaneous Endoscopic Approach

Table S3. Proportions of ischemic stroke patients undergoing thrombolysis and mechanical thrombectomy.

	No thrombolysis	Strategy 1	Strategy 2-1 (only included in strategy 2)	Total
No Mechanical Thrombectomy	136962(98.2%)	9575 (91.9%)	858 (68.1%)	147395
Mechanical Thrombectomy	2562 (1.8%)	846 (8.1%)	402 (31.9%)	3810
Total	139524 (100.0%)	10421 (100.0%)	1260 (100.0%)	

Table S4. Baseline demographics of ischemic stroke patients.

	No thrombolysis N=139524	Strategy 1 N=10421	Strategy 2-1 (only included in strategy 2) N=1260	All stroke
Mean Age (SD)	70.1 (14.6)	69.3 (14.7)	68.1 (15.4)	70.0 (14.7)
Female Sex (%)	71038 (50.9%)	5298 (50.8%)	603 (47.9%)	76939 (50.9%)
Race %				
White	92614 (66.4%)	6983 (67.0%)	823 (65.3%)	100420 (66.4%)
Black	22697 (16.3%)	1567 (15.0%)	189 (15.0%)	24453 (16.2%)
Hispanic	10437 (7.5%)	868 (8.3%)	103 (8.2%)	11408 (7.5%)
Asian or Pacific Islander	3862 (2.8%)	315 (3.0%)	44 (4.5%)	4221 (2.8%)
Native American	635 (0.5%)	24 (0.2%)	<10 (<0.1%)	663 (0.4%)
Other	3481 (2.5%)	294 (2.8%)	39 (3.1%)	3814 (2.5%)
Missing	5798 (4.2%)	370 (3.6%)	58 (4.6%)	6226 (4.1%)
Income Quartile by Zip-code*				
1st	43313 (31.0%)	2785 (26.7%)	357 (28.3%)	46455 (30.7%)
2nd	35143 (25.2%)	2414 (23.2%)	293 (23.3%)	37850 (25.0%)
3rd	32575 (23.4%)	2632 (25.3%)	306 (24.3%)	35513 (23.5%)
4th	26.166 (18.8%)	2421 (23.2%)	276 (21.9%)	28863 (19.9%)
Missing	2327 (1.7%)	169 (1.6%)	28 (2.2%)	2524 (1.7%)

*For annual median household income estimate quartiles in 2015 (1st <42,000 USD, 2nd 42,000-51,999, 3rd 52,000-67.999, 4th >68,000) and in 2016 (1st <43,000 USD, 2nd 42,000-53,999, 3rd 54,000-67.999, 4th >71,000)