

Strategy for reliable identification of ischaemic stroke, thrombolytics and thrombectomy in large administrative databases

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ABSTRACT

Background Administrative data are frequently used in stroke research. Ensuring accurate identification of patients who had an ischaemic stroke, and those receiving thrombolysis and endovascular thrombectomy (EVT) is critical to ensure representativeness and generalisability. We examined differences in patient samples based on mode of identification, and propose a strategy for future patient and procedure identification in large administrative databases.

Methods We used non-public administrative data from the state of California to identify all patients who had an ischaemic stroke discharged from an emergency department (ED) or inpatient hospitalisation from 2010 to 2017 based on International Classification of Disease (ICD-9) (2010–2015), ICD-10 (2015–2017) and Medicare Severity-Diagnosis-related Group (MS-DRG) discharge codes. We identified patients with interhospital transfers, patients receiving thrombolytics and patients treated with EVT based on ICD, Current Procedural Terminology (CPT) and MS-DRG codes. We determined what proportion of these transfers and procedures would have been identified with ICD versus MS-DRG discharge codes.

Results Of 365 099 ischaemic stroke encounters, most (87.70%) had both a stroke-related ICD-9 or ICD-10 code and stroke-related MS-DRG code; 12.28% had only an ICD-9 or ICD-10 code and 0.02% had only an MS-DRG code. Nearly all transfers (99.99%) were identified using ICD codes. We identified 32 433 thrombolytic-treated patients (8.9% of total) using ICD, CPT and MS-DRG codes; the combination of ICD and CPT codes identified nearly all (98%). We identified 7691 patients treated with EVT (2.1% of total) using ICD and MS-DRG codes; both MS-DRG and ICD-9/ICD-10 codes were necessary because ICD codes alone missed 13.2% of EVTs. CPT codes only pertain to outpatient/ED patients and are not useful for EVT identification.

Conclusions ICD-9/ICD-10 diagnosis codes capture nearly all ischaemic stroke encounters and transfers, while the combination of ICD-9/ICD-10 and CPT codes are adequate for identifying thrombolytic treatment in administrative datasets. However, MS-DRG codes are necessary in addition to ICD codes for identifying EVT, likely due to favourable reimbursement for EVT-related MS-DRG codes incentivising accurate coding.

INTRODUCTION

Administrative database studies of ischaemic stroke often use discharge diagnosis codes

(ie, International Classification of Disease, clinical modification, ninth revision, (ICD-9-CM) or tenth revision (ICD-10-CM)) and procedure codes (ICD-9-procedural coding system (ICD-9-PCS), ICD-10-PCS, Current Procedural Terminology (CPT)) to identify patients and the subset who receive thrombolytics or endovascular thrombectomy (EVT).^{1–8} However, variation in patient-level and hospital-level coding exists,⁹ and ICD-9 codes have been reported to underestimate thrombolytic treatment.¹⁰ Medicare Severity-Diagnosis-related Group (MS-DRG) codes are more closely connected with patient billing and may be a more accurate means for identification of patients and treatments received. Prior work has demonstrated changes in ICD-9 coding with the introduction of the MS-DRG system¹¹; however, there is limited information regarding the utility of using MS-DRG codes to identify patients who had a stroke and procedures.

We investigated different analytic strategies using the combination of diagnosis codes and procedure codes to identify the following patient groups in a large administrative database: patients who had an ischaemic stroke, transferred patients, patients receiving thrombolytics and patients receiving EVT. We sought to determine the optimal combination of codes for the identification of patients who had an ischaemic stroke and procedures using administrative data, and to determine whether there is additional value in the use of MS-DRG codes.

METHODS

Data sources

We used non-public data maintained by the California Office of Statewide Health Planning and Development¹² including all emergency department (ED) and hospital discharges from all non-federal, acute care

hospitals licensed in California. This study was approved by the local Institutional Review Board.

Patient and procedure identification

We identified all ED and hospital discharges from acute care hospitals for ischaemic stroke from 2010 to 2017 based on primary ICD-9-CM discharge codes (433.xx excluding 433.10, 434.xx and 436 for discharges from 2010 through the third quarter of 2015), or primary ICD-10-CM codes (I63 for discharges from the fourth quarter of 2015–2017), or MS-DRG codes (061, 062, 063).^{1–4 8 11} Hospital discharges identified any inpatient hospital stay, whereas ED discharges were used to identify ED records of patients who were subsequently transferred to another hospital for inpatient stay. In addition, we also obtained data on MS-DRGs codes 064, 065 and 066 which may be used for patients who had an ischaemic or haemorrhagic stroke, and 023 and 024 codes which may be used for patients who had an ischaemic stroke who receive EVT, or for other procedures not related to ischaemic stroke. When any of these additional MS-DRGs (064, 065, 066, 023 and 024) were used, we required one of the specified ICD-9-CM or ICD-10-CM codes for ischaemic stroke to be present also to identify the subject as a case of interest.

We identified patients transferred between hospitals using an established strategy.^{13 14} After identifying all ischaemic stroke hospitalisations, we used a unique patient identifier to look backward in ED and inpatient data to identify any earlier records. The earlier record could have any length of stay, provided that the discharge date was on the preceding or the same day as the index admission. If this earlier record had a discharge disposition consistent with transfer, and a discharge date that was the preceding or the same day as the index hospital admission date, then these records were linked to establish an ED-to-inpatient or an inpatient-to-inpatient transfer. We did not require any particular ICD or MS-DRG discharge code to be associated with the initial visit, recognising that, especially for patients transferred from an ED, a final diagnosis is often not yet established. The use of another code (eg, for weakness or headache) would not preclude a transfer for stroke as long as the final discharge diagnosis from the second hospital met our case definition of ischaemic stroke.

Using established methods and approaches,^{6 15} we identified patients receiving thrombolytic based on the presence of any one of the following: ICD-9-PCS code (9910), a secondary ICD-9-CM code (V4588), ICD-10-PCS code (3E03317), a secondary ICD-10-CM code (Z9282), CPT codes (37195, 37201, 37202) or MS-DRG codes (061, 062, 063 alone; or 065 with a corresponding ICD-9 or ICD-10 code indicating alteplase receipt). These codes were not required to be in the primary position.

We identified patients treated with EVT based on the presence of any one of the following: ICD-9-PCS code (3974, 1753, 1754), ICD-10-PCS code (03CG3ZZ, 03CH3ZZ, 03CJ3ZZ, 03CK3ZZ, 03CL3ZZ, 03CM3ZZ, 03CN3ZZ,

03CP3ZZ, 03CQ3ZZ) or MS-DRG (023, 024).^{6 7} MS-DRG codes 023 and 024 may also be used for craniotomy or device implantation procedures. Therefore, when 023 and 024 were present, we only identified EVT among observations with a primary ICD-9/ICD-10 diagnosis of ischaemic stroke, and who did not have any ICD-9-PCS/ICD-10-PCS codes for craniotomy, craniectomy or ventriculostomy (online supplemental table IV).^{16–19} These codes were not required to be in the primary position. We did not use CPT codes for EVT because (consistent with national coding standards) our data only used CPT codes for ED patients, and all EVT-treated patients were treated as inpatient hospitalisations rather than ED patients.

We examined patient age, sex, race/ethnicity, expected payer and urban/rural location, overall and for each group of patients based on identification strategy. Urban versus rural location was based on county-level urban influence codes in 2013.²⁰

We categorised each ischaemic stroke observation based on whether it was identifiable by ICD code only, by MS-DRG only or by both. Within each group, we determined the proportions of transfer, thrombolytic-treated and EVT-treated patients identified.

Among patients identified by ICD-9 or ICD-10 code only (ie, without one of our designated MS-DRG codes), we identified and reviewed the 10 most frequent MS-DRG codes used. Likewise, among patients identified by MS-DRG code (061, 062, 063) without a designated ICD-9 or ICD-10 code, we identified and reviewed the 10 most frequent ICD-9 or ICD-10 codes used.

RESULTS

Identification of patients who had an ischaemic stroke

We found 437 851 encounters with either a primary ICD-9-CM, ICD-10-CM or MS-DRG code for ischaemic stroke between 2010 and 2017. We excluded 30 890 for missing unique patient-identifier (ie, the visit link variable), 3627 records from non-acute hospitals and 38 235 because they lacked an inpatient admission, giving a final sample of 365 099 encounters (figure 1).

The vast majority of patients (87.70%, n=320 187) had both a designated ICD-9-CM or ICD-10-CM code and a designated MS-DRG code, the remainder had only a designated ICD-9-CM or ICD-10-CM code (12.28%, n=44 839); the most frequently appearing MS-DRG codes for these latter patients are presented in the online supplemental material. Very few patients were identified by MS-DRG code without a designated ICD-9-CM or ICD-10-CM code (0.02%, n=73); the most frequently appearing ICD-9-CM or ICD-10-CM codes for these patients are also presented in the online supplemental material. Observations in the MS-DRG only group tended to be younger, less often white and less often rural, than patients with ICD-9-CM or ICD-10-CM codes (table 1).

Identification of transferred patients

Of the 365 099 encounters in our sample, we identified 18 859 (5.2%) transfers between hospitals using

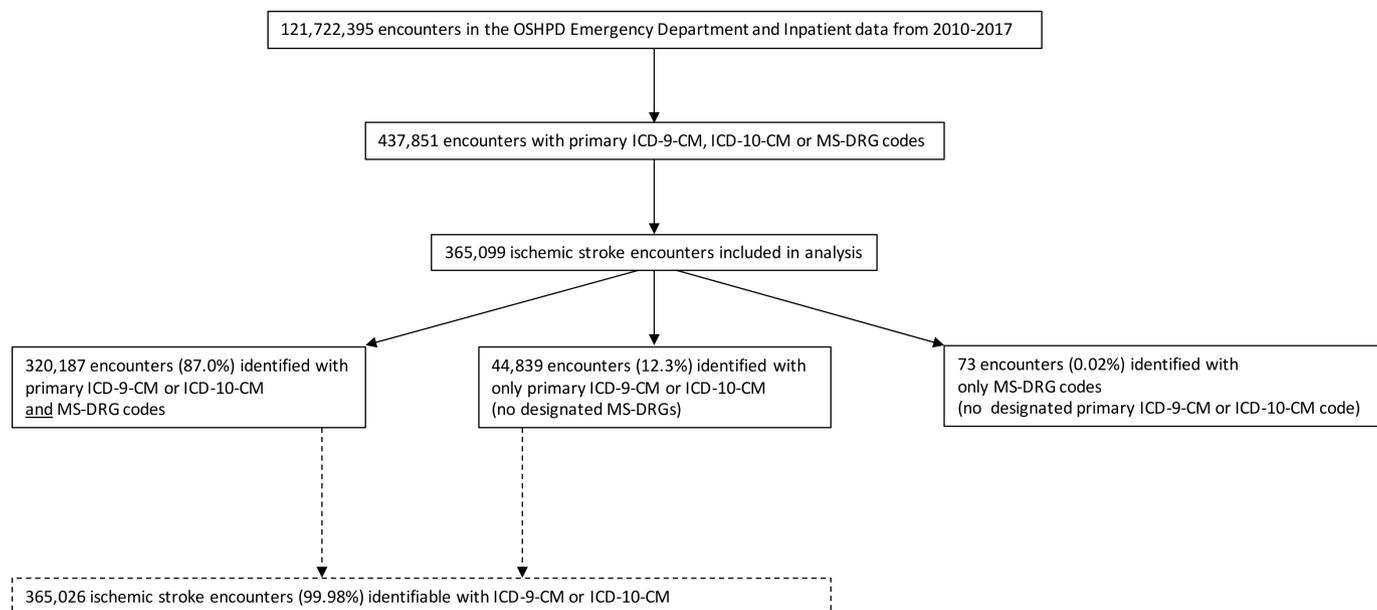


Figure 1 Patient inclusion and identification flow diagram. ICD-CM: International Classification of Disease, clinical modification; MS-DRG: Medicare Severity-Diagnosis-related Group; OSHPD: Office of Statewide Health Planning and Development.

either ICD-9-CM, ICD-10-CM or MS-DRG codes at each encounter; 12 616 of the transfers (66.9%) originated in the ED and 6243 of the transfers (33.1%) were inpatient-to-inpatient. When requiring each encounter to have both a designated primary ICD-9-CM or ICD-10-CM diagnosis code and a designated MS-DRG code, the total sample size was 320 187 (figure 1) only 5442 transfers (1.7%) were identifiable if both the first and second encounter were also required to have both a designated primary ICD-9-CM or ICD-10-CM diagnosis code and a designated MS-DRG code.

Of the 44 839 encounters with only a designated primary ICD-9-CM or ICD-10-CM diagnosis code, 779 transfers (1.7%) were identified, and of the 73 encounters with only a designated MS-DRG, no transfers were identified. Finally, we combined the encounters with the designated ICD-9-CM and ICD-10-CM codes that did and did not also have the designated MS-DRG codes to examine the group of observations identifiable by ICD code regardless of DRG code agreement. Among these 365 026 encounters, 18 855 transfers were identifiable (5.2%). Thus, in a dataset with only ICD codes, 99.99% of interhospital transfers would be identifiable (table 2).

Identification of thrombolytic receipt

In our sample of 365 099 ischaemic stroke encounters from 2010 to 2017, we identified 32 506 patients treated with thrombolytic (8.9%) based on the combination of ICD, CPT and MS-DRG codes. Of the 365 026 stroke encounters identified by ICD-9-CM or ICD-10-CM code with or without a designated MS-DRG, 31 862 patients received thrombolytic (8.7%) based on ICD and CPT codes. Because of the rules used to identify these encounters, all 73 of the stroke encounters identified by MS-DRG

only received thrombolytic treatment. Thus, in a dataset with only ICD and CPT codes, only a very small proportion of thrombolytic treatments would be missed (1.8%).

Identification of EVT receipt

In the same sample of 365 099 ischaemic stroke encounters, we identified 7691 treated with EVT (2.1%) based on the combination of ICD-PCS and MS-DRG codes. Because the MS-DRGs used for EVT may also be used for patients who had other non-ischaemic stroke diagnoses, when MS-DRG codes were used to identify patients, we required the patient to also have a primary ICD-9-CM or ICD-10-CM consistent with ischaemic stroke. Therefore, none of the observations in our sample identified by MS-DRG alone had received EVT.

Given that ICD-9-CM and ICD-10-CM codes could identify ischaemic stroke hospitalisations, interhospital transfers and administration of thrombolytic with sufficient accuracy and completeness, we sought to determine whether MS-DRG had any added value for identification of EVT, or if, instead ICD-9 and ICD-10 codes were entirely sufficient. Limiting to the sample of 365 026 patients with ischaemic stroke identified by ICD-9-CM or ICD-10-CM codes (with or without an MS-DRG code), 273 EVT procedures (3.6%) were identified by ICD-9-PCS or ICD-10-PCS code only; 6401 (83.2%) had both ICD-PCS and MS-DRG codes for EVT, and 1017 (13.2%) were identified by MS-DRG code only. Thus, in a dataset with only ICD codes, 13.2% of EVT cases would be missed.

Proposed identification strategy

To summarise, the use of primary ICD-9-CM and ICD-10-CM diagnosis codes identifies 99.98% of all patients who had an ischaemic stroke in this large administrative

Table 1 Characteristics of patients based on identification strategy

	Union			Overlap	P value
	(ICD-CM or MS-DRG) n=365 099	ICD-CM codes only n=44 839	MS-DRG codes only n=73	(ICD-CM and MS-DRG) n=320 187	
<i>Patient characteristics</i>					
Median age (IQR)	73 (62–83)	71 (61–81)	67 (55–81)	73 (62–83)	<0.001
Female, n (%)	182 588 (50.0)	20 249 (45.2)	36 (49.3)	162 303 (50.7)	<0.001
Race/ethnicity, n (%)					
White	201 704 (55.2)	25 514 (56.9)	36 (49.3)	176 154 (55.0)	<0.001
Black	37 780 (10.4)	4 571 (10.2)	7 (9.6)	33 202 (10.4)	
Asian/Pacific Islander	38 589 (10.6)	3 788 (8.4)	4 (5.5)	34 797 (10.9)	
Hispanic	72 226 (19.8)	8 767 (19.6)	23 (31.5)	63 436 (19.8)	
Other	12 137 (3.3)	1 636 (3.6)	2 (2.7)	10 499 (3.3)	
Missing	2 663 (0.7)	563 (1.3)	1 (1.4)	2 099 (0.6)	
Expected payer, n (%)					
Medicare	232 145 (63.6)	19 162 (42.7)	37 (50.7)	212 946 (66.5)	<0.001
Medicaid	43 287 (11.9)	4 804 (10.7)	13 (17.8)	38 470 (12.0)	
Private insurance	71 343 (19.5)	18 436 (41.1)	22 (30.1)	52 885 (16.5)	
Self-pay	9 050 (2.5)	1 461 (3.3)	0 (0.0)	7 589 (2.4)	
Other	9 274 (2.5)	976 (2.2)	1 (1.4)	8 297 (2.6)	
Rural residence, n (%)	10 487 (2.9)	2 298 (5.1)	1 (1.4)	8 188 (2.6)	<0.001
<i>Hospital characteristics*</i>					
Rural location, n (%)	7 807 (2.1)	2 150 (4.8)	0 (0.0)	5 657 (1.8)	<0.001
Academic, n (%)	52 617 (14.4)	5 604 (12.5)	12 (16.4)	47 001 (14.7)	<0.001
Stroke centre status, n (%)					
None	60 459 (16.5)	9 441 (21.0)	3 (4.1)	51 015 (15.9)	<0.001
Acute Stroke Ready Hospital	975 (0.3)	261 (0.6)	0 (0.0)	714 (0.2)	
Primary Stroke Center	239 603 (65.6)	28 504 (63.6)	58 (79.5)	211 041 (65.9)	
Thrombectomy-capable or Comprehensive Stroke Center	64 062 (17.6)	6 633 (14.8)	12 (16.4)	57 417 (18.0)	

*Hospital characteristics are presented at the visit level.

ICD-CM, International Classification of Disease, clinical modification; MS-DRG, Medicare Severity-Diagnosis-related Group.

database, regardless of MS-DRG. Identification of transferred patients also can be achieved with ICD codes only, with almost full capture. For identification of thrombolytic and EVT treatments, MS-DRGs should be considered in combination with ICD-9 or ICD-10 procedure codes or secondary ICD-9-CM or ICD-10-CM codes or CPT codes when available. However, if MS-DRGs are unavailable, the use of ICD and CPT codes only minimally underestimates thrombolytic receipt. With respect to EVT, both ICD-PCS codes and MS-DRG codes are required to fully capture all procedures (box 1).

DISCUSSION

In a large administrative database, with ICD diagnosis and procedure codes, CPT codes and MS-DRG codes available, we investigated the identification of patients who had an ischaemic stroke, interhospital transfers and

receipt of thrombolytic or EVT treatments. After identification of patients who had an ischaemic stroke, we identified nearly all patient transfers using ICD-9-CM and ICD-10-CM coding alone and nearly all patients treated with thrombolytic were identifiable using ICD-9-PCS and ICD-9-CM, ICD-10-PCS and ICD-10-CM, and CPT coding. By contrast, we found that use of MS-DRG codes enabled identification of a substantial group of EVT procedures that would have otherwise been missed.

Previous studies have evaluated the accuracy of ICD codes for identification of patients who had a stroke.^{8 21–25} These studies have found varying concordance between ICD codes and clinical diagnoses, with some reporting higher concordance^{21–23} while two international studies demonstrated lower sensitivity.^{24 25} It is likely that there are differences in coding practices and quality by region. We now extend this literature by reporting all-payer

Table 2 Identification of transfers, thrombolysis and EVT treatments, by patient identification strategy

	Interhospital transfer, n (%)	Thrombolysis, n (%)	EVT, n (%)
Ischaemic stroke observations with ICD-9-CM, ICD-10-CM or MS-DRG (ie, Union) n=365 099	18 859 (5.2) ICD-9-CM/ICD-10-CM MS-DRG	32 506 (8.9) ICD-9-CM/ICD-10-CM ICD-9-PCS/ICD-10-PCS MS-DRG CPT	7691 (2.1) ICD-9-PCS/ICD-10-PCS MS-DRG
Ischaemic stroke observations with ICD-9-CM, ICD-10-CM or MS-DRG (ie, Union) n=365 099	18 855 (5.2) ICD-9-CM/ICD-10-CM	31 932 (8.7) ICD-9-CM/ICD-10-CM ICD-9-PCS/ICD-10-PCS CPT	6674 (1.8) ICD-9-PCS/ICD-10-PCS 10-PCS
Ischaemic stroke observations with ICD-9-CM, ICD-10-CM (with or without MS-DRG) n=365 026	18 855 (5.2) ICD-9-CM/ICD-10-CM MS-DRG	32 433 (8.9) ICD-9-CM/ICD-10-CM ICD-9-PCS/ICD-10-PCS MS-DRG CPT	7691 (2.1) ICD-9-PCS/ICD-10-PCS 10-PCS MS-DRG
Ischaemic stroke observations with ICD-9-CM, ICD-10-CM (with or without MS-DRG) n=365 026	18 855 (5.2) ICD-9-CM/ICD-10-CM	31 862 (8.7) ICD-9-CM/ICD-10-CM ICD-9-PCS/ICD-10-PCS CPT	6674 (1.8) ICD-9-PCS/ICD-10-PCS 10-PCS
Ischaemic stroke observations with both ICD-9-CM or ICD-10-CM and MS-DRG (ie, overlap) n=320 187	5442 (1.7) ICD-9-CM/ICD-10-CM MS-DRG	27 874 (8.7) ICD-9-CM/ICD-10-CM ICD-9-PCS/ICD-10-PCS MS-DRG	7418 (2.3) ICD-9-PCS/ICD-10-PCS 10-PCS MS-DRG
Ischaemic stroke observations with ICD-9-CM or ICD-10-CM only* n=44 839	779 (1.7) ICD-9-CM/ICD-10-CM	2172 (4.8) ICD-9-CM/ICD-10-CM ICD-9-PCS/ICD-10-PCS CPT	273 (0.6) ICD-9-PCS/ICD-10-PCS 10-PCS
Ischaemic stroke observations with MS-DRG only† n=73	0 (0) MS-DRG	73 (100) MS-DRG	0 (0) MS-DRG

*MS-DRGs for these patients are presented in the online supplemental material.

†Primary ICD-9-CM/ICD-10-CM codes for these patients are presented in the online supplemental material.

CPT, Current Procedural Terminology; EVT, endovascular thrombectomy; ICD-CM, International Classification of Disease, clinical modification; ICD-PCS, International Classification of Disease, procedural coding system; MS-DRG, Medicare Severity-Diagnosis-related Group.

administrative data from California, and considering whether MS-DRG codes should also be included in the identification of stroke admissions, transfers and procedures used in patients who had an ischaemic stroke. Because many of the potential MS-DRGs for patients who had an ischaemic stroke are broad enough to include other non-ischaemic stroke observations, our strategy required a designated ICD-9-CM or ICD-10-CM code in combination with MS-DRG codes that are most commonly used for ischaemic stroke. As a result, the only MS-DRG codes that could identify an ischaemic stroke observation independently were those used for patients who had an ischaemic stroke that had received thrombolysis. This likely explains why the group of observations identified by MS-DRG alone was so small.

With increasing rates of EVT in the population,²⁶ in the future we may find the MS-DRGs for EVT may be even more frequently used. In our data, we found increasing frequency of EVT over time, and particularly after 2014. In each year of data, the addition of MS-DRG codes identified more EVT procedures than would have been

identified with ICD procedure codes alone. However, given that the MS-DRGs used for EVT may also be used for patients with procedures not related to ischaemic stroke, these MS-DRGs in isolation will still not be adequate for identifying ischaemic stroke observations, and so ICD-10-CM codes will be required to verify an ischaemic stroke diagnosis. It is important to note that CPT codes, used for outpatient or ED visits, have no additional value for EVT identification given that EVT-receiving patients are inpatients at the time of the procedure.

In prior studies, methods for identification and subsequent population-level estimates of thrombolytic and EVT use have varied.^{6 7 10 11 27} In order to adequately understand changes in stroke care delivery, disparities in care delivery between population and the effects on patient outcomes, it is critical to have a consensus standard for classification and identification of cases going forward. While administrative data files do not capture the same degree of nuance and diagnostic accuracy as clinical registry data, nevertheless they are commonly used by investigators and federal officials to conduct

Box 1 Proposed strategy for identification of patients who had an ischaemic stroke in administrative data

Identification of ischaemic stroke hospitalisations

Primary International Classification of Disease, clinical modification, ninth revision (ICD-9-CM) codes (433.xx.xx excluding 433.10, 434.xx.xx and 436), primary ICD-10-CM codes (I63) are sufficient for identification of ischaemic stroke hospitalisations.

Identification of interhospital transfers

After identifying all ischaemic stroke hospitalisations, look backward in ED and inpatient data to identify any earlier records with discharge date on the same or preceding day of the index admission. If this record had a discharge disposition consistent with transfer, these records are linked to establish an ED-to-inpatient or an inpatient-to-inpatient transfer. No restrictions are necessary for the initial hospital diagnosis, recognising that the final diagnosis may not always be apparent at the time of an acute hospital transfer.

Identification of patients treated with thrombolytic

ICD-9 procedural coding system (PCS) code (9910), a secondary ICD-9-CM code (V4588), ICD-10-PCS code (3E03317), a secondary ICD-10-CM code (Z9282) or Current Procedural Terminology (CPT) code (37195, 37201, 37202). If available, use of MS-DRG codes will enable identification of a small additional group (061, 062, 063, alone or 065 with a corresponding ICD-9 or ICD-10 code indicating alteplase receipt).

Identification of patients receiving EVT

ICD-9-PCS code (3974, 1753, 1754), ICD-10-PCS code (03CG3ZZ, 03CH3ZZ, 03CJ3ZZ, 03CK3ZZ, 03CL3ZZ, 03CM3ZZ, 03CN3ZZ, 03CP3ZZ, 03CQ3ZZ) or MS-DRG (023, 024). When MS-DRG 023 or 024 is used in the absence of an ICD-9-PCS/ICD-10-PCS code indicating EVT, we exclude those patients with an ICD-9-PCS/ICD-10-PCS code indicating craniectomy/craniotomy/ventriculostomy. An approach without MS-DRG codes will substantially underestimate thrombectomy procedures.

ED, emergency department; EVT, endovascular thrombectomy; MS-DRG, Medicare Severity-Diagnosis-related Group.

analyses on stroke prevalence, incidence, payment policy and outcomes. Given this reality, we feel it is important to present what we believe to be a more accurate method for optimal case ascertainment by leveraging ICD and DRG codes together. Furthermore, there must be vigilance to any changes in reimbursement or coding so that the strategy remains accurate. Our findings highlight the importance of this issue, by demonstrating the inadequacy of prior strategies using ICD-9 and ICD-10 codes alone for accurately capturing EVT rates in this large administrative dataset. It is important to note that our study period did include 2015, which coincided with the publication of benefit for EVT and the transition from ICD-9 to ICD-10.

In our proposed strategy for identification of patients who had an ischaemic stroke in administrative databases, we suggest that ICD codes are sufficient for patient identification, as well as interhospital transfers and administration of thrombolytic therapy. For accurate identification of EVT procedures, however, MS-DRGs were also required to ensure complete capture. Failing to also use MS-DRG

codes could lead to EVT underestimates and potentially bias results.

The study does have potential limitations. We used a single-state database and these results may not be generalisable to other states or other administrative data. However, California is a large state with a diversity of patients and hospital settings and is more broadly representative than many other states. In addition, we did not have clinical data to use as a criterion standard, so our comparisons were based in ICD versus DRG identification without knowing whether there is another group of patients who had a stroke that both types of administrative coding had missed altogether. However, previous research in US data suggests that ICD codes are accurate for patient with stroke identification,²⁸ therefore, we believe the primary contribution of our research is in determining the potential additional value added by MS-DRG codes. We also do not have a criterion standard for verification of transfers and procedures, and we are unable to determine whether our process led to inaccurate identification of some transfers or procedures (ie, false positives). Further validation studies are required to confirm the accuracy of using the MS-DRGs for EVT identification. Finally, previous work has found that pharmacy data (eg, the Premier database) may further augment identification of thrombolysis administration in administrative data.^{10 27} While we did not analyse pharmacy data in this analysis, we identified thrombolytic administration in over 8% of patients overall, which is higher than the rates in previous studies, suggesting differences in data sources or that changes in coding practices may have occurred since that time.

CONCLUSION

Administrative data are frequently used for the study of stroke care delivery and outcomes. ICD-9, ICD-10 and CPT codes are appropriate for identification of patients who had an ischaemic stroke, interhospital transfers and delivery of thrombolytics. However, MS-DRG codes are also required to identify EVT procedures. Based on these findings, we provide a strategy for the identification of patients who had an ischaemic stroke and relevant-related treatments using administrative data.

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Correction notice The article has been corrected since it has been published online first. The value "27202" has been corrected to "37202" in Box 1.

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Provenance and peer review Not commissioned; externally peer reviewed.

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SUPPLEMENTAL MATERIAL to**A Strategy for Reliable Identification of Ischemic Stroke, Thrombolytics, and Thrombectomy in Large Administrative Databases**

Table I. ICD-CM, ICD-PCS, CPT, and MS-DRG used for identification of stroke patients and procedures

Table II. Most frequent non-designated MS-DRG codes among patients identified by ICD-9-CM or ICD-10-CM only

Table III. Most frequent ICD-9-CM or ICD-10-CM codes among patients identified by MS-DRG only

Table I. ICD-CM, ICD-PCS, CPT, and MS-DRG used for identification of stroke patients and procedures

Ischemic Stroke Patient Identification	
ICD-9-CM Codes	
433.xx, excluding 433.10	Occlusion and stenosis of precerebral arteries, excluding occlusion and stenosis of carotid artery without mention of cerebral infarction
434.xx	Occlusion of cerebral arteries
436	Acute but ill-defined cerebrovascular disease
ICD-10-CM Code	
I63	Cerebral infarction
MS-DRG Codes	
061	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent with MCC
062	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent with CC
063	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent without CC/MCC
Additional MS-DRG codes used, if present in combination with an above ICD-9-CM or ICD-10-CM code for ischemic stroke	
064	Intracranial hemorrhage or cerebral infarction with MCC
065	Intracranial hemorrhage or cerebral infarction with CC or tPA in 24 hours
066	Intracranial hemorrhage or cerebral infarction without CC/MCC
023	Craniotomy w major device implant or acute complex central nervous system principal diagnosis w MCC
024	Craniotomy w major device implant or acute complex central nervous system principal diagnosis w/o MCC
Thrombolytic Identification	
ICD-9-PCS Code	
9910	Injection or infusion of thrombolytic agent
ICD-9-CM Code	
V4588	Status post administration of tPA in a different facility within the last 24 hours prior to admission to current facility
ICD-10-PCS Code	
3E03317	Introduction of other thrombolytic into peripheral vein, percutaneous approach
ICD-10-CM Code	

Z9282	Status post administration of tPA in a different facility within the last 24 hours prior to admission to current facility
CPT Codes	
37195	Thrombolysis, cerebral, by intravenous infusion
37201	Transcatheter therapy, infusion for thrombolysis other than coronary
37202	Transcatheter therapy, other than thrombolysis, chemotherapy, or embolization
MS-DRG Codes	
061	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent with MCC
062	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent with CC
063	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent without CC/MCC
065, if present in combination with a corresponding ICD-9 or ICD-10 code indicating alteplase receipt	Intracranial hemorrhage or cerebral infarction with CC or TPA in 24 hours
EVT Identification	
ICD-9-PCS Codes	
3974	Endovascular removal of obstruction from head and neck vessel(s)
1753	Percutaneous atherectomy of extracranial vessel(s)
1754	Percutaneous atherectomy of intracranial vessel(s)
ICD-10-PCS Codes	
03CG3ZZ	Extirpation of matter from intracranial artery, percutaneous approach
03CH3ZZ	Extirpation of matter from right common carotid artery, percutaneous approach
03CJ3ZZ	Extirpation of matter from left common carotid artery, percutaneous approach
03CK3ZZ	Extirpation of matter from right internal carotid artery, percutaneous approach
03CL3ZZ	Extirpation of matter from left internal carotid artery, percutaneous approach
03CM3ZZ	Extirpation of matter from right external carotid artery, percutaneous approach
03CN3ZZ	Extirpation of matter from left external carotid artery, percutaneous approach
03CP3ZZ	Extirpation of matter from left vertebral artery, percutaneous approach
03CQ3ZZ	Extirpation of matter from left vertebral artery, percutaneous approach

MS-DRG Codes	
023	Craniotomy w major device implant or acute complex central nervous system principal diagnosis w MCC
024	Craniotomy w major device implant or acute complex central nervous system principal diagnosis w/o MCC

Legend: ICD-CM: International Classification of Disease, Clinical Modification; ICD-PCS: ICD Procedural Coding System; CPT: Current Procedural Terminology; MS-DRG: Medicare Severity-Diagnosis-Related Group; MCC: major complication or comorbidity; CC: complication or comorbidity; tPA: tissue plasminogen activator; EVT: endovascular thrombectomy

Table II. Most frequent non-designated MS-DRG codes among patients identified by ICD-9-CM or ICD-10-CM only

MS-DRG	Frequency	
038	2,208	Extracranial procedures w CC
068	1,872	Nonspecific CVA & precerebral occlusion w/o infarct w/o MCC
039	1,797	Extracranial procedures w/o CC/MCC
037	1,431	Extracranial procedures w MCC
041	1,367	Periph/cranial nerve & other nerv syst proc w CC or periph neurostim
004	1,341	Tracheostomy with mv >96 hours or PDX except face, mouth and neck without major O.R. procedure
040	1,334	Periph/cranial nerve & other nerv syst proc w MCC
981	1,112	Extensive O.R. procedure unrelated to principal diagnosis w MCC

Legend: MS-DRG: Medicare Severity-Diagnosis-Related Group; ICD-CM: International Classification of Disease, Clinical Modification; CC: complication or comorbidity; CVA: cerebrovascular attack; MCC: major complication or comorbidity; O.R.: operating room

Table III. Most frequent ICD-9-CM or ICD-10-CM codes among patients identified by MS-DRG only

Primary Diagnosis Code	Frequency	
G459	57	Transient ischemic attack
G458	6	Subclavian steal syndrome
I651	2	Occlusion and stenosis of basilar artery
I6601	2	Occlusion and stenosis of right middle cerebral artery
I6602	2	Occlusion and stenosis of left middle cerebral artery
I6782	2	Reversible cerebral vasoconstriction syndrome
I6501	1	Occlusion and stenosis of right vertebral artery
I67841	1	Reversible cerebrovascular vasoconstriction syndrome

Legend: ICD-CM: International Classification of Disease, Clinical Modification; MS-DRG: Medicare Severity-Diagnosis-Related Group

Table IV. ICD-9 and ICD-10 PCS codes used to identify craniotomy, craniectomy, or ventriculostomy among patients with MS-DRG 023 and 024

Procedure	Type of Code	Code
Craniotomy or craniectomy	ICD-9 CM PCS	01.24 01.25 01.31 01.39 01.53 01.59
	ICD-10-CM PCS	00J00ZZ 00W00JZ 00W00KZ 0N800ZZ 0N803ZZ 0N804ZZ 0NC10ZZ 0NC13ZZ 0NC14ZZ 0NC30ZZ 0NC33ZZ 0NC34ZZ 0NC40ZZ 0NC43ZZ 0NC44ZZ 0NC50ZZ 0NC53ZZ 0NC54ZZ 0NC60ZZ 0NC63ZZ 0NC64ZZ 0NC70ZZ 0NC73ZZ 0NC74ZZ 0NH00MZ 0NH03MZ 0NH04MZ 0NP000Z 0NP004Z 0NP005Z 0NP007Z 0NP007Z 0NP00KZ 0NP00SZ 0NP030Z

		0NP034Z 0NP037Z 0NP03KZ 0NP03SZ 0NP040Z 0NP044Z 0NP047Z 0NP04KZ 0NP04SZ 0NP0X4Z 0NP0XSZ 0NW000Z 0NW004Z 0NW005Z 0NW007Z 0NW00JZ 0NW00KZ 0NW00MZ 0NW00SZ 0NW030Z 0NW034Z 0NW035Z 0NW037Z 0NW03JZ 0NW03KZ 0NW03MZ 0NW03SZ 0NW040Z 0NW044Z 0NW045Z 0NW047Z 0NW04JZ 0NW04KZ 0NW04MZ 0NW04SZ 0W9100Z 0W010ZZ 0W9130Z 0W913ZZ 0W9140Z 0W914ZZ 0WC10ZZ 0WC13ZZ 0WC14ZZ 0WH10YZ 0WH13YZ
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		0WH14YZ 0WJ10ZZ 0WP100Z 0WP101Z 0WP10JZ 0WP10YZ 0WP130Z 0WP131Z 0WP13JZ 0WP13YZ 0WP140Z 0WP141Z 0WP14JZ 0WP14HZ 0WW00Z 0WW101Z 0WW103Z 0WW10JZ 0WW10YZ 0WW130Z 0WW131Z 0WW133Z 0WW13JZ 0WW13YZ 0WW140Z 0WW141Z 0WW143Z 0WW14JZ 0WW14YZ 0N500ZZ 0N503ZZ 0N504ZZ 0NB00ZZ 0NB03ZZ 0NB04ZZ 0NT10ZZ 0NT30ZZ 0NT40ZZ 0NT50ZZ 0NT60ZZ 0NT70ZZ 009100Z 00910ZZ 00C10ZZ 00C13ZZ 00C14ZZ
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		00900ZZ
		009030Z
		00903ZZ
		009040Z
		00904ZZ
		00C00ZZ
		00C03ZZ
		00C04ZZ
		00H003Z
		00H003Z
		00H00YZ
		00H032Z
		00H033Z
		00H03YZ
		00H042Z
		00H043Z
		00H04YZ
		00H602Z
		00H603Z
		00H60YZ
		00H632Z
		00H633Z
		00H63YZ
		00H642Z
		00H643Z
		00H64YZ
		00P000Z
		00P002Z
		00P003Z
		00P007Z
		00P00JZ
		00P00KZ
		00P00YZ
		00P030Z
		00P032Z
		00P033Z
		00P037Z
		00P03JZ
		00P03KZ
		00P03YZ
		00P040Z
		00P042Z
		00P043Z
		00P047Z
		00P04JZ

		00P04KZ 00P04YZ 00P600Z 00P602Z 00P603Z 00P60YZ 00P630Z 00P632Z 00P633Z 00P63YZ 00P640Z 00P642Z 00P643Z 00P64YZ 00P6X2Z 00W000Z 00W002Z 00W003Z 00W007Z 00W00MZ 00W00YZ 00W030Z 00W032Z 00W033Z 00W037Z 00W03JZ 00W03KZ 00W03MZ 00W03YZ 00W040Z 00W042Z 00W043Z 00W047Z 00W04JZ 00W04KZ 00W04MZ 00W04YZ 00W600Z 00W602Z 00W603Z 00W60MZ 00W60YZ 00W630Z 00W632Z 00W633Z 00W63MZ
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		00W63YZ 00W640Z 00W642Z 00W643Z 00W64MZ 00W64YZ 00B70ZZ 00B73ZZ 00B74ZZ 00500ZZ 00503ZZ 00504ZZ 00B00ZZ 00B03ZZ 00B04ZZ
Ventriculostomy	ICD-9-CM PCS	V45.2 02.2 02.21 02.22
	ICD-10-CM PCS	Z982 009600Z 009630Z 009640Z 001607B 00160JB 00160KB 001637B 00163JB 00163KB 001647B 00164JB 00164KB 009130Z 00913ZZ 009140Z 00914ZZ 009230Z 00923ZZ 009240Z 00924ZZ 009430Z 00943ZZ 009440Z 00944ZZ 009530Z 009540Z

		00954ZZ 00963ZZ 00994ZZ
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063	Ischemic stroke, precerebral occlusion, or transient ischemia with thrombolytic agent without CC/MCC
Additional MS-DRG codes used, if present in combination with an above ICD-9-CM or ICD-10-CM code for ischemic stroke	
064	Intracranial hemorrhage or cerebral infarction with MCC
065	Intracranial hemorrhage or cerebral infarction with CC or tPA in 24 hours
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EVT Identification	
ICD-9-PCS Codes	
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03CM3ZZ	Extirpation of matter from right external carotid artery, percutaneous approach
03CN3ZZ	Extirpation of matter from left external carotid artery, percutaneous approach
03CP3ZZ	Extirpation of matter from left vertebral artery, percutaneous approach
03CQ3ZZ	Extirpation of matter from left vertebral artery, percutaneous approach

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041	1,367	Periph/cranial nerve & other nerv syst proc w CC or periph neurostim
004	1,341	Tracheostomy with mv >96 hours or PDX except face, mouth and neck without major O.R. procedure
040	1,334	Periph/cranial nerve & other nerv syst proc w MCC
981	1,112	Extensive O.R. procedure unrelated to principal diagnosis w MCC

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I6602	2	Occlusion and stenosis of left middle cerebral artery
I6782	2	Reversible cerebral vasoconstriction syndrome
I6501	1	Occlusion and stenosis of right vertebral artery
I67841	1	Reversible cerebrovascular vasoconstriction syndrome

Legend: ICD-CM: International Classification of Disease, Clinical Modification; MS-DRG: Medicare Severity-Diagnosis-Related Group

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		0NP034Z 0NP037Z 0NP03KZ 0NP03SZ 0NP040Z 0NP044Z 0NP047Z 0NP04KZ 0NP04SZ 0NP0X4Z 0NP0XSZ 0NW000Z 0NW004Z 0NW005Z 0NW007Z 0NW00JZ 0NW00KZ 0NW00MZ 0NW00SZ 0NW030Z 0NW034Z 0NW035Z 0NW037Z 0NW03JZ 0NW03KZ 0NW03MZ 0NW03SZ 0NW040Z 0NW044Z 0NW045Z 0NW047Z 0NW04JZ 0NW04KZ 0NW04MZ 0NW04SZ 0W9100Z 0W010ZZ 0W9130Z 0W913ZZ 0W9140Z 0W914ZZ 0WC10ZZ 0WC13ZZ 0WC14ZZ 0WH10YZ 0WH13YZ
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		0WH14YZ 0WJ10ZZ 0WP100Z 0WP101Z 0WP10JZ 0WP10YZ 0WP130Z 0WP131Z 0WP13JZ 0WP13YZ 0WP140Z 0WP141Z 0WP14JZ 0WP14HZ 0WW00Z 0WW101Z 0WW103Z 0WW10JZ 0WW10YZ 0WW130Z 0WW131Z 0WW133Z 0WW13JZ 0WW13YZ 0WW140Z 0WW141Z 0WW143Z 0WW14JZ 0WW14YZ 0N500ZZ 0N503ZZ 0N504ZZ 0NB00ZZ 0NB03ZZ 0NB04ZZ 0NT10ZZ 0NT30ZZ 0NT40ZZ 0NT50ZZ 0NT60ZZ 0NT70ZZ 009100Z 00910ZZ 00C10ZZ 00C13ZZ 00C14ZZ
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		009000Z
		00900ZZ
		009030Z
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		00H00YZ
		00H032Z
		00H033Z
		00H03YZ
		00H042Z
		00H043Z
		00H04YZ
		00H602Z
		00H603Z
		00H60YZ
		00H632Z
		00H633Z
		00H63YZ
		00H642Z
		00H643Z
		00H64YZ
		00P000Z
		00P002Z
		00P003Z
		00P007Z
		00P00JZ
		00P00KZ
		00P00YZ
		00P030Z
		00P032Z
		00P033Z
		00P037Z
		00P03JZ
		00P03KZ
		00P03YZ
		00P040Z
		00P042Z
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		00W032Z
		00W033Z
		00W037Z
		00W03JZ
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		00W600Z
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		00W60YZ
		00W630Z
		00W632Z
		00W633Z
		00W63MZ

		00W63YZ 00W640Z 00W642Z 00W643Z 00W64MZ 00W64YZ 00B70ZZ 00B73ZZ 00B74ZZ 00500ZZ 00503ZZ 00504ZZ 00B00ZZ 00B03ZZ 00B04ZZ
Ventriculostomy	ICD-9-CM PCS	V45.2 02.2 02.21 02.22
	ICD-10-CM PCS	Z982 009600Z 009630Z 009640Z 001607B 00160JB 00160KB 001637B 00163JB 00163KB 001647B 00164JB 00164KB 009130Z 00913ZZ 009140Z 00914ZZ 009230Z 00923ZZ 009240Z 00924ZZ 009430Z 00943ZZ 009440Z 00944ZZ 009530Z 009540Z

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