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A Systematic Review of Validated Methods for Identifying Cerebrovascular Accident or Transient Ischemic Attack Using Administrative Data

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Abstract

Purpose—To perform a systematic review of the validity of algorithms for identifying cerebrovascular accidents (CVAs) or transient ischemic attacks (TIAs) using administrative and claims data.

Methods—PubMed and Iowa Drug Information Service (IDIS) searches of the English language literature were performed to identify studies published between 1990 and 2010 that evaluated the validity of algorithms for identifying CVAs (ischemic and hemorrhagic strokes, intracranial hemorrhage and subarachnoid hemorrhage) and/or TIAs in administrative data. Two study investigators independently reviewed the abstracts and articles to determine relevant studies according to pre-specified criteria.

Results—A total of 35 articles met the criteria for evaluation. Of these, 26 articles provided data to evaluate the validity of stroke, 7 reported the validity of TIA, 5 reported the validity of intracranial bleeds (intracerebral hemorrhage and subarachnoid hemorrhage), and 10 studies reported the validity of algorithms to identify the composite endpoints of stroke/TIA or cerebrovascular disease. Positive predictive values (PPVs) varied depending on the specific outcomes and algorithms evaluated. Specific algorithms to evaluate the presence of stroke and intracranial bleeds were found to have high PPVs (80% or greater). Algorithms to evaluate TIAs in adult populations were generally found to have PPVs of 70% or greater.

Conclusions—The algorithms and definitions to identify CVAs and TIAs using administrative and claims data differ greatly in the published literature. The choice of the algorithm employed should be determined by the stroke subtype of interest.

Keywords

cerebrovascular accident; transient ischemic attack; validation; administrative data

Introduction

Administrative and claims databases of health plans and government programs (hereafter referred to as “administrative data”), such as Medicare and Medicaid, are often used to conduct epidemiologic and drug safety research. To conduct these studies and perform

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surveillance activities using these administrative data sources, it is important to determine the validity of the diagnostic information they contain.

A number of studies have been conducted using administrative data to evaluate the association between various medications and the acute manifestations of cerebrovascular disease.[1–9] Evaluation of the validity of diagnostic codes for cerebrovascular accident (CVA) and transient ischemic attack (TIA) documented in administrative data is complicated by the differing stroke subtypes based on pathophysiology (e.g., ischemic versus hemorrhagic strokes). Cerebrovascular disease encompasses a diverse set of conditions related to the blood vessels supplying the brain. A stroke or cerebrovascular accident (CVA) is defined by the World Health Organization (WHO) as "rapidly developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin." [10–11] A transient ischemic attack (TIA) is defined by this international organization as a sudden, focal neurologic deficit with symptoms lasting less than 24 hours.[10–11]

The aim of the present study was to perform a systematic review of studies that have evaluated the validity of diagnosis codes and algorithms developed using administrative health plan data to identify CVAs (ischemic and hemorrhagic strokes, intracerebral hemorrhage and subarachnoid hemorrhage) and TIAs. This project was conducted as part of the U.S. Food and Drug Administration Mini-Sentinel program. The full report can be found at http://mini-sentinel.org/foundational_activities/related_projects/default.aspx.

Methods

The methods and search strategy for Mini-Sentinel systematic reviews are described in the accompanying manuscript by Carnahan.[12] Briefly, PubMed and Iowa Drug Information Service (IDIS) searches of the English language literature were performed to identify studies published between 1990 and 2010 that evaluated the validity of algorithms for identifying CVAs and/or TIAs in administrative data. Search terms related to administrative data are described in detail by Carnahan[12] and were included in all Mini-Sentinel systematic review searches. In addition, the following key words were used as PubMed search terms for the CVA/TIA review: ("Brain Ischemia"[Mesh] OR "Basal Ganglia Cerebrovascular Disease" [Mesh]) OR "Carotid Artery Thrombosis"[Mesh]) OR "Intracranial Embolism and Thrombosis"[Mesh]) OR "Intracranial Hemorrhages"[Mesh]) OR "Stroke"[Mesh]) OR "Vasospasm, Intracranial"[Mesh]. The IDIS search included specification of the following terms: 435. or 432. or 433.1 or 434. or 436. (NOTE: 435. ISCHEMIA, CEREBRAL, TRANSIENT, 432. HEMORRHAGE, INTRACRANIAL NEC, 433.1 EMBOLISM/ THROMBOSIS, CAROTID, 434. EMBOLISM/THROMBOSIS, CEREB, 436. DISEASE, CEREBROVASCULAR NEC) for the disease and "ischemi*" or "intracranial" or "stroke" in the abstract.

Two study investigators independently reviewed the abstracts to identify potentially relevant articles for retrieval; articles identified as potentially relevant by either investigator were retrieved. The study investigators independently reviewed the articles with a goal of identifying validation of CVAs or TIAs described in the article itself or from the reference section of the article if it included validation studies. Citations from the article's references were selected for full-text review if they were cited as a source for the algorithm to identify CVAs or TIAs, or were otherwise deemed likely to be relevant. Discrepancies regarding the inclusion of a study for the review report were resolved by consensus following the independent reviews.

Mini-Sentinel investigators were surveyed to request information on any published or unpublished studies that validated an algorithm to identify CVAs or TIAs in administrative data. These studies were similarly reviewed by two study investigators to determine their relevance.

A single investigator abstracted information on the study design and population, algorithm, and validation statistics for each study. The data were confirmed by a second investigator for accuracy. Based upon the specific outcomes reported, we categorized studies by the following CVA/stroke subtypes: acute events including 1) strokes, 2) TIAs, and 3) intracranial bleeds (intracerebral hemorrhage and subarachnoid hemorrhage), and 4) the composite endpoints of stroke/TIA or cerebrovascular disease (including prevalent disease).

Results

Identification and selection of articles

Overall, 1,480 abstracts were reviewed; 587 were selected for full-text review. A total of 35 studies were included in the evidence tables (17 from the initial search strategy, 12 through references of articles that underwent full-text review, and 6 provided by Mini-Sentinel investigators and outside reviewers).[9,13–46] Of these studies, 26 provided data to evaluate the validity of algorithms to identify stroke, 7 provided data to evaluate the validity of TIAs, 5 provided data to evaluate the validity of intracranial bleeds, and 10 studies provided data to evaluate the composite endpoints of stroke/TIA or cerebrovascular disease. The algorithms for each of these outcomes are reported separately below.

Algorithms and Validation

See Appendix 1 for definitions of stroke-related codes.

Stroke (ischemic, hemorrhagic and unspecified)

Validation Algorithms: In general, studies that evaluated the validity of 3-, 4-, or 5-digit ICD-9 codes in the range 430.x to 438.x reported the highest PPVs for codes 430.x, 431.x, 434.x, and 436.x. For most studies evaluating codes 430.x, 431.x, or 434.x separately, the reported PPVs were 80% or higher (Table 1). For most studies evaluating code 436.x, the PPVs were 70% or higher. While most studies reported low PPVs for code 433.x, one study that evaluated hospital discharge codes 433.x1 separately from 433.x0 reported a much higher PPV for codes 433.x1 (71% compared with 13%).[38] The fifth digit specification of 0 indicates that the diagnosis of occlusion and stenosis of precerebral arteries occurred without mention of cerebral infarction.

The majority of studies also reported PPVs for algorithms using a combination of codes, with PPVs of 85% and higher reported for several studies. Iribarren et al.[26] evaluated an algorithm including inpatient ICD-8 code 431 and ICD-9 codes 431 and 432 to identify intracerebral hemorrhagic stroke and reported a PPV of 91%. Williams et al.[44] evaluated an algorithm that included primary position ICD-9 codes 434 and 436 to identify cases of acute ischemic stroke and reported a PPV of 98%. Using all hospital discharge codes (principal and secondary) 433.x1, 434 (excluding 434.x0) and 436, Tirschwell et al.[43] reported a PPV of 90% for ischemic stroke. Kokotailo et al.[29] evaluated an algorithm using hospitalization and emergency department most responsible diagnosis ICD-9 codes 433.x1, 434.x1, 436, and 362.8 and reported a PPV of 85% for ischemic stroke. To identify acute ischemic stroke, intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH), Roumie et al.[40] used ICD-9 codes 430, 431, 433.x1, 434 (excluding 434.x0) and 436, and reported a PPV of 97% using primary discharge diagnosis codes. Using an algorithm including codes 430, 431, 432,

434, and 436 in the discharge abstract, Ives et al.[45] reported a PPV of 90% for incident stroke.

Kokotailo et al.[29] directly compared the validation of ICD-9 and ICD-10 codes for evidence of acute ischemic stroke in medical charts. This study found the PPV of ICD-10 codes H34.1, I63.x, and I64.x to be the same as the PPV of ICD-9 codes 433.x1, 434.x1, 436, and 362.8 (85%).

Validation Criteria and Method: All studies included in this review validated administrative coding data through abstraction of medical charts. Criteria for the confirmation of stroke varied widely. Few studies stated that specific standard criteria were used to confirm cases (e.g., WHO definitions).[10,11] However, the stated definitions/criteria for confirmation of stroke often included elements of such standard criteria. For example, the WHO criteria defines stroke as a new neurologic deficit of presumed vascular origin lasting at least 24 hours or until death, if death occurred within 24 hours.[10,11] This definition excludes TIA, which is defined as focal neurologic symptoms lasting less than 24 hours; the definition also excludes cases of obvious nonstroke cause such as symptoms caused by trauma and tumors. While only the studies by Benesch et al.[14] and Lakshminarayan et al.[30] specifically stated that the WHO definitions were used, other studies[39,40] listed the basic elements of the WHO criteria as necessary to confirm a case of acute stroke.

Age of study population: Many studies included only adults; no information was provided on the proportion of validated cases by age group. Three studies evaluated stroke among children.[22,23,46] Golomb et al.[22] evaluated inpatient and outpatient ICD-9 codes 342, 433, 434, 435, 436, 437, 438, and 767, and reported higher PPVs than those reported in studies among adult populations for a number of codes. However, Agrawal et al.[46] et al. also evaluated inpatient and outpatient ICD-9 codes and generally reported lower PPVs than those reported in studies among adult populations. In another study, Golomb et al.[23] evaluated ICD-9 codes 325 to identify the presence of cerebral sinovenous thrombosis in children and reported a PPV of 93%.

Patient sex: No studies provided information on the proportion of validated cases of stroke in men as compared with women. One study reported the validity of ICD-9-codes 430, 431, 432.0 to 432.1, 432.9, 434, and 436 among women enrolled in the Women's Health Initiative.[24] The overall PPV of 81% and the PPVs for specific ICD-9 codes were within the range of other studies using similar codes.

Time period of data collection: The reported validation statistics did not vary substantially in earlier study periods (i.e., prior to 2000) compared to later study periods (e.g., 2000 and later). One study evaluated the PPVs of hospital discharge codes 431, 432, 434, 436, and 437 to identify acute stroke during 5 calendar years: 1980, 1985, 1990, 1995, and 2000.[30] Using WHO criteria, the overall PPV was lowest in 1980 (55%). However, there was no consistent trend over time, as the PPV reported for the most recent year evaluated (2000) was the second lowest found (PPV=60%).

Principal vs. secondary discharge diagnosis: Studies that compared algorithms using the primary discharge diagnosis to those using diagnoses in any position (primary and secondary diagnoses) found slightly higher PPVs for algorithms using the primary discharge diagnosis only (generally < 10% higher). However, one study by Roumie et al.[40] reported that the PPV for the primary discharge diagnosis of stroke was 97% compared to 32% for a secondary diagnosis. The overall PPV for the algorithm using both primary and secondary diagnoses was 89% compared to 97% using only the primary discharge diagnosis.

Hospitalization diagnosis vs. outpatient encounter: Few studies evaluated algorithms using both hospitalization and outpatient encounter data to identify cases of acute stroke.[18,22,29,36,46] The few studies that included outpatient data had PPVs at both the higher and lower range of values observed in studies evaluating the validity of algorithms to identify stroke. In a study that evaluated pediatric strokes, Agrawal[46] reported data that allowed a comparison of PPVs for inpatient versus outpatient codes, and generally reported substantially lower PPVs for outpatient codes; however, the confidence intervals for the PPVs often overlapped, given the small number of cases identified for specific codes. Thus, given the different algorithms and study populations used in the studies examined, it is difficult to adequately assess the impact of including outpatient encounter data.

TIAs

Validation Algorithms: In 3 of the 6 studies evaluating ICD-9 codes 435.x in hospitalizations or hospitalizations/emergency department encounters for the identification of TIA (Table 2), the PPVs were 70% or higher.[14,24,29] Ives et al[45] reported a much lower PPV of 28%; cases were confirmed by an events committee rather than by standardized clinical criteria which may be a potential explanation for the lower percentage of cases validated. Newton et al.[36] also reported a low PPV of 33%; however, this study included both inpatient and outpatient encounters and only evaluated 33 potential cases of TIA among a select population (patients diagnosed with diabetes). One study also assessed the validity of other codes (ICD-9 codes 433, 434, and 436) and found much lower PPVs than those reported for ICD-9 code 435.x (PPVs of 9% or lower for both primary and secondary diagnoses and 14% or lower for primary diagnoses).[14] The PPV for ICD-9 code 435.9 reported by Holick et al.[9] (28%) was also low.

One study directly compared the validation of ICD-9 and ICD-10 codes for evidence of TIA in medical charts.[29] The PPV of the ICD-10 codes (G45.x) was found to be higher than the PPV of ICD-9 code 435.x (97% vs. 70%).

Validation Criteria and Method: All 7 studies evaluating TIAs validated administrative coding data through the abstraction of data from medical charts. Criteria for confirmation of a TIA varied widely. Documentation of a written diagnosis was adequate to confirm a TIA in some studies.[9,36] One study used the WHO definition for TIA.[14]

Age of study population: Six studies included only adult populations. No information was provided on the proportion of validated cases of TIA by age group. One study evaluated TIA among children and reported a PPV of 67% for inpatient codes and 52% for outpatient codes.[46]

Patient sex: No studies provided information on the proportion of validated cases of TIA according to patient sex. One study reported the validity of ICD-9-code 435.x among women enrolled in the Women's Health Initiative.[24] The PPV of 72% was similar to those reported in 2 other studies that did not restrict the population to patients with specific conditions or sex.[14,29]

Time period of data collection: The reported validation statistics did not vary substantially in earlier study periods (i.e., prior to 2000) compared to more recent periods (e.g., 2000 and later).

Principal vs. secondary discharge diagnosis: Benesch et al.[14] reported a PPV of 89% for patients with a primary discharge diagnosis of ICD-9 435.x and a PPV of 77% for patients with this code as either a primary or secondary discharge diagnosis. Heckbert et al.[24]

evaluated ICD-9 code 435.x using discharge diagnoses in any position and reported a PPV of 72%. Ives et al.[45] evaluated ICD-9 code 435 in the discharge abstract, and reported a much lower PPV of 28%. Kokotailo et al.[29] reported a PPV of 70% for patients with a most responsible (primary position) diagnosis of ICD-9 435.x recorded in a hospitalization or emergency department visit.

Hospitalization diagnosis vs. outpatient encounter: Four studies evaluated algorithms based exclusively on hospitalizations for TIA.[9,14,24,45] One study evaluating TIA in an adult population[36] used both inpatient and outpatient encounters to identify patients with TIA, and reported a much lower PPV than most other studies (PPV=33%); however, this study only evaluated 33 potential cases of TIA. Another study evaluated TIA in a pediatric population and reported a PPV of 67% for inpatient codes and 52% for outpatient codes.[46]

Intracranial bleeds (intracerebral hemorrhage and subarachnoid hemorrhage)

Validation Algorithms: The PPVs reported in studies evaluating intracranial bleeds using inpatient codes were 77% or higher (Table 3). The lowest PPV was reported by Birman-Deych et al.;[15] this study evaluated an algorithm that used the largest number of codes (codes 430 to 432) plus a number of codes related to fracture of the skull with hemorrhage (e.g., codes 800.2, 800.3, 800.7). For studies that evaluated inpatient codes for SAH (ICD-9 codes 430.x) and ICH (ICD-9 codes 431.x) separately, the PPVs were similar for the two conditions, ranging from 82% to 98% for SAH and from 79% to 97% for ICH.

One study directly compared the validation of ICD-9 and ICD-10 codes for evidence of intracranial bleeds in the medical charts.[29] This study found the PPVs of the ICD-10 codes to be similar to those for ICD-9 codes (98% and 97% for ICH, and 91% and 98% for SAH, using ICD-10 and ICD-9 codes, respectively).

Validation Criteria and Method: All 5 studies included in the review validated administrative coding data through abstraction of medical charts. Criteria for confirmation of intracranial bleeds varied. Two studies specifically stated that the criteria included documentation of direct visualization of blood by a physician or imaging consistent with bleeding.[13,46]

Age of study population: No studies provided data on the proportion of validated cases of intracranial bleeds by age group. Agrawal et al.[46] et al. evaluated inpatient and outpatient ICD-9 codes in a pediatric population and reported lower PPVs than those reported in most studies in adult populations.

Patient sex: No studies provided information on the proportion of validated cases of intracranial bleeds by patient sex.

Time period of data collection: The reported validation statistics did not vary substantially in earlier study periods (i.e., prior to 2000) compared to later study periods (e.g., 2000 and later).

Principal vs. secondary diagnosis: The 2 studies that evaluated algorithms based upon the principal or most responsible diagnosis (primary position) reported high PPVs for ICH and SAH (89% or higher).[29,43] Tirschwell et al.[43] reported a PPV of 89% for patients with a primary discharge code for ICH and a PPV of 80% for patients with a primary or secondary discharge diagnosis; similarly, the investigators reported a PPV of 94% for patients with a primary discharge code for SAH and a PPV of 86% for patients with a primary or secondary discharge diagnosis. Kokotailo et al.[29] reported PPVs that ranged from 91% to 98% using

algorithms that identified hospitalizations and emergency department visits with a most responsible diagnosis for ICH or SAH, using ICD-9 and ICD-10 codes. However, in a study that used inpatient codes in any position, Arnason et al. also reported a high PPV for intracranial bleeds (PPV=94%).[13]

Hospitalization diagnosis vs. outpatient encounters: One study[29] using both hospitalizations and emergency department visits reported comparable PPVs to those studies using hospitalizations only.[13,15,43] Agrawal et al.[46] et al. evaluated inpatient and outpatient ICD-9 codes in a pediatric population. The reported PPV for ICH was substantially higher for inpatient compared to outpatient codes (79% and 49% respectively), while the reported PPV for SAH was higher for outpatient codes compared to inpatient codes (100% and 82% respectively); however, the confidence intervals for the PPV estimates overlapped.

Composite Endpoints, Stroke/TIA or Cerebrovascular Disease—Table 4 describes 10 publications that used ICD-9 or ICD-10 codes to identify patients with the composite endpoints of stroke/TIA or cerebrovascular disease. These studies included a variety of disease classifications (prevalent and acute), algorithms, and criteria for validation. Since the outcomes evaluated varied widely, and in some studies the definition or subtype of stroke was unclear, these algorithms may be less useful for studies evaluating drug or device safety. These studies are summarized more fully in the final report (http://mini-sentinel.org/foundational_activities/related_projects/default.aspx).

Range of PPV estimates according to individual codes—Table 5 shows the median and range (minimum and maximum) of PPV estimates reported in studies evaluating individual ICD-9 and ICD-10 codes in adult populations, according to the outcome evaluated (acute stroke event [ischemic and hemorrhagic], ischemic stroke, TIA, ICH, and SAH). While most studies evaluating acute stroke did not specify that confirmation was based upon agreement with the specific diagnostic code recorded (e.g., most studies determined the presence or absence of any stroke event rather than specifying that confirmed cases with discharge ICD-9 code 433.x were diagnosed with occlusion of precerebral arteries), studies that specifically evaluated ischemic stroke reported PPVs for codes 434 and 436 in the range observed for studies evaluating all acute stroke events (approximately 90% and 80% respectively for studies using the principal diagnosis code). As reported above, the PPVs for codes 430 and 431, to identify intracranial bleeds and SAH respectively, were generally > 80%, and the PPV for code 435 to identify TIAs was generally > 70%.

Discussion

Administrative databases are a useful source of information to identify clinical conditions and diagnoses relevant for drug and medical device safety research and surveillance activities. The ability to perform such activities in a timely and efficient manner is highly advantageous.

A number of different outcomes and definitions for CVAs and its major subtypes have been reported in studies using administrative data. In addition, the criteria for validation of outcomes varied greatly among the studies reviewed. Few studies reported that criteria for validation included confirmation based upon brain imaging data (i.e., computed tomography [CT], magnetic resonance imaging [MRI]), evidence that would enhance the validity of the stroke diagnosis. In addition, among studies reporting the PPV estimates for individual ICD-9 codes, most studies did not specify that confirmation was based upon agreement with the specific diagnostic code recorded (i.e., most studies determined the presence or absence of any stroke event rather than specific stroke subtype). In addition, most studies evaluating

ICD-9 codes 433.x and 434.x did not exclude ICD-9 codes with the fifth digit specification of 0, which indicates that the diagnosis occurred without mention of cerebral infarction.

Our report focused on studies evaluating acute events (stroke, TIA, and intracranial bleeds) rather than prevalent cerebrovascular disease. PPVs varied considerably depending on the specific outcomes (stroke subtypes) and algorithms evaluated. Specific algorithms to evaluate the presence of stroke and intracranial bleeds were found to have high PPVs (80% or greater). Algorithms to evaluate TIAs were generally found to have PPVs of 70% or greater.

The clinical usefulness of the algorithms presented in this report are best understood in light of the definitions of each of the various clinical entities, their pathophysiology, and the health outcome of interest relevant to a specific post-marketing surveillance study. For example, the pathologic basis for a stroke may relate to either ischemic or hemorrhagic disturbances of the cerebral circulation.[47] While ischemic strokes can be either thrombotic or embolic due to underlying atherosclerosis or blood clots, hemorrhagic strokes are mainly due to hypertensive disease, coagulation disorders, or vascular malformations. Lacunar cerebral infarctions are small deep infarcts in the territory of small penetrating arteries, due to a local disease of these vessels, mainly related to chronic hypertension. Subarachnoid hemorrhages are mainly due to the rupture of aneurysms.[47] Thus, if a medication or device is postulated to increase the risk of hemorrhagic disturbances of the cerebral circulation, the specific algorithm chosen should include codes demonstrated to have high validity for identification of acute hemorrhagic events (as described below), rather than including codes for all stroke subtypes (e.g. codes identifying ischemic stroke, TIAs).

For acute stroke, studies reported the highest PPVs for inpatient ICD-9 codes 430.x, 431.x, 434.x, and 436.x. To evaluate acute ischemic stroke, algorithms that included ICD-9 codes 433.x1, 434 (excluding 434.x0), and 436, performed well (85% or higher). Use of codes in the principal position generally increased the PPVs slightly.

For TIAs, ICD-9 codes 435.x in hospitalization or emergency encounter data generally demonstrated an adequate PPV (70% or higher in adult populations). The two studies using codes in the principal position both reported PPVs of 70% or higher.

While few studies evaluated intracranial bleeds, algorithms including hospitalization or emergency department visit codes 430.x and 431.x performed well for the identification of SAH and ICH in adult populations, with PPVs ranging from 80% to 98%. While only one study evaluated an algorithm using inpatient ICD-9 codes 430.x to 432.x for the identification of intracranial bleeds, the reported PPV was high (94%).

Our classifications (stroke, TIA, stroke/TIA, ICH, SAH, and cerebrovascular disease) were based on how the study authors identified their outcomes of interest. The authors of these papers used a variety of approaches. For example, some authors set out to identify patients with all types of cerebrovascular events including intracranial bleeds, while others chose to focus on ischemic strokes excluding bleeds. These varying approaches likely influenced PPVs and will impact how useful these algorithms will be in future investigations. Included in the report are algorithms that focused solely on ischemic strokes as well as those focused on bleeds (ICH and SAH). This level of detail may be helpful in categorizing subtypes of stroke based on pathophysiology, although some limitations remain. For instance, no investigators to date have attempted to differentiate ischemic strokes due to thrombotic versus embolic causes using administrative data. Some authors chose to focus solely on TIAs. Given the “transient” nature of TIAs in that there are no lasting physical deficits or radiographic findings, it is not surprising that the PPVs were lower than in studies focused on stroke. Lastly, several authors used composite measures whereby a patient could have

more than one condition. Some algorithms identified patients with composite endpoints (either stroke or TIA) or more broadly with cerebrovascular disease. In some studies it was unclear what specific conditions were included in the definition of the outcome of interest and this may substantially limit the usefulness of these algorithms.

Gaps in the current literature include a lack of information on potential differences in the validity of algorithms according to patient age and sex. In addition, the validity of algorithms to further differentiate ischemic strokes due to thrombosis versus emboli should be evaluated. Overall, comparison of the different algorithms using standard criteria, potentially incorporating brain imaging data, would be most useful. Lastly, few validation studies have been conducted on ICD-10 codes or in men and women of different race/ethnicities.

Conclusion

Large population-based administrative databases that include diagnosis data provide efficient sources of information to identify cases of acute CVAs and TIAs. A number of different algorithms for various stroke subtypes have been reported in the literature. The appropriateness and choice of the specific algorithm for drug and device safety research should not be made arbitrarily, but should have a sound pathophysiologic rationale, specifically, one that is appropriate for stroke subtype of interest.

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Take home messages

- The definitions, criteria for validation, and algorithms used to identify cerebrovascular accidents (CVAs) and transient ischemic attacks (TIAs) from administrative and claims data differ greatly in the published literature.
- Specific algorithms to evaluate the presence of stroke and intracranial bleeds were found to have high positive predictive values (80% or greater).
- Algorithms to evaluate TIA were generally found to have PPVs of 70% or greater.

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Table 1

Positive Predictive Values of Algorithms to Identify Cerebrovascular Accident (CVA)/Stroke

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
Agrawal, et al.[46]	Kaiser Permanente of Northern California members aged 0 to 19 years, 1993 to 2003	stroke	inpatient and outpatient ICD-9 codes 430, 431, 433.xx, 434.xx, 435.xx, 436, 437.x, 438.x, plus cerebral palsy (CP)-related codes: 342.x, 343.x, 344.xx	Medical record review was conducted (N=1307). Stroke was confirmed by neurologists based upon documented clinical presentation and CT or MRI evidence. Inpatient codes: Ischemic stroke: code 433: PPV=38% code 434: PPV=74% code 436: PPV=46% code 437: PPV=100% Outpatient codes: Ischemic stroke: code 433: PPV=0% code 434: PPV=40% code 436: PPV=10% code 437: PPV=19% Overall CP-related codes: PPV=2.2%
Benesch, et al.[14]	hospitalizations at 5 academic medical centers identified using the Academic Medical Center Consortium database, 1992	hospitalizations (stroke)	inpatient ICD-9 codes 433 to 436	Medical record review was conducted (N=649). Stroke was confirmed based upon the World Health Organization (WHO) definitions. primary and secondary diagnoses: code 433: PPV=6.1% code 434: PPV=85.0% code 435: PPV=9.1% code 436: PPV=82.6% primary diagnosis: code 433: PPV=9.1% code 434: PPV=90.3% code 435: PPV=6.3% code 436: PPV=88.9%
Brophy, et al.[18]	patients diagnosed with atrial fibrillation identified using the Veterans Affairs Boston Healthcare System database, 1998 to 2001	stroke	inpatient or outpatient ICD-9-CM codes 434, 435.0, 435.1, 435.3, 435.8, 435.9, 436, 437.1, 437.9, 438	Medical record review was conducted. Criteria for confirmation of cases (cerebrovascular accident) were unspecified. sensitivity=56% specificity=92% PPV=79%
Derby, et al.[19]	residents aged 35 to 74 years in Rhode Island and Massachusetts identified by	hospitalizations (stroke)	primary ICD-9 discharge diagnosis codes 431, 432, 434, 436, 437	Medical record review was conducted (N=2124). Outcomes were confirmed as determined by a study physician based on whether: 1) the clinical description was consistent with a new, localized neurological defect involving the hemispheres, brain stem, and/or the cerebellum, and 2) there was evidence for intracerebral hemorrhage. Definite or probable stroke excluded cases that were: exclusively subarachnoid hemorrhage; cerebral infarction related to rheumatic mitral stenosis or infective endocarditis, or stroke in the presence of prosthetic cardiac valves; exclusively TIA; and evidence from the medical history that the hospitalization was for a previous stroke

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
	hospital discharges from 7 hospitals, 1980 to 1992			PPV=80%
Derby, et al.[20]	residents aged 35 to 74 years, in Rhode Island and Massachusetts identified by hospital discharges from 7 hospitals, 1980 to 1992	hospitalizations (stroke)	primary or secondary ICD-9 discharge diagnosis code 431, 432, 434, 435, 436, 437	Medical record review was conducted (N=3975). Outcomes were confirmed by a study physician based on whether: 1) the clinical description was consistent with a new, localized neurological defect involving the hemispheres, brain stem, and/or the cerebellum, and 2) there was evidence for intracerebral hemorrhage. Definite or probable stroke excluded cases that were: exclusively subarachnoid hemorrhage; cerebral infarction related to rheumatic mitral stenosis or infective endocarditis, or stroke in the presence of prosthetic cardiac valves; exclusively TIA; and evidence from the medical history that the hospitalization was for a previous stroke overall: PPV=59.5% codes 431–432: PPV=70.3% code 434: PPV=84.0% code 435: PPV=26.7% codes 436–437: PPV=55.2%
Goldstein, et al.[21]	hospitalizations from the Durham Veterans Affairs Medical Center, 1995 to 1997	hospitalizations (acute ischemic stroke)	primary discharge diagnosis of ICD-9-CM codes 433, 434, and 436	Medical record review was conducted (N=175). Outcome was confirmed based upon evidence in discharge summary. overall PPV=61% code 433: PPV=4% code 434: PPV=82% code 434.11: PPV=85% code 434.91: PPV=82% code 436: PPV=79%
Golomb, et al.[22]	children with an inpatient or outpatient visit to Riley Hospital for Children in Indianapolis, IN, 1999 to 2004	stroke	inpatient or outpatient ICD-9 codes 342, 433, 434, 435, 436, 437, 438, 767	Medical record review was conducted (N=663). Outcome was confirmed by a pediatric neurologist, based upon radiographic evidence of infarction. stroke of any type **code in any position**: code 433: PPV=79% code 434: PPV=62% code 435: PPV=50% code 436: PPV=88% code 437: PPV=59% code 438: PPV=84% code 767: PPV=71% code 342: PPV=41% code 436 in **primary position**: PPV=92% arterial ischemic stroke **code in any position**: code 433: PPV=79% code 434: PPV=52% code 435: PPV=42% code 436: PPV=83% code 437: PPV=46% code 438: PPV=75% code 767: PPV=53% code 342: PPV=37% code 436 in the **primary position**: PPV=87% code 342 in the **primary position**: PPV=53%

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
Golomb, et al.[23]	children with an inpatient visit to Riley Hospital for Children in Indianapolis, IN, 1999 to 2005	hospitalizations (cerebral sinovenous thrombosis)	inpatient ICD-9 codes 325, 437.6, 671.5	Medical record review was conducted (N=56 patients for code 325, 1 patient for code 437.6, and 0 patients for code 671.5). Cerebral sinovenous thrombosis was determined by pediatric neurologist, based upon evidence in the chart code 325, any position: PPV=92.9% code 325, primary position (N=7): PPV=100%
Heckbert, et al.[24]	hospitalizations among women enrolled in the Women's Health Initiative (WHI), 1994 to 2000	hospitalizations (stroke)	ICD-9 codes 430, 431, 432.0 to 432.1, 432.9, 434, 436	Medical record review was conducted. Outcomes were confirmed based upon WHI criteria for cardiovascular endpoints. Overall: PPV= 81% sensitivity=82% code 430: PPV=74% code 431: PPV=93% codes 432.0 to 432.1: PPV=24% code 432.9: PPV=60% code 434: PPV=85% code 436 : PPV=70%
Holick, et al.[9]	adults aged 18 years or older who received a first dispensing of atomoxetine or stimulant ADHD medication and comparison group identified using the Ingenix Research DataMart; 2003 to 2006	hospitalizations (stroke)	inpatient ICD-9 codes: 430.xx to 432.xx, 434.xx, 436.xx;	Medical record review was conducted (N=132 potential CVAs). Criteria for confirming a CVA event included a stated diagnosis of CVA from a neurologist or in the hospital discharge summary, patient receiving a thrombolytic agent or stent placement, a positive imaging result, or a description of the event that is consistent with a CVA diagnosis. CVA: PPV=31.8%
Iribarren, et al.[26]	Kaiser Permanente of Northern California members aged 40 to 89 years who had a cholesterol determination; 1978 to 1993	hospitalizations (intracerebral hemorrhagic stroke)	inpatient ICD-8 code 431 and ICD-9 codes 431 and 432	Medical record review was conducted for 50 randomly selected patients. Intracerebral hemorrhagic stroke confirmed by CT of the head. PPV=91%
Ives, et al.[45]	Cardiovascular health Study: residents ≥ 65 years in Sacramento County, CA; Washington County, MD; Forsyth County, NC; Pittsburgh, PA, 1989 to 1992	hospitalizations (incident)	ICD-9-CM 430, 431, 432, 434, 436 in the discharge abstract	Medical record review was conducted (N=79). Outcome was confirmed based upon decision by an Events Committee, considering documentation of medical history, symptoms, course, and outcome. PPV=90%
Klatsky, et al.[28]	members of Northern California Kaiser Permanente who supplied data on voluntary health examinations from 1978 to 1985 and followed up through 1996	hospitalizations	primary discharge diagnosis ICD-9 codes 430 to 438	Medical record review was conducted (N=3441). A physician reviewed and confirmed all final diagnoses. PPV=77% for acute, classifiable events PPV=82% for chronic cerebrovascular disease or acute events Estimates calculated using data presented in the report.

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Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
Kokotailo, et al.[29]	patients with inpatient visits or seen at the emergency department identified from hospital discharge abstracts database from 3 acute care hospitals in the Calgary health region, 2000 to 2003	hospitalizations and emergency department visits (acute ischemic stroke)	most responsible (primary position) diagnosis ICD-9 codes 433.x1, 434.x1, 436, 362.8; ICD-10 codes I63.x, I64.x, H34.1	Medical record review was conducted on a sample of charts (N=133 identified with ICD-9 codes and N=75 identified with ICD-10 codes). Outcome was confirmed based upon trained research assistant determination, and neurologist determination in ambiguous cases. Assessment of correct coding was based on clinical data alone in 24% of charts and on clinical data and neurovascular imaging reports in 76% of charts. ICD-9 coding: PPV=85% ICD-10 coding: PPV=85%
Lakshminarayan, et al.[30]	hospitalizations at all acute care hospital serving the Minneapolis-St. Paul 7-county metropolitan area, 1980, 1985, 1990, 1995, 2000	hospitalizations (acute stroke)	inpatient discharge diagnoses ICD-9 codes 431, 432, 434, 436, 437	Medical record review was conducted (50% sample in 1980 to 1995 and 100% in 2000). Acute stroke was confirmed based upon 3 definitions: **1** WHO criteria, **2** Minnesota Stroke Survey (MSS) criteria **3** neuroimaging. 1980: WHO stroke definition, PPV=55%; MSS definition, PPV=36% 1985: WHO stroke definition, PPV=67%; MSS definition, PPV=47% 1990: WHO stroke definition, PPV=70%; MSS definition, PPV=41%; neuroimaging definition, PPV=49% 1995: WHO stroke definition, PPV=65%; MSS definition, PPV=45%; neuroimaging definition, PPV=45% 2000: WHO stroke definition, PPV=60%; MSS definition, PPV=44%; neuroimaging definition, PPV=59%
Leibson, et al.[31]	hospital discharges among Olmstead County residents, 1970, 1980, 1989	hospitalizations (incident or recurrent stroke)	inpatient ICD-9-CM codes 430 to 438	Linkage to the Rochester Stroke Registry and medical record review was conducted. Outcome was confirmed by the registry or neurologist review, using the same criteria used in the Rochester Stroke Registry (Rochester Epidemiology Project). **primary discharge code**: codes 430–438: PPV=47% (incident stroke) PPV=60% (incident or recurrent stroke) **up to 5 discharge codes**: code 430: PPV=100% (incident stroke) code 431: PPV=74% (incident stroke) PPV=87% (incident or recurrent) code 432: PPV=0% (incident or recurrent)

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
				code 433: PPV=15% (incident stroke) PPV=15% (incident or recurrent) code 434: PPV=69% (incident stroke) PPV=85% (incident or recurrent) code 435: PPV=12% (incident stroke) PPV=15% (incident or recurrent) code 436: PPV=67% (incident stroke) PPV=86% (incident or recurrent) code 437: PPV=11% (incident stroke) PPV=22% (incident or recurrent) code 438: PPV=0% (incident or recurrent)
Liu, et al.[33]	hospitalizations identified using the Saskatchewan Health Hospital Services Branch, 1990 to 1991	hospitalizations (acute stroke)	inpatient ICD-9 codes 430 to 438, 780.4, 780.0, 369.0 to 369.9, 342.0 to 342.9	Medical record review was conducted (N=1494). Outcomes were confirmed based upon the criteria of the 1980 USA National Survey of Stroke (NSS), with an acute stroke considered for diagnostic certainty ‘definite’ or ‘highly probable’. tertiary care hospitals, primary diagnosis: code 430: PPV=93% code 431: PPV=92% code 432: PPV=14% code 433: PPV=17% code 434.0: PPV=86% code 434.1 PPV=92% code 435: PPV=22% code 436: PPV=90% code 437: PPV=45% code 438: PPV= 17% codes 430–438: PPV=68% code 342: PPV=50% code 369: PPV=0% code 780: PPV=25% code 780.4: PPV=29% tertiary care hospitals, primary, secondary, or tertiary diagnosis: code 430: PPV=88% code 431: PPV=89% code 432: PPV=24% code 433: PPV=16% code 434.0: PPV=83% code 434.1 PPV=69% code 435: PPV=20% code 436: PPV=86% code 437: PPV=30% code 438: PPV= 7% codes 430–438: PPV=56% code 342: PPV=22% code 369: PPV=3% code 780: PPV=14% code 780.4: PPV=22% community hospitals, primary diagnosis: codes 430–438: PPV=61% community hospitals, primary, secondary, or tertiary diagnosis: codes 430–438: PPV=47%

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
Mayo, et al.[34]	hospitalizations identified from 5 acute-care hospitals in metropolitan Montreal, using MedEcho, Quebec's computerized listing of hospital discharges	hospitalizations (stroke)	primary discharge ICD-9 codes 430 to 434, 436, 437	Medical record review was conducted (N=96 total charts: 87 charts by one neurologist and 64 charts by another neurologist). Outcome was confirmed based upon documentation of neurological evidence, neuro-imaging, and other diagnoses ruled out. Neurologist 1: overall PPV= 80% code 430 PPV=100% code 431 PPV=100% codes 432 PPV=33% code 433 PPV=44% code 434 PPV=90% code 436 PPV=83% code 437 PPV=75% Neurologist 2: overall PPV= 72% code 430 PPV=100% code 431 PPV=100% codes 432 PPV=0% code 433 PPV=50% code 434 PPV=95% code 436 PPV=62% code 437 PPV=60%
Morgenstern, et al.[35]	residents of Nueces County, Texas, age 25 to 74 years hospitalized with AMI, CABG, or PTCA (Corpus Christi Health Project), 1988 to 1993	hospitalizations (stroke complication)	inpatient ICD-9 codes 430 to 437 during same hospital admission for AMI, PTCA, or CABG	Medical record review was conducted (N=161). A stroke complication following cardiac symptoms was confirmed based upon the National Institute of Neurological Disorders and Stroke Classification criteria. past/current stroke: PPV=53% current stroke after AMI, PTCA, or CABG all codes: PPV=44%
Newton, et al.[36]	Group Health Cooperative of Puget Sound members aged 18 and older with type 1 or type 2 diabetes, 1993 to 1995	incident or prevalent (stroke)	inpatient or outpatient ICD-9-CM codes 430, 431, 432.0, 432.1, 432.9, 434, 436; incident cases considered as those with code not present in 1992 (year before the observation period)	Medical record review was conducted among patients with multiple complications of diabetes (total N=471 and potential stroke N=118). Outcome was confirmed based upon the presence of a written diagnosis in the medical record. first confirmed date within 60 days of the automated record date: sensitivity=91.2% specificity=83.6% PPV=45.2% confirmed at any time during the observation period: sensitivity=92.3% specificity=85.4% PPV=52.2%
Reker, et al.[38]	patients receiving care at 11 Veterans Affairs medical centers, 1998 to 1999	hospitalizations (new stroke)	admission or discharge diagnosis ICD-9 430 to 438	Medical record review was conducted (N=671). Outcome was confirmed based upon documentation of a diagnosis of stroke. discharge diagnosis: code 430.x: PPV=33% code 431.x: PPV=80% code 432.x: PPV=21% code 433.x0: PPV=13% code 433.x1: PPV=71%

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
				code 434.x0: PPV=33% code 434.x1: PPV=72% code 435.x: PPV=3% code 436.x: PPV=48% code 437.x: PPV=50% code 438.x: PPV=33% any codes: PPV=42% broad, high sensitivity algorithm 2 (admission, discharge, and all secondary diagnosis fields, codes 430.x, 431.x, 432.x, 434.xx, and 436.x): sensitivity=89% specificity=57% PPV=60% narrow, high-specificity algorithm 2 (admission, discharge, and all secondary diagnosis fields, codes 431.x, 433.x1, 434.xx): sensitivity=59% specificity=84% PPV=72%
Rosamond, et al.[39]	Atherosclerosis Risk in Communities (ARIC) Study participants, aged 45 to 64 years at baseline, 1987 to 1995	hospitalizations (stroke)	inpatient ICD-9-CM codes 430 to 438	Medical record review was conducted (N=1185). Minimum criteria for definite or probable stroke were evidence of sudden or rapid onset of neurological symptoms lasting for > 24 hours or leading to death, in the absence of evidence for a nonstroke cause. code 430: PPV=86% code 431: PPV=83% code 432: PPV=9% code 433: PPV=14% code 434: PPV=77% code 435: PPV=12% code 436: PPV=70% code 437: PPV=2% code 438: PPV < 1% codes 430 to 434: PPV=44%
Roumie, et al.[40]	Tennessee Medicaid enrollees aged 50 to 84 years, 1999 to 2003.	hospitalizations (acute stroke)	discharge diagnosis of ischemic stroke (ICD-9-CM 433.x1, 434 [excluding 434.x0], or 436); intracerebral hemorrhage (431); and SAH (430). Hospitalizations with multiple stroke diagnoses were classified in the following priority: SAH > ICH > ischemic stroke	Medical record review was conducted (200 NSAID users and 50 non-users of NSAIDs). Abstraction tool combined elements of the REGARDS endpoint morbidity review form and the Rochester, Minnesota Stroke study form. A physician investigator determined the presence of a stroke, defined as rapid onset of a persistent neurologic deficit attributed to an obstruction or rupture of the arterial system; the deficit was required to last > 24 hours unless death supervened, or demonstrable lesion on CT or MRI scan. acute stroke: overall PPV=89% primary discharge diagnosis: PPV=97% secondary discharge diagnosis: PPV=32% true incident stroke (no history remote stroke): primary discharge diagnosis: PPV=74% excluding patients with a prior inpatient or outpatient diagnosis of stroke: primary discharge diagnosis: PPV=80%

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure and Operational Definition
Thompson, et al.[42]	patients who underwent a modified or radical neck dissection at 3 hospital sites in Calgary identified using Calgary Health Region's centralized administrative hospital discharge database, 1994 to 2002.	hospitalizations, perioperative stroke (incident)	inpatient ICD-9-CM codes: 433.x, 434.x, 436, 438.x, 997.02, 997.00, 997.01, 997.09	Medical record review was conducted (N=7). Perioperative stroke was confirmed through documentation in chart. PPV=14%
Tirschwell, et al.[43]	hospitalizations for patients ≥ 20 years of age in Seattle, Washington, hospitals, identified using the Comprehensive Hospital Abstract Reporting System, 1990 to 1996.	hospitalizations (ischemic stroke)	inpatient ICD-9-CM codes 433.x1, 434, [excluding 434.x0], and 436; excluded cases if any codes for traumatic brain injury (ICD-9-CM 800–804, 850–854) or rehabilitation care (primary ICD-9-CM code V57) was present.	Medical record review was conducted (total N=147 and potential ischemic stroke N=50). Outcome was confirmed and classified by a stroke neurologist. Using all discharge codes: sensitivity=86% specificity=95% PPV=90% Using primary discharge code: sensitivity=74% specificity=95% PPV=88%
Williams, et al.[44]	hospitalizations at Wishard Hospital, Indianapolis, IN, identified using the Regenstrief Medical Record System, 1993 to 1998.	hospitalizations (acute ischemic stroke)	primary position discharge diagnosis ICD-9 codes for acute ischemic stroke (434 and 436)	Medical record review was conducted (N=671). Criteria for confirmation of outcome were unspecified. PPV=98%

Table 2

Positive Predictive Values of Algorithms to Identify Transient Ischemic Attack (TIA)

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure, Operational Definition, and Validation Statistics
Agrawal, et al.[46]	Kaiser Permanente of Northern California members aged 0 to 19 years, 1993 to 2003	TIA	inpatient and outpatient ICD-9 code 435.xx	Medical record review was conducted. TIA was confirmed by neurologists based upon documentation of a focal neurological deficit or acute onset lasting < 24 hours with no readiographic evidence of an infarct and clinical suspicion of TIA by a physician. Inpatient code: PPV=68% Outpatient code: PPV=52%
Benesch, et al.[14]	hospitalizations at 5 academic medical centers identified using the Academic Medical Center Consortium database, 1992	hospitalizations (TIA)	inpatient ICD-9 codes 433 to 436	Medical record review was conducted (N=649). TIA was confirmed based upon the World Health Organization (WHO) definition. primary and secondary diagnoses: code 433: PPV=8.5%; code 434: PPV=5.3%; code 435: PPV=76.8%; code 436: PPV=3.4%; primary diagnosis: code 433: PPV=14.2%; code 434: PPV=5.9%; code 435: PPV=88.9%; code 436: PPV=5.6%;
Heckbert, et al.[24]	hospitalizations among women enrolled in the Women's Health Initiative (WHI), 1994 to 2000	hospitalizations (TIA)	TIA: ICD-9 code 435	Medical record review was conducted. Outcome was confirmed based upon WHI criteria for cardiovascular endpoints. PPV=72% sensitivity=73%
Holick, et al.[9]	adults who received a first dispensing of atomoxetine or stimulant ADHD medication and comparison group identified using the Ingenix Research DataMart, 2003 to 2006	hospitalizations (TIA)	inpatient ICD-9 codes for TIA: 435.9x	Medical record review was conducted (N=83). Criteria for confirming a TIA event included a stated diagnosis of TIA from a neurologist or in the hospital discharge summary or a description of the event that is consistent with a TIA diagnosis. PPV=28%
Ives, et al.[45]	Cardiovascular health Study: residents ≥ 65 years in Sacramento County, CA; Washington County, MD; Forsyth County, NC; Pittsburgh, PA, 1989 to 1992	hospitalizations (incident)	ICD-9-CM 435 in the discharge abstract	Medical record review was conducted (N=46). Outcome was confirmed based upon decision by an Events Committee, considering documentation of medical history, symptoms, course, and outcome of each event. PPV=28% Estimate calculated using data presented in the report.
Kokotailo, et al.[29]	patients with inpatient visits or seen at the emergency department identified from hospital discharge abstracts	hospitalizations and emergency department visits (TIA)	most responsible (primary position) diagnosis ICD-9	Medical record review was conducted on a sample of charts (N=37 identified with ICD-9 codes and N=60 identified with ICD-10 codes). Outcome was confirmed based upon trained research assistant determination, and neurologist determination in ambiguous cases. Cases were coded as TIA if they resolved within 24 hours of onset, and if imaging was performed, no detectable changes were evident. Assessment of correct coding was based on clinical data alone in 24% of charts and on clinical data and neurovascular imaging reports in 76% of charts. ICD-9 coding: PPV=70%

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure, Operational Definition, and Validation Statistics
	database from 3 acute care hospitals in the Calgary health region, 2000 to 2003		codes 435.x, ICD-10 G45.x	ICD-10 coding: PPV=97%
Newton, et al.[36]	Group Health Cooperative of Puget Sound members aged 18 and older with type 1 or type 2 diabetes, 1993 to 1995	incident or prevalent (TIA)	TIA: ICD-9-CM codes 435; incident cases considered as those with code not present in 1992 (year before the observation period)	Medical record review was conducted among patients with multiple complications of diabetes (N=471 total, N=33 potential TIAs). Outcome was confirmed based upon the presence of a written diagnosis in the medical record. first confirmed date within 60 days of the automated record date: sensitivity=61.1%; specificity=94.9%; PPV=33.3%; confirmed at any time during the observation period: sensitivity=66.7%; specificity=95.6%; PPV=42.2%;

Table 3

Positive Predictive Values of Algorithms to Identify Intracranial Bleed (ICH) and Subarachnoid Hemorrhage (SAH)

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure, Operational Definition, and Validation Statistics
Agrawal, et al.[46]	Kaiser Permanente of Northern California members aged 0 to 19 years, 1993 to 2003	hospitalizations and outpatient encounters (SAH and ICH)	inpatient and outpatient ICD-9 codes 430, 431	Medical record review was conducted. SAH and ICH were confirmed by neurologists based upon documented clinical presentation and CT or MRI evidence. Inpatient codes: code 430: PPV=82% code 431: PPV=79% Outpatient codes: code 430: PPV=100% code 431: PPV=49%
Arnason, et al.[13]	patients discharged from a university-associated teaching hospital in Ottawa, Canada, 1999 to 2000	hospitalizations (intracranial bleeds)	inpatient ICD-9-CM codes 430 to 432	Medical record review was conducted (N=78). Confirmation of 'definite bleeding' required at least one of the following: documentation of a direct visualization of blood by a physician; imaging consistent with bleeding; imaging of a bleeding source accompanied by signs of bleeding. PPV=94%
Birman-Deych, et al.[15]	Medicare beneficiaries who were hospitalized with atrial fibrillation identified using the National Registry of Atrial Fibrillation II dataset, , 1998 to 1999	hospitalizations (intracranial hemorrhage)	inpatient ICD-9-CM codes: 430, 431, 432.x, 800.2, 800.3, 800.7, 800.8, 801.2, 801.3, 801.7, 801.8, 803.2, 803.3, 803.7, 803.8, 804.2, 804.3, 804.7, 804.8, 852.x, 853.x	Medical record review was conducted. Outcome was confirmed if there was documentation of a current intracranial hemorrhage. sensitivity=60% specificity > 99% PPV=77%
Kokotailo, et al.[29]	patients with inpatient visits or seen at the emergency department identified from hospital discharge abstracts database from 3 acute care hospitals in the Calgary health region, 2000 to 2003	hospitalizations and emergency department visits (SAH and ICH)	most responsible (primary position) diagnosis ICD-9 codes 430.x (SAH) and 431.x (ICH), ICD-10 codes I60.x (SAH), I61.x (ICH)	Medical record review was conducted on a sample of charts (N=76 ICH and 51 SAH identified with ICD-9 codes and N=67 ICH and 32 SAH identified with ICD-10 codes). Outcome was confirmed based upon trained research assistant determination, and neurologist determination in ambiguous cases. ICD-9 coding: ICH: PPV=97% SAH: PPV=98% ICD-10 coding: ICH: PPV=98% SAH: PPV=91%
Tirschwell, et al.[43]	hospitalizations for patients ≥ 20 years of age in Seattle, Washington, hospitals, identified using the Comprehensive Hospital Abstract Reporting System, 1990 to 1996.	hospitalizations (SAH and ICH)	inpatient ICD-9-CM codes for ICH (431) or SAH (430); excluded cases if any codes for traumatic brain injury (ICD-9-CM 800–804, 850–854) or rehabilitation care (primary ICD-9-CM code V57) was present. Hospitalizations with	Medical record review was conducted N=147 total, including N=39 potential ICH and N=51 potential SAH). Outcome was confirmed and classified by a stroke neurologist. Using all discharge codes: **ICH**: sensitivity=82%

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure, Operational Definition, and Validation Statistics
			multiple stroke diagnoses were classified in the following priority: SAH > ICH > ischemic stroke > TIA.	specificity=93% PPV=80% **SAH**: sensitivity=98% specificity=92% PPV=86% Using primary discharge code: **ICH**: sensitivity=85% specificity=96% PPV=89% **SAH**: sensitivity=90% specificity=97% PPV=94%

Table 4

Positive Predictive Values of Algorithms to Identify Composite Endpoints (Stroke/Transient Ischemic Attack and Cerebrovascular Disease)

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure, Operational Definition, and Validation Statistics
Stroke/TIA				
Arnason, et al.[13]	patients discharged from a university-associated teaching hospital in Ottawa, Canada, 1999 to 2000	hospitalizations (stroke/TIA)	inpatient ICD-9-CM codes 433 to 436	Medical record review was conducted (N=179 cases of potential stroke/TIA). Confirmation of 'acute thromboembolism' required documentation of at least one of the following: direct visualization or imaging of a new thromboembolism or new clinical signs of a stroke/TIA combined with physician confirmation of newly completed stroke/TIA in the chart or a CT report showing acute or sub-acute cerebral infarct. PPV=57%
Birman-Deych, et al.[15]	Medicare beneficiaries who were hospitalized with atrial fibrillation identified using the National Registry of Atrial Fibrillation II dataset, 1998 to 1999	hospitalizations (stroke/TIA, prevalent and incident)	inpatient ICD-9-CM codes 433.x1, 434.x1, 435.x, 436, 437.1x, 437.9x, 438.x	Medical record review was conducted. Outcome was confirmed if there was documentation of a history and/or current stroke/TIA. Current or past stroke/TIA: sensitivity=35% specificity=99% PPV=96%
Broderick, et al.[17]	Black residents of the Greater Cincinnati/Northern Kentucky region, identified by hospitalization discharges from 19 acute-care hospitals, 1993 to 1994	hospitalizations (stroke/TIA including intracerebral hemorrhage and subarachnoid hemorrhage)	inpatient ICD-9-CM codes 430 to 438, 747.81, 674.0, 325	Medical record review was conducted (N=733). The criteria that determined the various diagnostic categories of stroke were adapted from the Classification of Cerebrovascular Diseases III and from epidemiological studies of stroke in Rochester, Minnesota. codes 430–438: PPV=46% codes 430–436: PPV=72% (and would detect 97% of all strokes and TIAs) primary discharge codes 430–436: PPV=83%
Humphries, et al.[25]	adults identified by the British Columbia Cardiac Registries as having undergone a percutaneous coronary intervention at St. Paul's Hospital, 1994 to 1995	hospitalizations (cerebrovascular disease: stroke, TIA, or carotid endarterectomy, prevalent or incident)	inpatient ICD-9 codes 430 to 438	Medical record review was conducted (N=817). The outcome was confirmed based upon documentation of a previous history of stroke, TIA, or carotid endarterectomy. sensitivity=42.9% specificity=99.2% PPV=71.4%
Kokotailo, et al.[29]	patients with inpatient visits or seen at the emergency department identified from hospital discharge abstracts database from 3 acute	hospitalizations and emergency department visits (stroke/TIA	most responsible (primary position) diagnosis ICD-9 codes 430.x, 431.x, 433.x1, 434.x1, 435.x, 436, 362.3;	Medical record review was conducted on a sample of charts (N=461 identified with ICD-9 codes and N=256 identified with ICD-10 codes). Outcome was confirmed based upon trained research assistant determination, and neurologist determination in ambiguous cases. Assessment of correct coding was based on clinical data alone in 24% of charts and on clinical data and neurovascular imaging reports in 76% of charts. ICD-9 coding: overall: PPV=90% ICD-10 coding:

Citation	Study Population and Time Period	Description of Outcome Studied	Algorithm	Validation/Adjudication Procedure, Operational Definition, and Validation Statistics
	care hospitals in the Calgary health region, 2000 to 2003	including intracerebral hemorrhage and subarachnoid hemorrhage)	ICD-10 codes I60.x, I61.x, I63.x, I64.x, H34.1, G45.x	overall: PPV=92%
Lentine, et al.[32]	kidney transplant patients at Washington University ages ≥ 18 years with Medicare as primary insurer, 1991 to 2002	incident or prevalent (stroke/TIA)	ICD-9-CM codes: 430, 431, 432, 433.x1, 434.x1, 435.x, 997.02; identified with Medicare Part A (institutional) claims and/or Medicare Part B (physician/ suppliers) claims	Transplant center's clinical database was used to confirm stroke or TIA. Definition of stroke included new focal neurologic deficit lasting ≥ 24 hours, confirmed by brain imaging. Definition of TIA included new focal deficit that resolves within 24 hours and was attributed to a central cause by the examining provider. Claims within 30 days from event date recorded in the database: **Medicare Part A claims** sensitivity = 75.0% (95% CI 53.8 – 96.2%); **Medicate Part B claims** sensitivity = 81.3% (95% CI 62.1% – 100.0%); **Medicare Part A or B claims** sensitivity = 87.5% (95%CI 71.3% – 100.0%);
Cerebrovascular Disease				
Borzecki, et al.[16]	Veterans Affairs patients with at least 1 hypertension diagnosis (ICD-9-CM code 401, 402, or 405) and a sample without a hypertension diagnosis Department of Veterans Affairs (VA) databases, 1998 to 1999	incident or prevalent (cerebrovascular disease)	inpatient or outpatient ICD-9-CM codes: 430.x to 438.x	Medical record review was conducted (981 patients with a hypertension diagnosis and 195 without a hypertension diagnosis). Outcome was confirmed based upon documentation of cerebrovascular disease in medical notes. sensitivity=64% specificity=95%
Jollis, et al.[27]	discharges containing a procedure code for coronary arteriography identified using administrative or insurance claims of Duke University Medical Center, 1985 to 1990	hospitalizations (cerebrovascular disease, incident and prevalent)	discharges with an ICD-9-CM code of 435, 436, 438, 437.1, 434, 38.12, 38.42	Clinical database was compared to coding by medical record technicians (N=12937). Cerebrovascular disease was confirmed based upon documentation in the clinical data. sensitivity= 14% specificity= 99%
Piriyawat, et al.[37]	residents of Nueces County Texas ≥ 45 years of age, 2000	hospitalizations (acute cerebrovascular events)	primary and secondary ICD-9 discharge codes for 430 to 438, except those with a fifth digit specification of 0 (xxx.x0); also excluded codes 437.0, 437.2, 437.3, 437.4, 437.5, 437.7, 437.8, and 438	Medical record review was conducted (N=815). Acute cerebrovascular events were confirmed based upon criteria specified by Morgenstern et al. Cerebrovascular events resulting from trauma were excluded. sensitivity=89% PPV=72.8%
So, et al.[41]	patients ≥ 20 years of age hospitalized with acute myocardial infarction at 4 teaching hospitals in Alberta, Canada, 2003	hospitalizations (cerebrovascular disease, incident and prevalent)	inpatient ICD-9-CM codes: 430.x to 438.x; ICD-10 codes: G45.x, G46.x, H34.0, I60.x – I69.x	Medical record review was conducted (N=193) and outcome was confirmed based upon evidence of cerebrovascular disease in chart. ICD-9-CM codes: sensitivity = 100.0% (95% CI 54.1 – 100.0) specificity = 93.6% (89.1 – 96.6) PPV = 33.3% (13.3 – 59.0) ICD-10 codes: sensitivity = 100.0% (54.1 – 100.0) specificity = 95.7% (91.7 – 98.1) PPV = 42.9% (17.7 – 71.1)

Table 5

Positive Predictive Values (PPVs) of International Classification of Diseases (ICD) Codes to Identify Cerebrovascular Accident and Transient Ischemic Attacks (TIAs) in Adult Populations*

ICD-9/ICD-10 code	Number of studies reporting PPV estimate	Median PPV estimate	Range of PPV estimates (minimum, maximum)	Number of studies reporting PPV estimate	Median PPV estimate	Range of PPV estimates (minimum, maximum)
Studies Evaluating Acute Stroke Events						
	Using Principal or Most Responsible Diagnosis Only			Using All Discharge Diagnoses		
430	3	87	33, 100	4	84	74, 100
431	3	88	80, 100	4	86	83, 93
432	3	21	17, 29	4	20	0, 32
432.9	0			1	60	
433	3	17	9, 46	4	15	6, 15
433.x0	1	13		0		
433.x1	1	71		0		
434	3	90	84, 92	4	85	77, 85
434.x0	1	33		0		
434.x1	1	72		0		
434.0	1	85		1	82	
434.1	1	80		1	58	
435	4	17	3, 29	4	14	9, 26
436	4	80	48, 89	5	81	70, 86
437	3	50	45, 69	3	22	2, 31
438	2	20	8, 33	3	1	0, 7
Studies Evaluating Ischemic Stroke Events						
	Using Principal or Most Responsible Diagnosis Only			Using All Discharge Diagnoses		
433	1	4		1	14	
434	2	87	82, 92	1	77	
434.11	1	85		0		
434.91	1	82		0		
435	0			1	12	

ICD-9/ICD-10 code	Number of studies reporting PPV estimate	Median PPV estimate	Range of PPV estimates (minimum, maximum)	Number of studies reporting PPV estimate	Median PPV estimate	Range of PPV estimates (minimum, maximum)
436	1	79		1	68	
437	0			1	2	
438	0			1	0	
Studies Evaluating TIA						
	Using Principal or Most Responsible Diagnosis Only			Using All Discharge Diagnoses		
433	1	14		1	9	
434	1	6		1	5	
435	2	79	70, 89	3	72	28, 77
435.9	0			1	28	
436	1	6		1	3	
G45.X	1	97		0		
Studies Evaluating Intracranial Bleed (ICH) and Subarachnoid Hemorrhage (SAH)						
	Using Principal or Most Responsible Diagnosis Only			Using All Discharge Diagnoses		
430	2	96	94, 98	1	86	
431	2	93	89, 97	1	80	
I60	1	91		0		
I61	1	98		0		

* Includes studies reporting data from hospitalizations and emergency department visits. Excludes studies reporting PPVs estimates for in-hospital complications exclusively. For studies reporting more than one PPV estimate (i.e., estimates for adjudications conducted by different neurologists or estimates for tertiary versus community hospital settings), we determined the weighted average (weighted by the number of potential cases reviewed for the specific ICD code).

Appendix 1

List and Definitions of ICD or Procedural Codes Included in Algorithms

Type of Code	Code	Description
ICD-9	325	PHLEBITIS AND THROMBOPHLEBITIS OF INTRACRANIAL VENOUS SINUSES
ICD-9	342	HEMIPLEGIA
ICD-9	342.0	FLACCID HEMIPLEGIA
ICD-9	342.00	FLACCID HEMIPLEGIA UNSPECIFIED SIDE
ICD-9	342.01	FLACCID HEMIPLEGIA DOMINANT SIDE
ICD-9	342.02	FLACCID HEMIPLEGIA NONDOMINANT SIDE
ICD-9	342.1	SPASTIC HEMIPLEGIA
ICD-9	342.10	SPASTIC HEMIPLEGIA UNSPECIFIED SIDE
ICD-9	342.11	SPASTIC HEMIPLEGIA DOMINANT SIDE
ICD-9	342.12	SPASTIC HEMIPLEGIA NONDOMINANT SIDE
ICD-9	342.80	OTHER SPECIFIED HEMIPLEGIA UNSPECIFIED SIDE
ICD-9	342.81	OTHER SPECIFIED HEMIPLEGIA DOMINANT SIDE
ICD-9	342.82	OTHER SPECIFIED HEMIPLEGIA NONDOMINANT SIDE
ICD-9	342.9	HEMIPLEGIA UNSPECIFIED
ICD-9	342.90	UNSPECIFIED HEMIPLEGIA UNSPECIFIED SIDE
ICD-9	342.91	UNSPECIFIED HEMIPLEGIA DOMINANT SIDE
ICD-9	342.92	UNSPECIFIED HEMIPLEGIA NONDOMINANT SIDE
ICD-9	362.3	RETINAL VASCULAR OCCLUSION
ICD-9	369.0	PROFOUND BLINDNESS BOTH EYES
ICD-9	369.00	BOTH EYES BLIND-WHO DEFINITION
ICD-9	369.01	TOTAL IMPAIRMENT-BOTH EYES
ICD-9	369.02	ONE EYE-NEAR TOTAL IMPAIRMENT/OTHER EYE-NOT SPECIFIED
ICD-9	369.03	ONE EYE-NEAR TOTAL IMPAIRMENT/OTHER EYE-TOTAL IMPAIRMENT
ICD-9	369.04	NEAR-TOTAL IMPAIRMENT-BOTH EYES
ICD-9	369.05	ONE EYE-PROFOUND IMPAIRMENT/OTHER EYE-NOT SPECIFIED
ICD-9	369.07	ONE EYE-PROFOUND IMPAIRMENT/OTHER EYE-NEAR TOTAL IMPAIRMENT
ICD-9	369.08	PROFOUND IMPAIRMENT BOTH EYES
ICD-9	369.1	MODERATE/SEVERE IMPAIRMENT ONE EYE WITH PROFOUND IMPAIRMENT OTHER EYE
ICD-9	369.10	BLINDNESS/LOW VISION
ICD-9	369.11	ONE EYE-SEVERE/OTHER EYE-BLIND NOT SPECIFIED
ICD-9	369.12	ONE EYE-SEVERE/OTHER EYE-TOTAL IMPAIRMENT
ICD-9	369.13	ONE EYE-SEVERE/OTHER EYE-NEAR TOTAL IMPAIRMENT
ICD-9	369.14	ONE EYE-SEVERE/OTHER EYE-PROFOUND IMPAIRMENT
ICD-9	369.15	ONE EYE-MODERATE/OTHER EYE-BLIND
ICD-9	369.16	ONE EYE-MODERATE/OTHER EYE-TOTAL IMPAIRMENT
ICD-9	369.17	ONE EYE-MODERATE/OTHER EYE-NEAR TOTAL IMPAIRMENT
ICD-9	369.18	ONE EYE-MODERATE/OTHER EYE-PROFOUND IMPAIRMENT

Type of Code	Code	Description
ICD-9	369.2	MODERATE/SEVERE IMPAIRMENT-BOTH EYES
ICD-9	369.20	LOW VISION, TWO EYES NOT SPECIFIED
ICD-9	369.21	ONE EYE-SEVERE/OTHER EYE-NOT SPECIFIED
ICD-9	369.22	SEVERE IMPAIRMENT-BOTH EYES
ICD-9	369.23	ONE EYE-MODERATE/OTHER EYE-NOT SPECIFIED
ICD-9	369.24	ONE EYE-MODERATE/OTHER EYE-SEVERE IMPAIRMENT
ICD-9	369.25	MODERATE IMPAIRMENT-BOTH EYES
ICD-9	369.3	BLINDNESS NOT SPECIFIED, BOTH EYES
ICD-9	369.4	LEGAL BLINDNESS-USA DEFINITION
ICD-9	369.6	PROFOUND IMPAIRMENT-ONE EYE
ICD-9	369.60	BLINDNESS, ONE EYE
ICD-9	369.61	ONE EYE-TOTAL IMPAIRMENT/OTHER EYE-UNKNOWN
ICD-9	369.62	ONE EYE-TOTAL IMPAIRMENT/OTHER EYE-NEAR NORMAL
ICD-9	369.63	ONE EYE-TOTAL IMPAIRMENT/OTHER EYE-NORMAL
ICD-9	369.64	ONE EYE-NEAR TOTAL IMPAIRMENT/OTHER EYE-NOT SPECIFIED
ICD-9	369.65	NEAR-TOTAL IMPAIRMENT/OTHER EYE-NEAR-NORMAL
ICD-9	369.66	NEAR-TOTAL IMPAIRMENT/OTHER EYE NORMAL
ICD-9	369.67	ONE EYE-PROFOUND IMPAIRMENT/OTHER EYE-UNKNOWN
ICD-9	369.68	PROFOUND IMPAIRMENT/OTHER EYE-NEAR NORMAL
ICD-9	369.69	PROFOUND IMPAIRMENT/OTHER EYE-NORMAL
ICD-9	369.7	MODERATE/SEVERE IMPAIRMENT, ONE EYE
ICD-9	369.70	LOW VISION, ONE EYE
ICD-9	369.71	ONE EYE-SEVERE/OTHER EYE-UNKNOWN
ICD-9	369.72	ONE EYE-SEVERE/OTHER EYE-NEAR NORMAL
ICD-9	369.74	ONE EYE-MODERATE/OTHER EYE-UNKNOWN
ICD-9	369.75	ONE EYE-MODERATE/OTHER EYE-NEAR NORMAL
ICD-9	369.76	ONE EYE-MODERATE/OTHER EYE NORMAL
ICD-9	369.8	VISUAL LOSS, ONE EYE NOT SPECIFIED
ICD-9	369.9	VISUAL LOSS NOT SPECIFIED
ICD-9	430	SUBARACHNOID HEMORRHAGE
ICD-9	431	INTRACEREBRAL HEMORRHAGE
ICD-9	432	INTRACRANIAL HEMORRHAGE, OTHER AND UNSPECIFIED
ICD-9	432.0	NONTRAUMATIC EXTRADURAL HEMORRHAGE
ICD-9	432.1	SUBDURAL HEMORRHAGE
ICD-9	432.9	INTRACRANIAL HEMORRHAGE NOT SPECIFIED
ICD-9	433	PRECEREBRAL OCCLUSION
ICD-9	433.0	BASILAR ARTERY OCCLUSION
ICD-9	433.00	OCCLUSION BASILAR ARTERY WITHOUT MENTION OF INFARCTION
ICD-9	433.01	OCCLUSION BASILAR ARTERY WITH INFARCTION

Type of Code	Code	Description
ICD-9	433.1	CAROTID ARTERY OCCLUSION
ICD-9	433.10	OCCLUSION CAROTID ARTERY WITHOUT MENTION OF INFARCTION
ICD-9	433.11	OCCLUSION CAROTID ARTERY WITH INFARCTION
ICD-9	433.2	VERTEBRAL ARTERY OCCLUSION
ICD-9	433.20	OCCLUSION VERTEBRAL ARTERY WITHOUT MENTION OF INFARCTION
ICD-9	433.21	OCCLUSION VERTEBRAL ARTERY WITH INFARCTION
ICD-9	433.3	MULTIPLE AND BILATERAL PRECEREBRAL OCCLUSION
ICD-9	433.30	OCCLUSION MULTIPLE AND BILATERAL ARTERY WITHOUT MENTION OF INFARCTION
ICD-9	433.31	OCCLUSION MULTIPLE AND BILATERAL ARTERY WITH INFARCTION
ICD-9	433.8	PRECEREBAL OCCLUSION, OTHER SPECIFIED
ICD-9	433.80	OCCLUSION SPECIFID ARTERY WITHOUT MENTION OF INFARCTION
ICD-9	433.81	OCCLUSION SPECIFIED ARTERY WITH INFARCTION
ICD-9	433.9	PRECEREBRAL OCCLUSION UNSPECIFIED
ICD-9	433.90	OCCLUSION ARTERY UNSPECIFIED WITHOUT MENTION OF INFARCTION
ICD-9	433.91	OCCLUSION ARTERY UNSPECIFIED WITH INFARCTION
ICD-9	434	CEREBRAL ARTERY OCCLUSION
ICD-9	434.0	CEREBRAL THROMBOSIS
ICD-9	434.00	CEREBRAL THROMBOSIS WITHOUT MENTION OF INFARCTION
ICD-9	434.01	CEREBRALL THROMBOSIS WITH INFARCTION
ICD-9	434.1	CEREBRAL EMBOLISM
ICD-9	434.10	CEREBRAL EMBOLISM WITHOUT MENTION OF INFARCTION
ICD-9	434.11	CEREBRAL EMBOLISM WITH INFARCTION
ICD-9	434.9	CEREBRAL ARTERY OCCLUSION UNSPECIFIED
ICD-9	434.90	CEREBRAL ARTERY OCCLUSION UNSPECIFIED WITHOUT MENTION OF INFARCTION
ICD-9	434.91	CEREBRAL ARTERY OCCLUSION UNSPECIFIED WITH INFARCTION
ICD-9	435	TRANSIENT CEREBRAL ISCHEMIA
ICD-9	435.0	BASILAR ARTERY SYNDROME
ICD-9	435.1	VERTEBRAL ARTERY SYNDROME
ICD-9	435.2	SUBCLAVIAN STEAL SYNDROME
ICD-9	435.3	VERTEBROBASILAR ARTERY SYNDROME
ICD-9	435.8	TRANSIENT CEREBRAL ISCHEMIA OTHER SPECIFIED
ICD-9	435.9	TRANSIENT CEREBRAL ISCHEMIA UNSPECIFIED
ICD-9	436	ACUTE CEREBROVASCULAR DISEASE
ICD-9	437	OTHER CEREBROVASCULAR DISEASE
ICD-9	437.0	CEREBRAL ATHEROSCLEROSIS
ICD-9	437.1	ACUTE CEREBROVASCULAR INSUFFICIENCY NOT SPECIFIED
ICD-9	437.2	HYPERTENSIVE ENCEPHALOPATHY
ICD-9	437.3	NONRUPTURED CEREBRAL ANEURYM
ICD-9	437.4	CEREBRAL ARTERITIS

Type of Code	Code	Description
ICD-9	437.5	MOYAMOYA DISEASE
ICD-9	437.6	NONPYOGENIC THROMBOSIS SINUS
ICD-9	437.7	TRANSIENT GLOBAL AMNESIA
ICD-9	437.8	CEREBROVASCULAR DISEASE OTHER
ICD-9	437.9	CEREBROVASC DISEASE UNSPECIFIED
ICD-9	438	LATE EFFECTS CEREBROVASCULAR DISEASE
ICD-9	438.0	LATE EFFECTS CEREBROVASCULAR DISEASE-COGNITIVE DEFICITS
ICD-9	438.10	LATE EFFECTS CEREBROVASCULAR DISEASE - SPEECH/LANGUAGE DEFICITS UNSPECIFIED
ICD-9	438.11	LATE EFFECTS CEREBROVASCULAR DISEASE - APHASIA
ICD-9	438.12	LATE EFFECTS CEREBROVASCULAR DISEASE-DYSPHASIA
ICD-9	438.19	LATE EFFECTS CEREBROVASCULAR DISEASE-SPEECH/LANGUAGE DEFICITS OTHER
ICD-9	438.20	LATE EFFECTS CEREBROVASCULAR DISEASE-HEMIPLEGIA UNSPECIFIED SIDE
ICD-9	438.21	LATE EFFECTS CEREBROVASCULAR DISEASE-HEMIPLEGIA DOMINANT SIDE
ICD-9	438.22	LATE EFFECTS CEREBROVASCULAR DISEASE-HEMIPLEGIA NONDOMINANT SIDE
ICD-9	438.30	LATE EFFECTS CEREBROVASCULAR DISEASE-MONOPLEGIA UPPER LIMB UNSPECIFIED
ICD-9	438.31	LATE EFFECTS CEREBROVASCULAR DISEASE-MONOPLEGIA UPPER LIMB DOMINANT SIDE
ICD-9	438.32	LATE EFFECTS CEREBROVASCULAR DISEASE-MONOPLEGIA UPPER LIMB NONDOMINANT SIDE
ICD-9	438.40	LATE EFFECTS CEREBROVASCULAR DISEASE-MONOPLEGIA LOWER LIMB UNSPECIFIED
ICD-9	438.41	LATE EFFECTS CEREBROVASCULAR DISEASE-MONOPLEGIA LOWER LIMB DOMINANT SIDE
ICD-9	438.42	LATE EFFECTS CEREBROVASCULAR DISEASE-MONOPLEGIA LOWER LIMB NONDOMINANT SIDE
ICD-9	438.50	LATE EFFECTS CEREBROVASCULAR DISEASE-OTHER PARALYTIC SYNDROME UNSPECIFIED SIDE
ICD-9	438.51	LATE EFFECTS CEREBROVASCULAR DISEASE-OTHER PARALYTIC SYNDROME DOMINANT SIDE
ICD-9	438.52	LATE EFFECTS CEREBROVASCULAR DISEASE-OTHER PARALYTIC SYNDROME NONDOMINANT SIDE
ICD-9	438.53	LATE EFFECTS CEREBROVASCULAR DISEASE-OTHER PARALYTIC SYNDROME-BILATERAL
ICD-9	438.81	LATE EFFECTS CEREBROVASCULAR DISEASE-APRAXIA
ICD-9	438.82	LATE EFFECTS CEREBROVASCULAR DISEASE-DYSPHAGIA
ICD-9	438.89	LATE EFFECTS CEREBROVASCULAR DISEASE-OTHER
ICD-9	438.9	LATE EFFECTS CEREBROVASCULAR DISEASE-UNSPECIFIED
ICD-9	671.5	OTHER THROMBOSIS COMPLICATING PREGNANCY
ICD-9	674.0	CEREBROVASCULAR DISEASE IN PUERPERIUM
ICD-9	747.81	CEREBROVASCULAR ANOMALY
ICD-9	767	BIRTH TRAUMA
ICD-9	767.0	CEREBRAL HEMHORRAGE AT BIRTH
ICD-9	780.0	COMA AND STUPOR

Type of Code	Code	Description
ICD-9	780.4	DIZZINESS AND GIDDINESS
ICD-9	800.2	CLOSED SKULL VAULT FRACTURE/HEMORRHAGE
ICD-9	800.3	CLOSED SKULL VAULT FRACTURE/HEMORRHAGE OTHER
ICD-9	800.7	OPEN SKULL VAULT FRACTURE/HEMORRHAGE
ICD-9	800.8	OPEN SKULL VAULT FRACTURE/HEMORRHAGE OTHER
ICD-9	801.2	CLOSED SKULL BASE FRACTRE/HEMORRHAGE
ICD-9	801.3	CLOSED SKULL BASE FRACTURE/HEMORRHAGE OTHER
ICD-9	801.7	OPEN SKULL BASE FACTURE/HEMORRHAGE
ICD-9	801.8	OPEN SKULL BASE FRACTURE-/HEMORRHAGE
ICD-9	803.2	CLOSED SKULL FRACTURE OTHER/HEMORRHAGE
ICD-9	803.3	CLOSED SKULL FRACTURE OTHER/HEMORRHAGE OTHER
ICD-9	803.7	OPEN SKULL FRACTURE OTHER/HEMORRHAGE
ICD-9	803.8	OPEN SKULL FRACTURE OTHER/HEMORRHAGE OTHER
ICD-9	804.2	CLOSED SKULL/OTHER FRACTURE/HEMORRHAGE
ICD-9	804.3	CLOSED SKULL OTHER FRACTURE/HEMORRHAGE OTHER
ICD-9	804.7	OPEN SKULL/OTHER FRACTURE-HEMORRHAGE
ICD-9	804.8	OPEN SKULL OTHER FRACTURE/HEMORRHAGE OTHER
ICD-9	852	SUBARACHNOID, SUBDURAL, EXTRADURAL HEMORRHAGE FOLLOW INJURY
ICD-9	852.0	TRAUMATIC SUBARACHNOID HEMORRHAGE
ICD-9	852.00	TRAUMATIC SUBARACHNOID HEMORRHAGE
ICD-9	852.01	SUBARACHNOID HEMORRHAGE-NO COMA
ICD-9	852.02	SUBARACHNOID HEMORRHAGE-BRIEF COMA
ICD-9	852.03	SUBARACHNOID HEMORRHAGE-MODERATE COMA
ICD-9	852.04	SUBARACHNOID HEMORRHAGE-PROLONGED COMA
ICD-9	852.05	SUBARACHNOID HEMORRHAGE-DEEP COMA
ICD-9	852.06	SUBARACHNOID HEMORRHAGE-COMA UNSPECIFIED
ICD-9	852.09	SUBARACHNOID HEMORRHAGE-CONCUSSION
ICD-9	852.1	SUBARACHNOID HEMORRHAGE WITH OPEN WOUND
ICD-9	852.10	SUBARACHNOID HEMORRHAGE WITH OPEN WOUND
ICD-9	852.11	OPEN SUBARACHNOID HEMORRHAGE-NO COMA
ICD-9	852.16	OPEN SUBARACHNOID HEMORRHAGE-COMA UNSPECIFIED
ICD-9	852.2	TRAUMATIC SUBDURAL HEMORRHAGE
ICD-9	852.20	TRAUMATIC SUBDURAL HEMORRHAGE
ICD-9	852.21	SUBDURAL HEMORRHAGE WITHOUT COMA
ICD-9	852.22	SUBDURAL HEMORRHAGE-BRIEF COMA
ICD-9	852.23	SUBDURAL HEMORRHAGE-MODERATE COMA
ICD-9	852.24	SUBDURAL HEMORRHAGE-PROLONGED COMA
ICD-9	852.25	SUBDURAL HEMORRHAGE-DEEP COMA
ICD-9	852.26	SUBDURAL HEMORRHAGE-COMA UNSPECIFIED

Type of Code	Code	Description
ICD-9	852.29	SUBDURAL HEMORRHAGE-CONCUSSION
ICD-9	852.3	SUBDURAL HEMORRHAGE WITH OPEN WOUND
ICD-9	852.30	SUBDURAL HEMORRHAGE WITH OPEN WOUND
ICD-9	852.31	OPEN SUBDURAL HEMORRHAGE WITHOUT COMA
ICD-9	852.4	TRAUMATIC EXTRADURAL HEMORRHAGE
ICD-9	852.40	TRAUMATIC EXTRADURAL HEMORRHAGE
ICD-9	852.41	EXTRADURAL HEMORRHAGE WITHOUT COMA
ICD-9	852.42	EXTRADUR HEMORRHAGE-BRIEF COMA
ICD-9	852.43	EXTRADURAL HEMORRHAGE-MODERATE COMA
ICD-9	852.44	EXTRADURAL HEMORRHAGE-PROLONGED COMA
ICD-9	852.45	EXTRADURAL HEMORRHAGE-DEEP COMA
ICD-9	852.46	EXTRADURAL HEMORRHAGE-COMA UNSPECIFIED
ICD-9	852.50	EXTRADURAL HEMORRHAGE WITH OPEN WOUND
ICD-9	852.52	EXTRADUR HEMORRHAGE-BRIEF COMA
ICD-9	852.56	EXTRADURAL HEMORRHAGE-COMA UNSPECIFIED
ICD-9	852.59	EXTRADURAL HEMORRHAGE-CONCUSSION
ICD-9	853	OTHER TRAUMATIC BRAIN HEMORRHAGE
ICD-9	853.0	TRAUMATIC BRAIN HEMORRHAGE OTHER
ICD-9	853.00	TRAUMATIC BRAIN HEMORRHAGE OTHER
ICD-9	853.01	BRAIN HEMORRHAGE OTHER WITHOUT COMA
ICD-9	853.02	BRAIN HEMORRHAGE OTHER-BRIEF COMA
ICD-9	853.03	BRAIN HEMORRHAGE OTHER-MODERATE COMA
ICD-9	853.04	BRAIN HEMORRHAGE OTHER-PROLONGED COMA
ICD-9	853.05	BRAIN HEMORRHAGE OTHER-DEEP COMA
ICD-9	853.06	BRAIN HEMORRHAGE OTHER-COMA UNSPECIFIED
ICD-9	853.09	BRAIN HEMORRHAGE OTHER-CONCUSSION
ICD-9	853.1	BRAIN HEMORRHAGE OTHER WITH OPEN WOUND
ICD-9	853.10	BRAIN HEMORRHAGE WITH OPEN WOUND
ICD-9	853.11	BRAIN HEMORRHAGE OPEN WOUND WITHOUT COMA
ICD-9	853.12	BRAIN HEMORRHAGE OPEN WOUND-BRIEF COMA
ICD-9	853.14	BRAIN HEMORRHAGE OPEN WOUNF-PROLONGED COMA
ICD-9	853.15	BRAIN HEMORRHAGE OPEN WOUND-DEEP COMA
ICD-9	853.19	BRAIN HEMORRHAGE OPEN WOUND-CONCUSSION
ICD-9	997.00	NERVOUS SYSTEM COMPLICATION UNSPECIFIED
ICD-9	997.01	SURGICAL COMPLICATION CENTRAL NERVOUS SYSTEM
ICD-9	997.02	IATROGENIC CEREBROVASCULAR INFARCTION/HEMORRHAGE
ICD-9	997.09	SURGICAL COMPLICATION NERVOUS SYSTM OTHER
ICD-9	V57	REHABILITATION PROCEDURE
ICD-9	V57.0	BREATHING EXERCISES

Type of Code	Code	Description
ICD-9	V57.1	PHYSICAL THERAPY OTHER
ICD-9	V57.2	OCCUPATIONAL/VOCATIONAL THERAPY
ICD-9	V57.21	ENCOUNTER OCCUPATIONAL THERAPY
ICD-9	V57.22	ENCOUNTER VOCATIONAL THERAPY
ICD-9	V57.3	SPEECH THERAPY
ICD-9	V57.4	ORTHOPTIC TRAINING
ICD-9	V57.8	OTHER REHABILITATION PROCEDURE
ICD-9	V57.81	ORTHOTIC TRAINING
ICD-9	V57.89	REHABILITATION PROCEDURE OTHER
ICD-9	V57.9	REHABILITATION PROCEDURE UNSPECIFIED
ICD-9 procedure	38.12	ENDARTERECTOMY
ICD-9 procedure	38.42	RESECTION VESSEL WITH REPLACEMENT-HEAD AND NECK
ICD-10	G45	TRANSIENT ISCHEMIC ATTACK/RELATED SYNDROMES
ICD-10	G45.0	VERTEBRO-BASILAR ARTERY SYNDROME
ICD-10	G45.1	CAROTID ARTERY SYNDROME (HEMISPHERIC)
ICD-10	G45.2	MULTIPLE/BILATERAL PRECEREBRAL ARTERY SYNDROME
ICD-10	G45.3	AMAUROSIS FUGAX
ICD-10	G45.4	TRANSIENT GLOBAL AMNESIA
ICD-10	G45.8	OTHER TRANSIENT ISCHEMIC ATTACK/RELATED SYNDROMES
ICD-10	G45.9	TRANSIENT CEREBRAL ISCHEMIC ATTACK, UNSPECIFIED
ICD-10	G46	VASCULAR SYNDROME BRAIN IN CEREBROVASCULAR DISEASES
ICD-10	G46.0	MIDDLE CEREBRAL ARTERY SYNDROME
ICD-10	G46.1	ANTERIOR CEREBRAL ARTERY SYNDROME
ICD-10	G46.2	POSTERIOR CEREBRAL ARTERY SYNDROME
ICD-10	G46.3	BRAIN STEM STROKE SYNDROME
ICD-10	G46.4	CEREBELLAR STROKE SYNDROME
ICD-10	G46.5	PURE MOTOR LACUNAR SYNDROME
ICD-10	G46.6	PURE SENSORY LACUNAR SYNDROME
ICD-10	G46.7	OTHER LACUNAR SYNDROMES
ICD-10	G46.8	OTH VASCULAR SYND BRAIN IN CEREBROVASCULAR DISEASES
ICD-10	H34.0	TRANSIENT RETINAL ARTERY OCCLUSION
ICD-10	H34.1	CENTRAL RETINAL ARTERY OCCLUSION
ICD-10	I60	SUBARACHNOID HEMORRHAGE
ICD-10	I60.0	SUBARACHNOID HEMORRHAGE CAROTID SIPHON AND BIFURCATION
ICD-10	I60.1	SUBARACHNOID HEMORRHAGE MIDDLE CEREBRAL ARTERY
ICD-10	I60.2	SUBARACHNOID HEMORRHAGE ANTERIOR COMMUNICATING ARTERY
ICD-10	I60.3	SUBARACHNOID HEMORRHAGE POSTERIOR COMMUNICATING ARTERY
ICD-10	I60.4	SUBARACHNOID HEMORRHAGE FROM BASILAR ARTERY
ICD-10	I60.5	SUBARACHNOID HEMORRHAGE FROM VERTEBRAL ARTERY

Type of Code	Code	Description
ICD-10	I60.6	SUBARACHNOID HEMORRHAGE FROM OTHER INTRACRANIAL ARTERIES
ICD-10	I60.7	SUBARACHNOID HEMORRHAGE FROM INTRACRANIAL ARTERY
ICD-10	I60.8	OTHER SUBARACHNOID HEMORRHAGE
ICD-10	I60.9	SUBARACHNOID HEMORRHAGE, UNSPECIFIED
ICD-10	I61	INTRACEREBRAL HEMORRHAGE
ICD-10	I61.0	INTRACEREBRAL HEMORRHAGE IN HEMISPHERE, SUBCORTICAL
ICD-10	I61.1	INTRACEREBRAL HEMORRHAGE IN HEMISPHERE, CORTICAL
ICD-10	I61.2	INTRACEREBRAL HEMORRHAGE IN HEMISPHERE, UNSPECIFIED
ICD-10	I61.3	INTRACEREBRAL HEMORRHAGE IN BRAIN STEM
ICD-10	I61.4	INTRACEREBRAL HEMORRHAGE IN CEREBELLUM
ICD-10	I61.5	INTRACEREBRAL HEMORRHAGE, INTRAVENTRICULAR
ICD-10	I61.6	INTRACEREBRAL HEMORRHAGE, MULTIPLE LOCALISED
ICD-10	I61.8	OTHER INTRACEREBRAL HEMORRHAGE
ICD-10	I61.9	INTRACEREBRAL HEMORRHAGE, UNSPECIFIED
ICD-10	I62	OTHER NONTRAUMATIC INTRACRANIAL HEMORRHAGE
ICD-10	I62.0	SUBDURAL HEMORRHAGE (ACUTE) (NONTRAUMATIC)
ICD-10	I62.1	NONTRAUMATIC EXTRADURAL HEMORRHAGE
ICD-10	I62.9	INTRACRANIAL HEMORRHAGE (NONTRAUMATIC), UNSPECIFIED
ICD-10	I63	CEREBRAL INFARCTION
ICD-10	I63.0	CEREBRAL INFARCTION DUE TO THROMBOSIS OF PRECEREBRAL ARTERIES
ICD-10	I63.1	CEREBRAL INFARCTION DUE TO EMBOLISM OF PRECEREBRAL ARTERIES
ICD-10	I63.2	CEREBRAL INFARCTION DUE TO UNSPECIFIED OCCLUSION OF PRECEBRAL ARTERIES
ICD-10	I63.3	CEREBRAL INFARCTION DUE TO THROMBOSIS OF CEREBRAL ARTERIES
ICD-10	I63.4	CEREBRAL INFARCTION DUE TO EMBOLISM OF CEREBRAL ARTERIES
ICD-10	I63.5	CEREBRAL INFARCTION DUE TO UNSPECIFIED OCCLUSION OF CEREBRAL ARTERIES
ICD-10	I63.6	CEREBRAL INFARCTION DUE TO CEREBRAL VENOUS THROMBOSIS
ICD-10	I63.8	OTHER CEREBRAL INFARCTION
ICD-10	I63.9	CEREBRAL INFARCTION, UNSPECIFIED
ICD-10	I64	STROKE, NOT SPECIFIED AS HEMORRHAGE OR INFARCTION
ICD-10	I65	OCCLUSION/STENOSIS PRECEREBRAL ARTERIES, NOT RESULTING IN INFARCTION
ICD-10	I65.0	OCCLUSION AND STENOSIS OF VERTEBRAL ARTERY
ICD-10	I65.1	OCCLUSION AND STENOSIS OF BASILAR ARTERY
ICD-10	I65.2	OCCLUSION AND STENOSIS OF CAROTID ARTERY
ICD-10	I65.3	OCCLUSION AND STENOSIS OF MULTIPLE AND BILATERAL PRECEBRAL ARTERIES
ICD-10	I65.8	OCCLUSION AND STENOSIS OF OTHER PRECEREBRAL ARTERY
ICD-10	I65.9	OCCLUSION AND STENOSIS OF UNSPECIFIED PRECEREBRAL ARTERY
ICD-10	I66	OCCLUSION/STENOSIS OF CEREBRAL ARTERIES, NOT RESULTING IN INFARCTION
ICD-10	I66.0	OCCLUSION AND STENOSIS OF MIDDLE CEREBRAL ARTERY
ICD-10	I66.1	OCCLUSION AND STENOSIS OF ANTERIOR CEREBRAL ARTERY

Type of Code	Code	Description
ICD-10	I66.2	OCCLUSION AND STENOSIS OF POSTERIOR CEREBRAL ARTERY
ICD-10	I66.3	OCCLUSION AND STENOSIS OF CEREBELLAR ARTERIES
ICD-10	I66.4	OCCLUSION AND STENOSIS OF MULTIPLE AND BILATERAL
ICD-10	I66.8	OCCLUSION AND STENOSIS OF OTHER CEREBRAL ARTERY
ICD-10	I66.9	OCCLUSION AND STENOSIS OF UNSPECIFIED CEREBRAL ARTERY
ICD-10	I67	OTHER CEREBROVASCULAR DISEASES
ICD-10	I67.0	DISSECTION OF CEREBRAL ARTERIES, NONRUPTURED
ICD-10	I67.1	CEREBRAL ANEURYSM, NONRUPTURED
ICD-10	I67.2	CEREBRAL ATHEROSCLEROSIS
ICD-10	I67.3	PROGRESSIVE VASCULAR LEUKOENCEPHALOPATHY
ICD-10	I67.4	HYPERTENSIVE ENCEPHALOPATHY
ICD-10	I67.5	MOYAMOYA DISEASE
ICD-10	I67.6	NONPYOGENIC THROMBOSIS OF INTRACRANIAL VENOUS SYSTEM
ICD-10	I67.7	CEREBRAL ARTERITIS, NOT ELSEWHERE CLASSIFIED
ICD-10	I67.8	OTHER SPECIFIED CEREBROVASCULAR DISEASES
ICD-10	I67.9	CEREBROVASCULAR DISEASE, UNSPECIFIED
ICD-10	I68	CEREBROVASCULAR DISORDERS IN DISEASES CLASSIFIED ELSEWHERE
ICD-10	I68.0	CEREBRAL AMYLOID ANGIOPATHY
ICD-10	I68.1	CEREBRAL ARTERITIS IN INFECTIOUS AND PARASITIC DISEASE
ICD-10	I68.2	CEREBRAL ARTERITIS IN OTHER DISEASES CLASSIFIED ELSEWHERE
ICD-10	I68.8	OTHER CEREBROVASCULAR DISORDERS IN DISEASES CLASSIFIED ELSEWHERE
ICD-10	I69	SEQUELAE OF CEREBROVASCULAR DISEASE
ICD-10	I69.0	SEQUELAE OF SUBARACHNOID HEMORRHAGE
ICD-10	I69.1	SEQUELAE OF INTRACEREBRAL HEMORRHAGE
ICD-10	I69.2	SEQUELAE OF OTH NONTRAUMATIC INTRACRANIAL HEMORRHAGE
ICD-10	I69.3	SEQUELAE OF CEREBRAL INFARCTION
ICD-10	I69.4	SEQUELAE OF STROKE, NOT SPECIFIED AS HEMORRHAGE
ICD-10	I69.8	SEQUELAE OF OTHER AND UNSPECIFIED CEREBROVASCULAR DISEASES