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ORIGINAL ARTICLE

Factors Associated with the Need for Intensive Care Unit Admission Following Supratentorial Intracerebral Hemorrhage: The Triage ICH Model

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Abstract

Background Providing the correct level of care for patients with intracerebral hemorrhage (ICH) is crucial, but the level of care needed at initial presentation may not be clear. This study evaluated factors associated with admission to intensive care unit (ICU) level of care.

Methods This is an observational study of all adult patients admitted to our institution with non-traumatic supratentorial ICH presenting within 72 h of symptom onset between 2009–2012 (derivation cohort) and 2005–2008 (validation cohort). Factors associated with neuroscience ICU admission were identified via logistic regression analysis, from which a triage model was derived, refined, and retrospectively validated.

Results For the derivation cohort, 229 patients were included, of whom 70 patients (31 %) required ICU care. Predictors of neuroscience ICU admission were: younger age [odds ratio (OR) 0.94, 95 % CI 0.91–0.97; $p = 0.0004$], lower Full Outline of UnResponsiveness (FOUR) score (0.39, 0.28–0.54; $p < 0.0001$) or Glasgow Coma Scale (GCS) score (0.55, 0.45–0.67; $p < 0.0001$), and larger ICH volume (1.04, 1.03–1.06; $p < 0.0001$). The model was further refined with clinician input and the addition of intraventricular hemorrhage (IVH). GCS was chosen for the model rather than the FOUR score as it is more widely used. The proposed triage ICH model utilizes three variables: ICH volume $\geq$30 cc, GCS score $<$13, and IVH. The triage ICH model predicted the need for ICU admission with a sensitivity of 94.3 % in the derivation cohort [area under the curve (AUC) = 0.88; $p < 0.001$] and 97.8 % (AUC = 0.88) in the validation cohort.

Conclusions Presented are the derivation, refinement, and validation of the triage ICH model. This model requires prospective validation, but may be a useful tool to aid clinicians in determining the appropriate level of care at the time of initial presentation for a patient with a supratentorial ICH.

Keywords Intracerebral hemorrhage · Triage · Intensive care

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Introduction

Primary, non-traumatic intracerebral hemorrhage (ICH) is a common cause of stroke (10–30 % of all strokes) with an estimated incidence of 12–25 per 100,000 person-years [1, 2]. The vast majority of hemorrhages are supratentorial [3, 4]. Despite advances in stroke care, ICH still has a high morbidity and mortality rate and results in significant expenditure of healthcare resources. The cost of ICH treatment in the USA in 2009 was estimated to be 1.7 billion dollars [5].

Current guidelines recommend that patients with an ICH be admitted to either an intensive care unit (ICU) or dedicated stroke unit with acute neuroscience expertise (Class I; Level of Evidence: B) [6]. This recommendation reflects data that showed lower hospital mortality rates for patients with an ICH admitted to neuroscience ICUs compared to general ICUs [7]. However, ICU care is expensive (an estimated 81.7 billion dollars annually in the USA) [8]. Without compromising patient care, identifying a subgroup of ICH patients who do not need ICU level care may lead to lower healthcare costs, which is of particular relevance given the renewed and ongoing focus on cost-effective and high-value resource utilization.

Previous ICH studies have successfully identified predictors of hematoma expansion and clinical outcomes, such as functional independence and mortality [9–11]. While these predictors may be related to need for ICU care, no predictive model currently exists to appropriately triage patients with an ICH. Therefore, we performed a retrospective analysis to identify variables associated with the need for neuroscience ICU as opposed to stroke ward level of care. Based on the results, we developed a model that could aid clinicians in the triage of patients with an ICH.

Methods

Derivation Cohort and Study Protocol

We retrospectively analyzed all adult (age ≥18 years) patients with a primary, supratentorial intracerebral hemorrhage admitted to our institution within 72 h of symptom onset over a 4-year period (from 2009 through 2012). Patients were excluded if the ICH was due to trauma, a known tumor, hemorrhagic conversion of an ischemic infarct, or a surgical procedure. Patients that were admitted solely for palliative care were also excluded. At our institution, patients with an ICH are initially admitted to a neuroscience ICU. Therefore, for this study, we used the following criteria to define the need for ICU level of care (monitoring and interventions): intubation/mechanical ventilation, hyperosmolar therapy, any neurosurgical procedure, or significant clinical deterioration during hospitalization resulting in transition to palliative care or death. This study was approved by the Mayo Clinic Institutional Review Board.

Patient demographics

Demographic data recorded from the comprehensive medical record included age, sex, medical comorbidities, and medications at the time of presentation. A patient was considered to have a comorbid medical condition if it was listed in the medical record, or if he/she was taking a disease-specific medication (e.g., insulin for diabetes). In addition, use of antiplatelet and anticoagulant agents was recorded. Current tobacco use was defined as ongoing cigarette usage, and previous tobacco use was defined as a previous smoking history >1 pack-year. A diagnosis of a prior ischemic or hemorrhagic stroke was based on medical records.

Clinical Presentation

Patients presenting directly to our institution and those transferred from other institutions were included in the study. Time from symptom onset to initial medical evaluation was recorded. For the patients who were transferred, this included time from symptom onset to initial evaluation as well as time to arrival at our institution. Data extracted at the time of initial evaluation included vital signs, Glasgow Coma Scale (GCS) [12] and Full Outline of UnResponsiveness (FOUR) [13] scores, laboratory studies, and treatment with intravenous antihypertensive medications and/or anticoagulation reversal agents. GCS and FOUR scores were routinely calculated on presentation to our emergency department. If not available in the medical record, these scores were calculated using the admitting neurologist's examination.

Imaging

All patients in this study had head imaging with a noncontrast CT (NCCT) scan at the time of initial evaluation. Time from symptom onset to NCCT as well as hemorrhage location, volume, appearance, intraventricular hemorrhage, and degree of leukoaraiosis was recorded. Hemorrhage volume was calculated using the ABC/2 method [14]. Hemorrhage appearance was classified by review of the images (authors JK and SB) as either homogenous or heterogeneous (often due to the presence of blood-fluid levels). Leukoaraiosis was graded using a previously published scoring system [15]. Additional imaging studies performed prior to admission were reviewed to assess for interval hematoma expansion (defined as >6 ml or ≥33 % growth) and intraventricular extension. If a CT angiogram was performed, the images were reviewed for the presence of a "spot sign." [16]. Imaging studies obtained after admission were not reviewed.

Outcomes

Outcomes were location of hospitalization (stroke ward vs. neuroscience ICU), transition to palliative care, time to hospital discharge, and death.

Validation Cohort

We performed a retrospective validation to assess the performance of the triage ICH model. We analyzed all adult patients with a supratentorial ICH presenting to our institution from 2005 to 2008 that met the same inclusion criteria as the derivation cohort from 2009 to 2012. Patient demographics, GCS score, hemorrhage volume, IVH, and hospitalization outcomes were recorded, as was the need for intubation/mechanical ventilation, hyperosmolar therapy, or a neurosurgical procedure.

Statistical Analysis

Summary statistics were reported as mean (standard deviation) or frequency (percentages) as appropriate. Univariable and multivariable logistic regression analyses were used to identify independent factors associated with the need for ICU admission. Only variables that were statistically significant at the 0.05 level on the univariable analysis were considered for multivariable logistic regression analysis. The area under the receiver operative characteristic curve (AUC) was used as a measure of the ability of our model to predict the need for ICU level of care. An area under the ROC estimate of 0.8–0.9 was defined as excellent, and an estimate >0.9 as outstanding [17]. Measurements of diagnostic test accuracy were reported.

In order to develop a triage model, we needed to categorize continuous variables of interest. Recursive partitioning approach was utilized. All of the analyses were done using SAS software (version 9.3, SAS Inc. Cary, NC).

Results

Derivation of the Triage ICH Model

A total of 229 patients were included (Supplemental Figure 1). Median age at time of ICH was 70.8 years (mean SD 14.36) and 53 % were men. A total of 70 patients (31 %) met the established criteria for ICU level of care. These patients were younger than patients not requiring ICU care (median age 66.1 years, SD 15.2 vs. 72.8 years, SD 13.5; $p = 0.0015$). Complete demographic, medical comorbidity, antithrombotic use, clinical presentation, laboratory, and imaging findings are presented in Table 1.

Univariate and Multivariable Logistic Regression

Variables associated with ICU level of care on univariate analyses were younger age (66.1 vs. 72.8 years, $p = 0.0015$), lower prevalence of coronary artery disease (14.3 vs. 28.3 %, $p = 0.025$), shorter time from hemorrhage to first evaluation (2.6 vs. 7.9 h, $p = 0.0051$), lower GCS (9.3 vs. 14.1, $p < 0.0001$) and lower FOUR (10.6 vs. 15.7, $p < 0.0001$) scores, greater initial diastolic blood pressure (94.8 vs. 86.2 mmHg, $p = 0.011$), lower temperature (36.6 vs. 36.8 Celsius, $p = 0.02$), higher serum glucose level (148.5 vs. 125.1 mg/dl, $p = 0.0004$), and imaging findings including larger ICH volume (52.6 vs. 17.4 cc, $p < 0.0001$), intraventricular hemorrhage (60 vs. 24.5 %, $p < 0.0001$), hemorrhage heterogeneity (42.9 vs. 24.5 %, $p = 0.0059$), and greater degree of leukoaraiosis ($p = 0.018$) (Table 1). On multivariable analysis, younger age, lower FOUR score, and larger ICH volume were the strongest predictors for requiring ICU level of care with an AUC of 0.94 (Table 2). Although the FOUR score is an established and validated score, the GCS score is still more widely utilized. Therefore, we performed an additional multivariable analysis after excluding FOUR score. This analysis identified the same variables (age, hemorrhage volume) with GCS replacing the FOUR score. The AUC was excellent, at 0.93 (Table 3).

Refinement of the Triage ICH Model

Analysis of the continuous variables from the multivariable analysis did not yield any significant cut points for model/score development. Therefore, we performed a regression analysis in an attempt to identify statistically significant cut points. The cut points identified (GCS ≤ 10, hemorrhage volume >42 ml, and age <83 years) failed to triage 16 patients to the ICU that required critical care. A majority of these patients (11 out of 16) required ICU level of care due to hydrocephalus resulting from IVH. Thus, we repeated the analysis adding IVH into the model. Based on clinician input, age was not included in the final model. This allowed us to formulate a model based on three variables: ICH volume ≥ 30 cc, GCS score <13, and IVH (Fig. 1). Presence of any of these three variables was associated with the need for ICU admission with a sensitivity of 94.3 % (AUC = 0.88; $p < 0.001$) (Supplementary Table 1). Only 4/97 (4.1 %) cases that would have been triaged to the stroke ward by the triage ICH model actually required ICU level of care. Figure. 1 illustrates the performance of the triage ICH model in our derivation cohort.

We reviewed the medical records of the four patients that were inappropriately triaged to non-ICU level of care using the triage ICH model. Two of the patients had ICH expansion (one with IVH) within 24 h of symptom onset. Another patient was intubated in the emergency department for airway protection following an episode of emesis, and the fourth had a ruptured arteriovenous malformation, but only required ICU level of care after the hemorrhage expanded on the second day of hospitalization following a cerebral angiogram.

Table 1 Univariable analysis of demographic, medical comorbidity, antithrombotic use, clinical presentation, laboratory, and imaging variables

Variable	Do not need ICU [*N* (%) or mean (SD)] (*N* = 159)	Need ICU [*N* (%) or mean (SD)] (*N* = 70)	*p* value	Odds ratio (95 % CI)
Demographics				
Age	**72.8 (13.5)**	**66.1 (15.2)**	**0.0015**	**0.97 (0.95–0.99)**
Male	85 (53.5 %)	36 (51.4 %)	0.78	0.92 (0.53–1.62)
Comorbidities				
Hypertension	116 (73 %)	53 (75.7 %)	0.66	1.16 (0.60–2.21)
Coronary artery disease	**45 (28.3 %)**	**10 (14.3 %)**	**0.025**	**0.42 (0.20–0.90)**
Kidney disease	9 (5.7 %)	5 (7.1 %)	0.67	1.28 (0.41–3.97)
Diabetes	31 (19.5 %)	12 (17.1 %)	0.67	0.85 (0.41–1.78)
COPD	12 (7.5 %)	2 (2.9 %)	0.19	0.36 (0.08–1.65)
Prior tobacco use (>1-pack-year)	66 (41.5 %	26 (37.1 %)	0.53	0.83 (0.47–1.49)
Previous ischemic stroke	25 (15.7 %)	10 (14.3 %)	0.78	0.89 (0.40–1.98)
Previous ICH	11 (6.9 %)	5 (7.1 %)	0.95	1.04 (0.35–3.10)
Medications				
Anticoagulant	33 (20.8 %)	22 (31.4 %)	0.083	1.75 (0.93–3.30)
Antiplatelet	82 (51.6 %)	28 (40 %)	0.11	0.63 (0.35–1.11)
Clinical presentation				
Time to first evaluation (h)	**7.9 (12.7)**	**2.6 (4.9)**	**0.0051**	**0.92 (0.86–0.98)**
Glasgow coma scale	**14.1 (1.5)**	**9.3 (4.1)**	**<0.0001**	**0.53 (0.48–0.66)**
FOUR score	**15.7 (0.8)**	**10.6 (4.5)**	**<0.0001**	**0.44 (0.33–0.58)**
Initial SBP (mmHg)	162.8 (29.3)	168.3 (35.6)	0.23	1.006 (0.99–1.02)
Initial DBP (mmHg)	**86.2 (22.2)**	**94.8 (24)**	**0.011**	**1.016 (1.00–1.03)**
Temperature (Celsius)	**36.8 (0.4)**	**36.6 (0.8)**	**0.02**	**0.513 (0.29–0.90)**
Laboratory				
Hemoglobin (g/dl)	13.2 (1.7)	13.2 (1.7)	0.87	1.014 (0.86–1.20)
Platelet count ($\times 10^3$/mcL)	218.1 (70)	227.2 (77)	0.38	1.002 (0.99–1.01)
INR	1.5 (0.99)	1.7 (1.4)	0.17	1.19 (0.93–1.50)
Sodium (mmol/l)	138.5 (3.1)	136.2 (15.3)	0.23	0.95 (0.88–1.03)
Glucose (mg/dl)	**125.1 (39.5)**	**148.5 (45)**	**0.0004**	**1.013 (1.01–1.02)**
Troponin (ng/ml)	<0.01 (0.1)	<0.01 (0.06)	0.92	1.22 (0.03–54.60)
Hemorrhage				
Volume (cc)	**17.4 (18.6)**	**52.6 (42.3)**	**<0.0001**	**1.04 (1.03–1.05)**
Intraventricular extension	**39 (24.5 %)**	**42 (60 %)**	**<0.0001**	**4.62 (2.54–8.40)**
Heterogeneous hemorrhage	**39 (24.5 %)**	**30 (42.9 %)**	**0.0059**	**2.31 (1.27–4.20)**
Degree of leukoaraiosis			**0.018**	**0.73 (0.56–0.95)**
0	22 (13.8 %)	17 (24.3 %)		
1	50 (31.4 %)	24 (34.3 %)		
2	43 (27 %)	16 (22.9 %)		
3	32 (20.1 %)	12 (17.1 %)		
4	12 (7.5 %)	1 (1.4 %)		

Rows highlighted in bold indicate statistically significant variables

CI confidence interval, *COPD* chronic obstructive pulmonary disease, *ICH* intracerebral hemorrhage, *FOUR* Full Outline of UnResponsiveness, *INR* international normalized ratio, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

Table 2 Multivariable analysis results identifying predictors for ICU level of care

Variable	Odds ratio	Lower 95 % CI	Upper 95 % CI	*p* value
Age	0.94	0.91	0.97	0.0004
FOUR score	0.39	0.28	0.54	<0.0001
Hemorrhage volume	1.04	1.03	1.06	<0.0001

Area under the ROC curve = 0.94

Odds ratios presented are for 1 unit increment

CI confidence interval, *FOUR* Full Outline of UnResponsiveness, *ROC* receiver operator curve

Table 3 Multivariable analysis results identifying predictors for ICU level of care using GCS instead of FOUR score

Variable	Odds ratio	Lower 95 % CI	Upper 95 % CI	*p* value
Age	0.95	0.92	0.98	0.0008
GCS	0.55	0.45	0.67	<0.0001
Hemorrhage volume	1.03	1.02	1.01	<0.0001

Area under the ROC curve = 0.93

Odds ratios presented are for 1 unit increment

CI confidence interval, *GCS* Glasgow coma scale, *ROC* receiver operator curve)

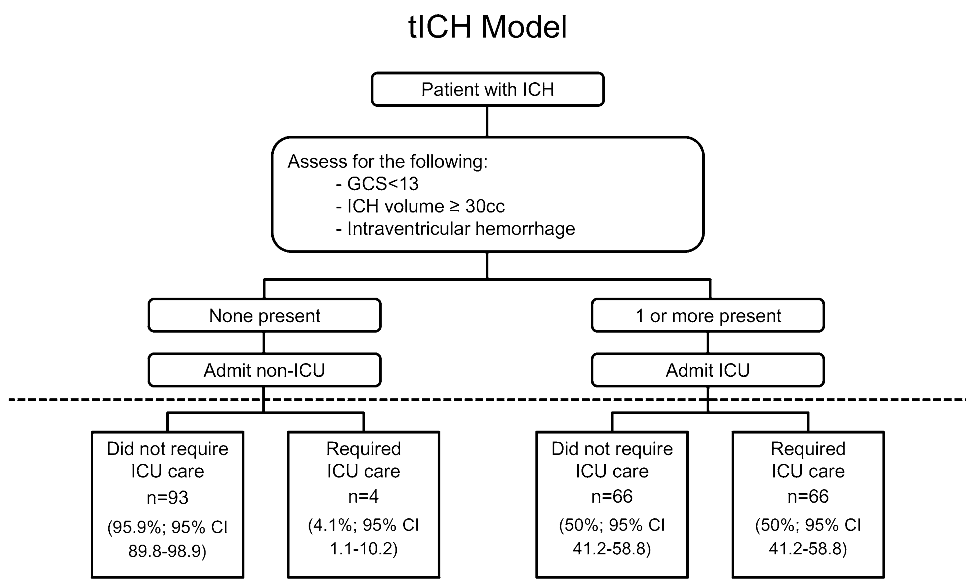

Fig. 1 Proposed triage ICH (tICH) model for patients with supratentorial ICH. Presented is the performance of the triage ICH model in our derivation cohort (*CI* confidence interval, *GCS* Glasgow coma scale)

Retrospective Validation

A total of 153 patients were included (Supplementary Figure 2). When applied to this patient cohort, the triage ICH model performed well, with an AUC of 0.88 and sensitivity of 97.8 % (95 % CI 88.2–99.9), specificity 58.3 % (95 % CI 48.5–67.8), positive likelihood ratio 2.35 (95 % CI 1.87–2.95), negative likelihood ratio 0.04 (95 % CI 0.01–0.27), positive predictive value 49.4 % (95 % CI 38.7–60.3 %), and negative predictive value of 98.4 % (95 % CI 91.6–100 %) (Supplementary Table 2). Only 1/64 (2.2 %) case was incorrectly triaged to the non-ICU stroke service hospital ward by the triage ICH model. This patient did not have any change in the size of the hemorrhage, but did develop increased vasogenic edema and worsening weakness, which prompted surgical evacuation approximately 44 h after symptom onset.

Discussion

Previous ICH studies have identified predictors of hematoma expansion, neurologic deterioration, mortality, and functional outcome [10, 11, 18–21], but this is the first study to identify parameters linked to ICU admission as per current practices. Several variables have been reported to be associated with greater risk of early neurologic decline, including age, time from hemorrhage to first evaluation, initial hemorrhage volume, IVH, and GCS score. These variables were also associated with the need for ICU care on our univariate analyses. On multivariable analysis, we found that younger age, lower GCS/FOUR scores, and hemorrhage volume were the strongest predictors for the need for ICU level of care.

Our goal was to create a simple, clinically relevant model that could aid clinicians in the triage of patients with a supratentorial ICH. We sought to design a model that was very sensitive for recognizing the need for ICU level of care, as inappropriate triage of a patient that requires ICU care to a non-ICU setting would be a concern. The three variables included in the final triage ICH model (GCS, ICH volume, and IVH) are all components of the validated and commonly utilized ICH score [10, 22]. Our results suggest that based on current practices the ICH score, minus age, could possibly be used to help triage patients with a supratentorial ICH. Based on clinician input, age was not included in the final model. The rationale was that triaging based on age did not make clinical sense (no significant difference between a 79-year-old and an 81-year-old patient) and was not practical as it would result in numerous unnecessary ICU admissions (triaging every patient less than 80-years to ICU level of care). However, although age was not included in the triage ICH model, it is important to note that our results suggest younger patients may be more likely to require ICU level of care.

Applying the triage ICH model to our study population predicted the need for ICU admission with a sensitivity of 94.3 % and a negative predictive value of 98.4 %, meaning that those that had none of the predictors are very likely to be appropriately triaged to non-ICU level of care, and the model is excellent in "ruling out" the need for ICU level of care. However, this comes at a cost, with the model having a specificity of 58.5 % that resulted in 66 patients being triaged to the ICU but not receiving ICU-specific treatments.

Our model resulted in four patients being inappropriately triaged to non-ICU level of care. On individual review of these cases, it is debatable whether two of these four patients deemed to be inappropriately triaged to non-ICU level actually required ICU level of care on admission. One of these patients was intubated in the emergency department for airway protection following an episode of emesis, but was extubated upon admission to the ICU. The second patient only required ICU level of care after the hemorrhage expanded following a cerebral angiogram during the second day of hospitalization. The triage ICH model also performed well when applied to our validation cohort, with a sensitivity of 97.8 %, and only inappropriately triaged a single patient to non-ICU level of care. These results suggest that an emergency medicine provider can determine appropriate triage based on the assessment of these three simple variables and be confident that, if all are absent, the patient is very unlikely to deteriorate and require higher levels of care.

This single-center study has several limitations. A major limitation was the need to define criteria for ICU admission, since patients with an ICH at our institution are initially admitted to a neuroscience ICU. The criteria chosen may not be always applicable to other institutional practices (for instance, some stroke units without ICU capability allow the administration of osmotherapy). Another notable limitation of our study is that it is not our institution's routine practice to perform a CT angiogram for patients presenting with an ICH. Therefore, for most patients, we could not assess for the presence/absence of the "spot sign," a well-recognized predictor for hematoma expansion [16, 23]. Early hematoma expansion is a predictor of early neurologic deterioration and worse outcome [24] and therefore may be a relevant variable in determining appropriate triage. The study did evaluate time from hemorrhage to initial evaluation, as early presentation (often defined as $\leq$6 h) is also a predictor of hemorrhage expansion [18, 25]. Although this variable was significant on the univariate analysis, this association was not independent of other factors.

Another limitation is the exclusion of patients admitted solely for palliative care. This was necessary for the purpose of the study. However, since these are often the very elderly or those with massive hemorrhages, it may have reduced the mean age and hemorrhage volume in our cohort. Additionally, patients with infratentorial hemorrhages were excluded. Infratentorial hemorrhages portend a higher mortality rate and worse outcome [10], and most patients require ICU level of care. Further studies into the appropriate triage of patients with infratentorial hemorrhages are needed.

Lastly, the retrospective nature of the study made accurate ascertainment of certain variables challenging, such as preexisting hypertension and antithrombotic use. The use of a detailed electronic medical record helps reduce, but does not eliminate this limitation. Additionally, if a patient deteriorated, the rate and severity of deterioration could not necessarily be determined from the record. This is a significant limitation as previous studies have shown that serial neuroimaging and hourly neurologic examinations can frequently change management [26], but in this study it was not possible to know whether earlier detection in an ICU setting would have changed the clinical outcome or not. Furthermore, although we attempted to retrospectively validate the triage ICH model, prospective validation of the model, ideally at a multiple different institutions, is needed. Finally, it is important to note that the model was derived from and is therefore a reflection of, current practice. It does not address whether current practices are "ideal" or not.

In conclusion, we identified factors that are currently associated with the need for admission to a neuroscience ICU as opposed to a stroke ward and formulated a model that, if prospectively validated, could aid clinicians in the triage of patients with acute supratentorial ICH. Based on our results, patients with GCS score >13, ICH volume ≤ 30 cc, and no IVH upon initial presentation can be safely triaged to non-ICU level of care.

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References

1. Feigin VL, Lawes CM, Bennett DA, Barker-Collo SL, Parag V. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. Lancet Neurol. 2009;8:355–69.
2. Sudlow CL, Warlow CP. Comparable studies of the incidence of stroke and its pathological types: results from an international collaboration. International stroke incidence collaboration. Stroke. 1997;28:491–9.
3. Bejot Y, Cordonnier C, Durier J, Aboa-Eboule C, Rouaud O, Giroud M. Intracerebral haemorrhage profiles are changing: results from the Dijon population-based study. Brain. 2013;136:658–64.
4. van Asch CJ, Luitse MJ, Rinkel GJ, van der Tweel I, Algra A, Klijn CJ. Incidence, case fatality, and functional outcome of intracerebral haemorrhage over time, according to age, sex, and ethnic origin: a systematic review and meta-analysis. Lancet Neurol. 2010;9:167–76.
5. Stepanova M, Venkatesan C, Altaweel L, Mishra A, Younossi ZM. Recent trends in inpatient mortality and resource utilization for patients with stroke in the united states: 2005–2009. J Stroke Cerebrovasc Dis. 2013;22:491–9.
6. Hemphill JC 3rd, Greenberg SM, Anderson CS, Becker K, Bendok BR, Cushman M, et al. Guidelines for the management of spontaneous intracerebral hemorrhage: a guideline for healthcare professionals from the American heart association/American stroke association. Stroke. 2015;46:2032–60.
7. Diringer MN, Edwards DF. Admission to a neurologic/neurosurgical intensive care unit is associated with reduced mortality rate after intracerebral hemorrhage. Crit Care Med. 2001;29:635–40.
8. Finfer S, Vincent JL. Critical care—an all-encompassing specialty. N Engl J Med. 2013;369:669–70.
9. Ariesen MJ, Algra A, van der Worp HB, Rinkel GJ. Applicability and relevance of models that predict short term outcome after intracerebral haemorrhage. J Neurol Neurosurg Psychiatry. 2005;76:839–44.
10. Hemphill JC 3rd, Bonovich DC, Besmertis L, Manley GT, Johnston SC. The ICH score: a simple, reliable grading scale for intracerebral hemorrhage. Stroke. 2001;32:891–7.
11. Rost NS, Smith EE, Chang Y, Snider RW, Chanderraj R, Schwab K, et al. Prediction of functional outcome in patients with primary intracerebral hemorrhage: the func score. Stroke. 2008;39:2304–9.
12. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2:81–4.
13. Wijdicks EF, Bamlet WR, Maramattom BV, Manno EM, McClelland RL. Validation of a new coma scale: the four score. Ann Neurol. 2005;58:585–93.
14. Kothari RU, Brott T, Broderick JP, Barsan WG, Sauerbeck LR, Zuccarello M, et al. The abcs of measuring intracerebral hemorrhage volumes. Stroke. 1996;27:1304–5.
15. van Swieten JC, Hijdra A, Koudstaal PJ, van Gijn J. Grading white matter lesions on CT and MRI: a simple scale. J Neurol Neurosurg Psychiatry. 1990;53:1080–3.
16. Demchuk AM, Dowlatshahi D, Rodriguez-Luna D, Molina CA, Blas YS, Dzialowski I, et al. Prediction of haematoma growth and outcome in patients with intracerebral haemorrhage using the ct-angiography spot sign (predict): a prospective observational study. Lancet Neurol. 2012;11:307–14.
17. Hosmer DW, Lemeshow S, Sturdivant RX. Applied logistic regression. Wiley series in probability and statistics. 3rd ed. Hoboken, NJ: John Wiley & Sons, Inc.; 2013.
18. Brouwers HB, Chang Y, Falcone GJ, Cai X, Ayres AM, Battey TW, et al. Predicting hematoma expansion after primary intracerebral hemorrhage. JAMA Neurol. 2014;71:158–64.
19. Flemming KD, Wijdicks EF, Li H. Can we predict poor outcome at presentation in patients with lobar hemorrhage? Cerebrovasc Dis. 2001;11:183–9.
20. Leira R, Davalos A, Silva Y, Gil-Peralta A, Tejada J, Garcia M, et al. Early neurologic deterioration in intracerebral hemorrhage: predictors and associated factors. Neurology. 2004;63:461–7.
21. Sun W, Pan W, Kranz PG, Hailey CE, Williamson RA, Laskowitz DT, et al. Predictors of late neurological deterioration after spontaneous intracerebral hemorrhage. Neurocrit Care. 2013;19:299–305.
22. Hemphill JC 3rd, Farrant M, Neill TA Jr. Prospective validation of the ICH score for 12-month functional outcome. Neurology. 2009;73:1088–94.
23. Wada R, Aviv RI, Fox AJ, Sahlas DJ, Gladstone DJ, Tomlinson G, et al. Ct angiography "spot sign" predicts hematoma expansion in acute intracerebral hemorrhage. Stroke. 2007;38:1257–62.
24. Rodriguez-Luna D, Rubiera M, Ribo M, Coscojuela P, Pineiro S, Pagola J, et al. Ultraearly hematoma growth predicts poor outcome after acute intracerebral hemorrhage. Neurology. 2011;77:1599–604.
25. Fujii Y, Takeuchi S, Sasaki O, Minakawa T, Tanaka R. Multivariate analysis of predictors of hematoma enlargement in spontaneous intracerebral hemorrhage. Stroke. 1998;29:1160–6.
26. Maas MB, Rosenberg NF, Kosteva AR, Bauer RM, Guth JC, Liotta EM, et al. Surveillance neuroimaging and neurologic examinations affect care for intracerebral hemorrhage. Neurology. 2013;81:107–12.