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A Risk Score to Predict Death Early After Hospitalization for an Acute Ischemic Stroke

Gustavo Saposnik, MD, MSc; Moira K. Kapral, MD, FRCPC; Ying Liu, MSc; Ruth Hall, MSc, PhD; Martin O'Donnell, MD, FRCPC; Stavroula Raptis, MSc; Jack V. Tu, MD, FRCPC; Muhammad Mamdani, PharmD, MPH, MA*; Peter C. Austin, PhD*; on behalf of the Investigators of the Registry of the Canadian Stroke Network and the Stroke Outcomes Research Canada (SORCan) Working Group

Background—A predictive model of stroke mortality may be useful for clinicians to improve communication with and care of hospitalized patients. Our aim was to identify predictors of mortality and to develop and validate a risk score model using information available at hospital presentation.

Methods and Results—This retrospective study included 12 262 community-based patients presenting with an acute ischemic stroke at multiple hospitals in Ontario, Canada, between 2003 and 2008 who had been identified from the Registry of the Canadian Stroke Network (8223 patients in the derivation cohort, 4039 in the internal validation cohort) and the Ontario Stroke Audit (3720 for the external validation cohort). The mortality rates for the derivation and internal validation cohorts were 12.2% and 12.6%, respectively, at 30 days and 22.5% and 22.9% at 1 year. Multivariable predictors of 30-day and 1-year mortality included older age, male sex, severe stroke, nonlacunar stroke subtype, glucose ≥7.5 mmol/L (135 mg/dL), history of atrial fibrillation, coronary artery disease, congestive heart failure, cancer, dementia, kidney disease on dialysis, and dependency before the stroke. A risk score index stratified the risk of death and identified low- and high- risk individuals. The c statistic was 0.850 for 30-day mortality and 0.823 for 1-year mortality for the derivation cohort, 0.851 for the 30-day model and 0.840 for the 1-year mortality model in the internal validation set, and 0.790 for the 30-day model and 0.782 for the 1-year model in the external validation set.

Conclusion—Among patients with ischemic stroke, factors identifiable within hours of hospital presentation predicted mortality risk at 30 days and 1 year. The predictive score may assist clinicians in estimating stroke mortality risk and policymakers in providing a quantitative tool to compare facilities. **(*Circulation*. 2011;123:739-749.)**

Key Words: mortality ■ outcomes ■ risk model ■ risk score ■ stroke

In acute stroke, time is essential in selecting appropriate treatment so as to minimize or prevent residual effects produced by the injury. The ability to estimate prognosis in stroke patients directly affects clinician treatment decisions for patients and may indirectly permit the ability to improve monitoring of patient outcomes, thereby providing a measure of quality in health care. Although stroke is one of the leading causes of death worldwide, with population-based studies reporting a 1-year mortality rate between 20% and 40%,[1–4] few methods are available to quantitatively estimate prognosis. As a result, clinicians usually rely on their own personal experience, which is inherently subject to recall bias, or on published mortality rates from clinical trials or research studies in which patient populations differ from those encountered in the clinical setting.

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Clinical Perspective on p 749

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From the Stroke Outcomes Research Centre, Division of Neurology, Department of Medicine, St Michael's Hospital, Toronto (G.S.); Registry Canadian Stroke Network (R.H.), Institute for Clinical Evaluative Sciences, Toronto (G.S., M.K.K., Y.L., J.V.T., M.M., P.C.A.); Departments of Medicine and Health Policy, Management and Evaluation, University of Toronto, Toronto (G.S., M.K.K., J.V.T., M.M., P.C.A.); Division of General Internal Medicine and Clinical Epidemiology, Department of Medicine, Sunnybrook Hospital, Toronto (M.K.K.); Division of Hematology and Thromboembolism, Department of Medicine, McMaster University, Hamilton (M.O.); Applied Health Research Centre, Keenan Research Centre, Li Ka Shing Knowledge Institute of St Michael's Hospital, Toronto (G.S., S.R., M.M.); and Division of General Internal Medicine and Clinical Epidemiology, Department of Medicine, University Health Network, Toronto (J.V.T.), Ontario, Canada.

*Drs Mamdani and Austin equally contributed to this article.

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Correspondence to Dr Gustavo Saposnik, Assistant Professor, Director, Stroke Outcomes Research Centre, Stroke Outcome Research Canada (SORCan) Working Group, Department of Medicine, St. Michael's Hospital, University of Toronto, 55 Queen St E, Toronto, ON, M5C 1R6, Canada. E-mail saposnikg@smh.toronto.on.ca

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Prediction of mortality may be useful not only for prognostic purposes for clinicians but also for guiding supportive care plans (eg, at discharge), coordinating appropriate rehabilitation services, facilitating patient and/or family counseling or discussions pertaining to end-of-life decisions, and assisting policymakers in conducting fair comparisons when evaluating stroke fatality among different facilities for hospital outcomes and performance assessment.

Unfortunately, few risk scores are available that include simple and relevant clinical variables, including stroke severity on admission. Furthermore, most studies do not account for relevant factors known to influence survival after stroke such as cancer, renal failure, congestive heart disease, or dependency on admission.

Our objective was to develop and validate a score to predict mortality risk in ischemic stroke patients based on information routinely available to clinicians at hospital presentation such as demographic features, clinical presentation, and patient comorbid conditions. Ischemic strokes are the most common type of stroke, accounting for ≈85% of all strokes. The 30-day adjusted mortality rate for ischemic stroke ranges from 5% to 20%[5,6]; most deaths occurring within a week of the index event are the result of complications from the stroke itself or from comorbid conditions. We hypothesized that the new prediction model could effectively stratify mortality risk at both 30 days and 1 year for patients recently admitted with an acute ischemic stroke.

Methods

The development of the risk score models involved a systematic review of the literature to generate a list of predictors of mortality, a consensus meeting with clinical experts to select the variables, the selection of data sources, the development of criteria for the creation of the derivation and validation cohorts, and the conceptualization of the model to be used to create the risk scores.

Variable Selection

A review of the literature was done to identify candidate predictor variables for potential inclusion in our prediction models. We selected for further consideration those variables that we identified as having face validity and that were available in the Registry of the Canadian Stroke Network (RCSN). Finally, we contacted a team of stroke neurologists to ensure that the most relevant variables had been included; these selected variables are listed in Table 1.

Detailed clinical data were collected by chart abstraction performed during and after admission to hospital for the index event by trained neurology research nurses using custom software. Stroke severity was assessed on admission with the Canadian Neurological Scale (CNS), which is a simple and validated scale in which lower scores indicate greater stroke severity (see Figure I in the online-only Data Supplement).[7] The CNS includes the following components: comprehension, level of consciousness, speech, and motor function (face, arm, and leg). Previous studies showed good to excellent interrater agreement (κ or weighted κ scores, 0.76 to 1.00).[8,9] For the purpose of descriptive analysis, stroke severity was categorized a priori as mild (CNS ≥8), moderate (CNS, 5 to 7), or severe (CNS, 1 to 4) stroke on the basis of previous studies[10,11]; a score of zero was assigned to patients in a coma. All ischemic stroke subtypes were included in the present study. Ischemic stroke subtype was classified as lacunar, nonlacunar, and undetermined according to the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria[12] by the study coordinator using documentation by the treating physician and the investigations recorded in the chart.

Mortality Model Derivation and Internal Validation Cohorts

The RCSN is a clinical database of >40 000 patients having experienced an acute stroke and transient ischemic attack. Legislation in the province of Ontario (Canada) enacted in 2004, known as the Personal Health Information Protection Act, established rules for the collection, use, and disclosure of personal health information to protect the privacy and confidentiality of individuals; under section 39(1)(c), the RCSN has the designation of a "prescribed registry," thereby permitting the collection of patient data without consent for the purpose of facilitating the provision of stroke care in the province of Ontario.

The current phase of the RCSN began in July 2003 and involves continuous prospective data on all consecutive patients seen in the emergency department or admitted to hospital with stroke in 13 participating institutions in the provinces of Ontario and Nova Scotia, Canada (12 sites in Ontario and 1 in Nova Scotia).[13] Since its inception in 2001, the goal of the RCSN remains to measure and monitor the quality of hospital stroke care delivery.

The cohort used in the present study included patients from phase 3 of the RCSN who were ≥18 years of age with a primary diagnosis of acute ischemic stroke and presented to any of the 12 participating institutions in Ontario between July 1, 2003, and June 30, 2008. Patients with missing baseline characteristics (age, CNS score, glucose on admission, and date last seen "normal" before the index event; n=910, 0.74%) and invalid health card numbers were excluded. Patients with transient ischemic attack were not included in this study. Patients with hemorrhagic strokes were also not included because they have different underlying stroke mechanisms, risk factors, and prognosis compared with individuals with ischemic stroke.

We identified a total of 12 262 stroke patients using the criteria indicated above. Information on poststroke all-cause mortality was available through linkages to the Ontario Registered Persons Database, which was available through the Institute for Clinical Evaluative Sciences. The Ontario Registered Persons Database, a population-based administrative database that includes basic demographic data and date of death, provides complete follow-up for all residents in the province.

Of the 12 262 patients identified, we randomly selected two thirds (8223) of these patients for the derivation cohort; the remaining one third (4039) were used for our internal validation cohort. Sampling was done in each of the hospitals, so two thirds of each hospital's patients were included in the derivation sample and one third in the internal validation sample.

Approvals from the institutional review boards of St Michael's Hospital and the participating stroke centers and from the RCSN Publications Committee were obtained before the beginning of this study.

External Validation Cohort

During phase 3 of the RCSN, a population-based, random sampling of stroke patients seen at every acute care institution in Ontario was performed (the Ontario Stroke Audit). Data collection for the Ontario Stroke Audit occurs every 2 years through the abstraction of charts of eligible patients seen in the emergency department or admitted to hospital with a diagnosis of stroke. The hospitals (n=154) include teaching hospitals and community-based institutions from rural and urban areas throughout Ontario with >10 stroke admissions per year; pediatric and psychiatric hospitals are excluded.[13]

In the present study, we used Ontario Stroke Audit data collected in 2 periods: 2002 to 2003 and 2004 to 2005. The external validation cohort consisted of 3270 ischemic stroke patients. Patients included in the derivation or internal validation cohorts were not eligible for inclusion in the external validation cohorts. Similar to the derivation and internal validation cohorts, all-cause mortality after hospital discharge was accessed through linking the Ontario Stroke Audit with the Ontario Registered Persons Database.

RCSN Data Quality

Chart abstraction studies have shown good to excellent agreement within the RCSN database, with κ scores of >0.8 for key variables such as age, sex, stroke type, and thrombolysis use.[13]

Statistical Analysis

We used χ^2 tests to compare categorical variables between groups and ANOVA or Kruskal-Wallis tests to compare mean and median

Table 1. Characteristics of the Derivation and Validation Ischemic Stroke Cohorts

Characteristic	Derivation Cohort (n=8223)*	Validation Cohort A (n=4039)†	P‡	Validation Cohort B (n=3270)§	P‡
Age, mean±SD, y	72.04±13.86	72.07±13.73	0.921	74.44±12.24	<0.001
Median (Q1–Q3), y	75 (64–82)	75 (64–82)	0.867	77 (68–83)	<0.001
Age, n (%)			0.510		<0.001
≤59 y	1520 (18.5)	738 (18.3)		388 (11.9)	
60–69 y	1491 (18.1)	722 (17.9)		548 (16.8)	
70–79 y	2370 (28.8)	1217 (30.1)		1080 (33.0)	
≥80 y	2842 (34.6)	1362 (33.7)		1254 (38.3)	
Gender, n (%)			0.998		0.004
Female	3901 (47.4)	1916 (47.4)		1649 (50.4)	
Male	4322 (52.6)	2123 (52.6)		1621 (49.6)	
Stroke severity (using CNS),‖ %			0.696		<0.001
0	238 (2.9)	104 (2.6)		63 (1.9)	
≤4	1361 (16.6)	659 (16.3)		328 (10.0)	
5–7	1860 (22.6)	904 (22.4)		822 (25.1)	
≥8	4764 (57.9)	2372 (58.7)		2057 (62.9)	
Stroke subtype, n (%)			0.933		<0.001
Lacunar	1388 (16.9)	692 (17.1)		721 (22.0)	
Nonlacunar	3563 (43.3)	1749 (43.3)		731 (22.4)	
Undetermined origin	3272 (39.8)	1598 (39.6)		1818 (55.6)	
Risk factor, n (%)					
Atrial fibrillation			0.814		0.49
Yes	1405 (17.1)	697 (17.3)		541 (16.5)	
No	6818 (82.9)	3342 (82.7)		2729 (83.5)	
CAD			0.238		0.86
Yes	1936 (23.5)	990 (24.5)		775 (23.7)	
No	6287 (76.5)	3049 (75.5)		2495 (76.3)	
CHF			0.575		0.99
Yes	734 (8.9)	373 (9.2)		292 (8.9)	
No	7489 (91.1)	3666 (90.8)		2978 (91.1)	
Diabetes mellitus			0.333		<0.001
Yes	2067 (25.1)	1048 (25.9)		948 (29.0)	
No	6156 (74.9)	2991 (74.1)		2322 (71.0)	
Previous myocardial infarction			0.382		0.14
Yes	1239 (15.1)	633 (15.7)		529 (16.2)	
No	6984 (84.9)	3406 (84.3)		2741 (83.8)	
Current smoker			0.894		<0.001
Yes	1600 (19.5)	790 (19.6)		483 (14.8)	
No	6623 (80.5)	3249 (80.4)		2787 (85.2)	
Comorbid condition, n (%)					
Cancer			0.479		0.006
Yes	815 (9.9)	384 (9.5)		270 (8.3)	
No	7408 (90.1)	3655 (90.5)		3000 (91.7)	
Dementia			0.468		0.35
Yes	712 (8.7)	334 (8.3)		301 (9.2)	
No	7511 (91.3)	3705 (91.7)		2969 (90.8)	
Renal dialysis			0.665		0.80
Yes	69 (0.8)	37 (0.9)		29 (0.9)	
No	8154 (99.2)	4002 (99.1)		3241 (99.1)	

(*Continued*)

Table 1. Continued

Characteristic	Derivation Cohort (n=8223)*	Validation Cohort A (n=4039)†	P‡	Validation Cohort B (n=3270)§	P‡
Preadmission disability, n (%)			0.438		<0.001
Independent	6524 (79.3)	3180 (78.7)		2440 (74.6)	
Dependent	1699 (20.7)	859 (21.3)		830 (25.4)	
Glucose on admission, mmol/L			0.507		0.04
<7.5	5290 (64.3)	2623 (64.9)		2037 (62.3)	
≥7.5	2933 (35.7)	1416 (35.1)		1233 (37.7)	

Q indicates quintile; CAD, coronary artery disease; CHF, congestive heart failure. To convert glucose to mg/dL, divide by 0.0555.

*Ischemic stroke identified from the RCSN between July 1, 2003, and June 30, 2008, two thirds of all the cases identified.

†Validation cohort A identified from the RCSN, one third of all the cases identified (internal validation).

‡We used χ^2 tests to compare categorical variables and ANOVA or Kruskal-Wallis tests to compare mean and median differences for continuous variables in baseline characteristics.

§Validation cohort B identified from the Ontario Stroke Audit in the period between 2002–2003 and 2004–2005 (external validation).

‖A score of 0 was assigned for the CNS if participants were in a coma.

differences for continuous variables in baseline characteristics between groups. Candidate variables that were associated with 30-day and 1-year mortality on single-variable analysis were selected as potential covariates in a multiple logistic regression model.[14] Stepwise variable selection with a significance level of 0.05 for variable retention was used to develop parsimonious predictor models. Model discrimination was assessed by the area under the receiver-operating characteristic (ROC) curve (which is equivalent to the c statistic).[15] Calibration was assessed with the Hosmer-Lemeshow test. Because this test is known to be oversensitive to small deviations from good fit in large samples, we also assessed the calibration of the risk score by comparing predicted and observed mortality in the derivation sample.

Risk score prediction rules for 30-day and 1-year mortality were developed from multiple logistic regression models by using a regression coefficient–based scoring method.[16,17] Integer scores were assigned by dividing risk-factor β coefficients by the age coefficient and rounding up to the nearest unit for continuous variables and up to the nearest 5 points for midpoints of stratified continuous or categorical variables.[18]

The overall risk score was calculated by adding each component together. Mortality rates were estimated within each of 5 strata (based on the quintiles of the risk score) of the 30-day and 1-year risk scores.

We validated the 30-day and 1-year mortality models using our internal and external validation cohorts. Using coefficients estimated in the derivation sample, we obtained predictions for each subject in each of the 2 validation samples. For each model, mortality rates were compared across strata of the risk score. Furthermore, we compared observed and predicted mortality within each stratum of the risk score.

Analyses were conducted with SAS statistical software (version 9.2, SAS institute Inc, Cary, NC).

Results

Description of the Derivation and Validation Cohorts

There were 8223 ischemic stroke patients in the derivation cohort, 4039 patients in the internal validation cohort, and 3270 in the external validation cohort. There were no significant differences in baseline characteristics between the derivation and internal validation cohorts. Although minor differences were observed in demographic characteristics and risk factors between the derivation and external validation cohorts (Table 1), these 2 samples were still comparable.

Mortality rates for the derivation cohort were 12.2% (1004 deaths) at 30 days and 22.5% (1853 deaths) at 1 year; for the internal validation cohort, 12.6% (509 deaths) at 30 days and 22.9% (924 deaths) at 1 year; and for the external validation cohort, 11.6% (380 deaths) at 30 days and 24.4% (798 deaths) at 1 year. Mortality rates at 30 days and 1 year were comparable between the derivation and validation cohorts and were similar to those reported in other population-based studies.[1,2,4]

In the single-variable analysis, older age, female sex, severe stroke, nonlacunar stroke subtype, glucose ≥7.5 mmol/L, history of atrial fibrillation, diabetes mellitus, coronary artery disease, congestive heart failure, cancer, dementia, kidney disease on dialysis, and dependency before the stroke were associated with higher mortality at both 30 days and 1 year (Table 2). Smoking and male gender were observed to have a protective effect. This was likely due to known differences in baseline characteristics between individuals who smoke and those who do not smoke (ie, smokers are younger and have fewer comorbid conditions than nonsmokers). Table 3 summarizes the magnitude of the effect for each variable. Although previous myocardial infarction and smoking were predictors of mortality at 1 year in the multivariable analysis, they were not associated with 30-day mortality.

Stroke Risk Scores

Multivariable risk scores for the prediction of both 30-day and 1-year mortality were calculated (Table 4). Both scores were approximately normally distributed, with mean scores and SDs of 109±40 at 30 days and 86±29 at 1 year. Quintiles were used to divide the cohort into 5 risk categories. The magnitude of the scores had prognostic implications (Figure 1A and 1B). There was a graded increase in risk of mortality by quintile of risk score. The 30-day mortality was 1.07% for quintile 1 (with a corresponding score <105), 2.47% for quintile 2 (score, 106 to 120), 5.25% for quintile 3 (score, 121 to 145), 14.80% for quintile 4 (score, 146 to 175), and 39.07% for quintile 5 (score, >175). Similarly, a graded increase in risk occurred with 1-year score quintiles. The 1-year mortality was 2.97% for quintile 1 (with a corresponding score <90), 8.88% for quintile 2 (score, 91 to 105), 17.04% for quintile 3 (score, 106 to 120), 29.26% for quintile 4 (score, 121 to 140), and 58.92% for quintile 5 (score, >140).

Table 2. Single-Variable Analysis of Mortality in the Ischemic Stroke Derivation Cohort (n=8223)

	30-Day Mortality (n=1004)		1-Year Mortality (n=1853)	
Variable	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.05 (1.05–1.06)	<0.001	1.06 (1.06–1.07)	<0.001
Sex				
Female	1.00 (Reference)	. . .	1.00 (Reference)	. . .
Male	0.78 (0.68–0.89)	<0.001	0.78 (0.70–0.87)	<0.001
Stroke severity (using CNS)				
0	61.00 (44.54–83.53)	<0.001	27.47 (20.08–37.58)	<0.001
≤4	13.64 (11.20–16.61)	<0.001	7.73 (6.71–8.90)	<0.001
5–7	4.85 (3.95–5.97)	<0.001	3.25 (2.84–3.73)	<0.001
≥8	1.00 (Reference)	. . .	1.00 (Reference)	. . .
Stroke subtype				
Lacunar	1.00 (Reference)	. . .	1.00 (Reference)	. . .
Nonlacunar	5.57 (3.98–7.80)	<0.001	3.23 (2.66–3.92)	<0.001
Undetermined origin	6.15 (4.39–8.61)	<0.001	3.23 (2.66–3.94)	<0.001
Risk factor				
Atrial fibrillation	2.51 (2.17–2.91)	<0.001	2.43 (2.14–2.75)	<0.001
CAD	1.42 (1.23–1.65)	<0.001	1.61 (1.43–1.80)	<0.001
CHF	2.47 (2.05–2.97)	<0.001	2.97 (2.54–3.47)	<0.001
Diabetes mellitus	1.18 (1.01–1.36)	0.032	1.28 (1.14–1.43)	<0.001
Previous myocardial infarction	1.45 (1.22–1.71)	<0.001	1.56 (1.37–1.79)	<0.001
Current smoker	0.54 (0.45–0.66)	<0.001	0.55 (0.47–0.64)	<0.001
Comorbid condition				
Cancer	1.57 (1.29–1.91)	<0.001	1.97 (1.68–2.29)	<0.001
Dementia	2.53 (2.10–3.05)	<0.001	3.23 (2.75–3.78)	<0.001
Renal dialysis	2.37 (1.37–4.12)	0.002	4.04 (2.51–6.50)	<0.001
Preadmission disability				
Dependent	2.78 (2.44–3.22)	<0.001	3.45 (3.12–4.0)	<0.001
Independent	1.00 (Reference)	. . .	1.00 (Reference)	. . .
Glucose on admission, mmol/L				
<7.5	1.00 (Reference)	. . .	1.00 (Reference)	. . .
≥7.5	2.04 (1.78–2.32)	<0.001	1.75 (1.56–1.96)	<0.001

OR indicates odds ratio; CI, confidence interval; CAD, coronary artery disease; and CHF, congestive heart failure. To convert glucose to mg/dL, divide by 0.0555.

Because the above results ignore within-quintile risk gradients, we plotted the observed and predicted mortality at 30 days (Figure 2A) and 1 year (Figure 2B) as a continuous function of the risk score at 10-point intervals. Figure 2A and 2B shows an increased estimated mortality with higher risk scores. Examples of the application of the risk score are provided in Figure II in the online-only Data Supplement. In addition, we compared our risk score with other simple, well-accepted models by creating a risk score consisting of 2 variables, age and stroke severity, using our data set.[19–21] The simpler risk model showed similar ROC curve values (0.83 for 30-day mortality and 0.792 for 1-year mortality). However, it did not permit discrimination between patients with the same age and stroke severity but with different clinical characteristics or medical history (see Figure III in the online-only Data Supplement). With our model, accounting for the presence of additional relevant clinical variables (ie, hyperglycemia, renal failure on dialysis, congestive heart failure, etc) markedly changed the predicted mortality between patients with similar age and stroke severity (see Figure 3A and 3B). For example, for a low-risk category (age of 70 years with a moderate stroke), the additional presence of hyperglycemia (>135 mg/dL) and dependency on admission (+15 points) would double the predicted 30-day mortality from 1.87% to 3.73% (Figure 3A). A more impressive increase is observed in the predicted 1-year mortality for a higher-risk category from 20.4% (derived from the model including only age of 90 years and severe stroke) to 59.3% by adding dialysis (+40 points) and to 87.4% by adding sex (+5 points) and dependency (+20 points) (Figure 3B).

Model Validation

In the derivation set, the area under the ROC curve was 0.850 and 0.823 for 30-day and 1-year mortality, respectively. When the 30-day and 1-year models were applied to the internal validation set, the areas under the ROC curve were 0.851 and 0.84, respectively. In the external valida-

Table 3. Multivariable Analysis: Predictors of Mortality at 30 Days and 1 Year

	30-Day Mortality (n=1004)		1-Year Mortality (n=1853)	
Variable	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.04 (1.03–1.05)	<0.001	1.05 (1.04–1.06)	<0.001
Sex				
Female	1.00 (Reference)		1.00 (Reference)	
Male	1.22 (1.04–1.43)	0.015	1.18 (1.04–1.34)	0.011
Stroke severity (using CNS)				
0	49.22 (35.17–68.90)	<0.001	26.72 (18.87–37.83)	<0.001
≤4	9.75 (7.93–11.97)	<0.001	5.75 (4.93–6.71)	<0.001
5–7	3.98 (3.22–4.92)	<0.001	2.74 (2.37–3.18)	<0.001
≥8	1.00 (Reference)		1.00 (Reference)	
Stroke subtype				
Lacunar	1.00 (Reference)		1.00 (Reference)	
Nonlacunar	2.58 (1.79–3.70)	<0.001	1.89 (1.51–2.35)	<0.001
Undetermined origin	3.53 (2.47–5.05)	<0.001	2.16 (1.74–2.68)	<0.001
Risk factor				
Atrial fibrillation	1.42 (1.18–1.70)	0.002	1.26 (1.08–1.47)	0.003
CHF	1.32 (1.05–1.65)	0.015	1.63 (1.35–1.98)	<0.001
Previous myocardial infarction	. . .	. . .	1.24 (1.06–1.46)	0.008
Current smoker	. . .	. . .	1.27 (1.06–1.52)	0.009
Comorbid condition				
Cancer	1.42 (1.13–1.78)	0.002	1.85 (1.54–2.21)	<0.001
Renal dialysis	3.16 (1.63–6.16)	<0.001	6.46 (3.70–11.30)	<0.001
Preadmission disability				
Dependent	1.56 (1.32–1.85)	<0.001	2.13 (1.85–2.44)	<0.001
Independent	1.00 (Reference)	. . .	1.00 (Reference)	. . .
Glucose on admission, mmol/L				
<7.5	1.00 (Reference)	. . .	1.00 (Reference)	. . .
≥7.5	1.63 (1.40–1.90)	<0.001	1.49 (1.31–1.68)	<0.001

OR indicates odds ratio; CI, confidence interval; and CHF, congestive heart failure. To convert glucose to mg/dL, divide by 0.0555.

tion set, the area under the ROC curve was 0.79 and 0.782 for 30-day mortality and 1-year mortality, respectively. Figure 1 shows the observed mortality in each risk category in the derivation and internal and external validation cohorts. Because of the diminished prediction in the external validation sample (Hosmer-Lemeshow test, $P<0.001$) compared with the derivation cohort (Hosmer-Lemeshow test, $P=0.248$) and internal validation sample (Hosmer-Lemeshow test, $P=0.554$), we randomly divided the external validation sample into 2 halves. We then recalibrated the regression model in the first half of the external validation sample and obtained predictions in the second half. Predictive accuracy in the second half of the external validation sample was improved by this model recalibration. We also plotted observed versus predicted mortality in the validation sample (Figure 2A for 30-day mortality and Figure 2B for 1-year mortality). There was a high correlation between observed and expected mortality (Pearson correlation coefficient, 0.992 for 30-day and 0.996 for 1-year mortality), indicating excellent calibration.

Discussion

Predicting outcomes is one of the most difficult tasks in medicine. The early use of prognostic data using simple elements may help clinicians make treatment decisions and provide reliable information when counseling patients and their families. Furthermore, it may assist policymakers by serving as a tool for comparing outcomes between different healthcare institutions. Clearly, the challenge is to create a simple, easy-to-use tool that also accounts for common complex diseases such as kidney disease, cancer, and congestive heart failure that are known to influence stroke outcome.

In the present study, we found that age, sex, stroke severity and subtype, smoking, history of atrial fibrillation, coronary artery disease, congestive heart failure, cancer, kidney disease on dialysis, hyperglycemia on admission, and dependency before the stroke were associated with an increased risk of 30-day and/or 1-year stroke mortality. Both mortality models included acute clinical parameters and chronic comorbid conditions. The risk score that was developed showed a graded effect. Predicted mortality and observed mortality in the validation cohort were in close agreement across the entire spectrum of risk, and the results were validated in both independent internal and external validation samples. This new risk score provides a simple method to stratify a patient's

Table 4. Stroke 30-Day Mortality/1-Year Mortality Risk Scoring System

	No. of Points	
Variable	30-Day Score	1-Year Score
Age	+Age (in years)	+Age (in years)
Sex	0	0
Female		
Male	+10	+5
Stroke severity (using CNS)		
0*	+105	+70
≤4	+65	+40
5–7	+40	+25
≥8	0	0
Stroke subtype		
Lacunar	0	0
Nonlacunar	+30	+15
Undetermined origin	+35	+20
Risk factor		
Atrial fibrillation	+10	+5
CHF	+10	+10
Previous myocardial infarction	N/A	+5
Current smoker	N/A	+5
Comorbid condition		
Cancer	+10	+15
Renal dialysis	+35	+40
Preadmission disability		
Independent	0	0
Dependent	+15	+20
Glucose on admission, mmol/L (mg/dL)		
<7.5 (<135)	0	0
≥7.5 (≥135)	+15	+10

CHF indicates congestive heart failure; N/A, not applicable to this model.
*Patients in a coma should be assigned a score of 0.

risk of death at the time of initial hospital presentation into 5 categories ranging from very low to very high average risk.

Our findings are consistent with prior investigations evaluating predictors of mortality in patients with ischemic stroke; however, our study was able to extend these observations further by building a risk score with fairly high prognostic accuracy using variables available within hours after stroke and through adequate validation (both internal and external).

Several prior studies have been conducted to try to predict stroke outcomes. In 1 study, both clinical and imaging variables were combined, and the investigators were able to find good discrimination (ROC curve >0.80) for nursing home–level disability or death at 3 months by including initial National Institutes of Health Stroke Scale (NIHSS) score, stroke subtype, history of diabetes mellitus or stroke, preadmission status, and infarct volume determined on computed tomography 7 to 10 days after stroke.[22] However, no score was developed.

In 2 previous studies, attempts were made to predict mortality by combining multiple factors; these studies used all stroke subtypes and smaller sample sizes.[23,24] A similar study by Williams and Jiang[25] looked at developing a survival score to predict 12-month mortality for ischemic stroke patients by using clinical variables and by including established instruments used to determine functional status and disability; this mortality prediction score was derived with a relatively small sample of patients (n=453) enrolled in a randomized controlled trial, and the score was not externally validated.[25] Other initiatives that attempted to develop and validate a risk score model to predict mortality involved a study using 737 patients who experienced a stroke and were ≥60 years of age; a 3-variable risk score (consisting of age, CNS score, and Charlson Index) was devised and was able to predict mortality with an area under the ROC curve of 0.71.[19] Following previous work,[20] the investigators in the Virtual International Stroke Trials Archive (VISTA) identified a simple score to predict functional independency and survival between 1 to 6 months in 5419 patients with an ischemic stroke. They found that age, sex, and NIHSS score predicted stroke mortality at 3 months with an area under the curve of 0.71. These investigators provided a nomogram to calculate the corresponding mortality.[21]

More recently, Smith and colleagues[26] used the Get With the Guidelines data to create a prediction tool for in-hospital mortality. Overall, in-hospital mortality was 5.2% with an observed mortality of 12% for the ninth decile. The low observed mortality is likely related to the short length of stay. NIHSS was recorded in 40% of the Get With the Guidelines cohort. The performance of the score improved by adding stroke severity; the c statistic for the overall validation was 0.72 and 0.85 in the model that included NIHSS. This model is useful for calculating in-hospital mortality and includes ethnicity, mode of arrival, and time of the admission. In contrast, our risk score estimates 30-day and 1-year mortality with higher ranges (mean mortality range between the lowest- and the highest-risk groups, 1% to 39% at 30 days and 3% to 59% at 1 year) and includes other independent predictors of death (eg, cancer, renal failure on dialysis, preadmission dependency). Moreover, our risk score contains nearly complete stroke severity ascertainment, has long-term follow-up for all cohorts, and only includes individual patient-level variables.

Despite the fact that some previous simple prognostic models have been able to demonstrate good discrimination (c statistic, 0.70 to 0.85) by including only age and stroke severity,[20,21,26,27] these models omitted other relevant and prevalent characteristics, eg, renal failure, cancer, and congestive heart failure, that have a direct influence on stroke outcomes (see Figure 3).[20,21,26,27] Moreover, the predicted mortality for the highest categories has been relatively low, perhaps related to the small number of variables included in the model or the exclusion of patients with adverse prognosis.[19] Other studies used inadequate sample sizes, lacked external validation, and/or predicted either short-term or long-term survival, thereby limiting their use in clinical practice or in research.[19–21,28] Moreover, in a 2001 review by Counsell and Dennis,[29] an evaluation of a number of models reported a similar finding: Each model evaluated was not developed with great precision or accuracy.

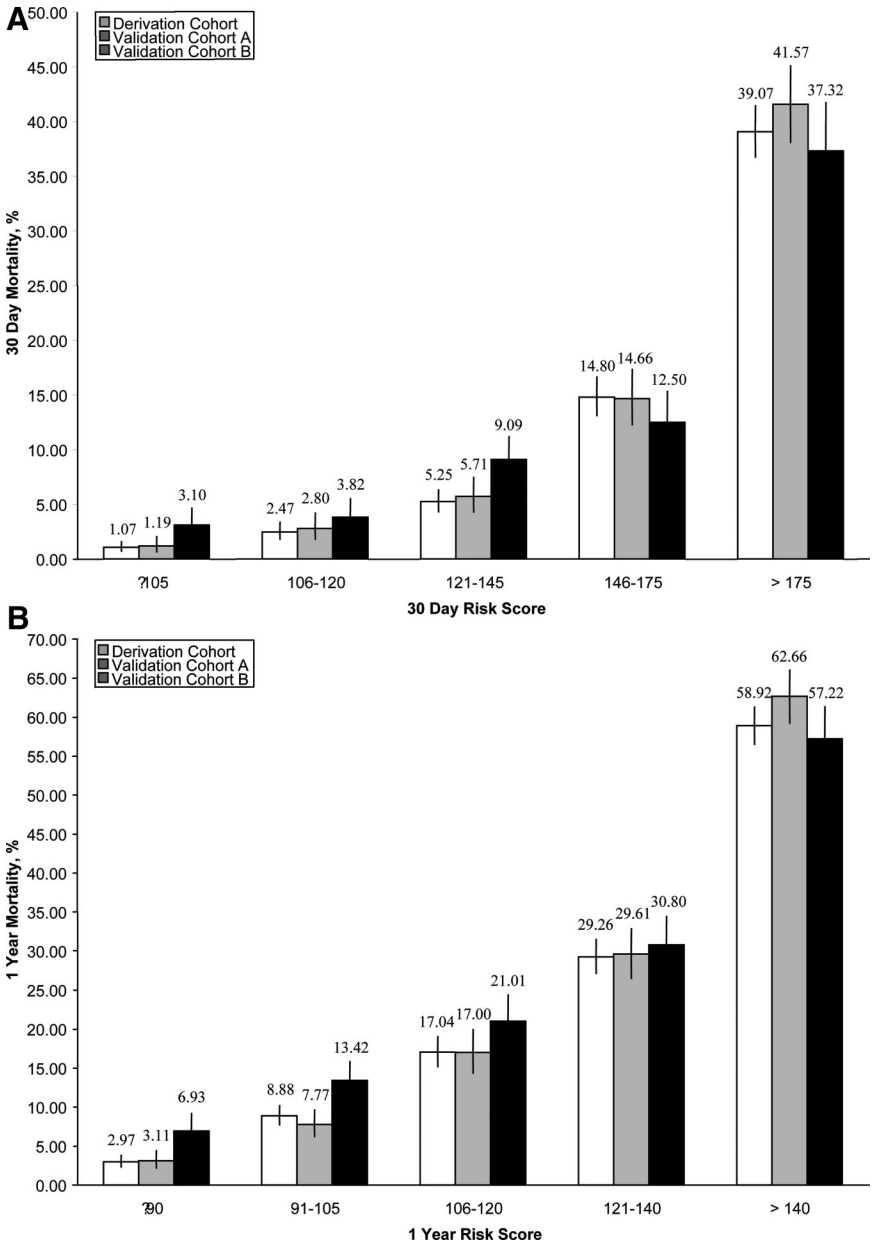


Figure 1. A, Thirty-day mortality by 30-day score. Error bars shown represent 95% confidence interval. B, One-year mortality by 1-year score. Error bars shown represent 95% confidence interval.

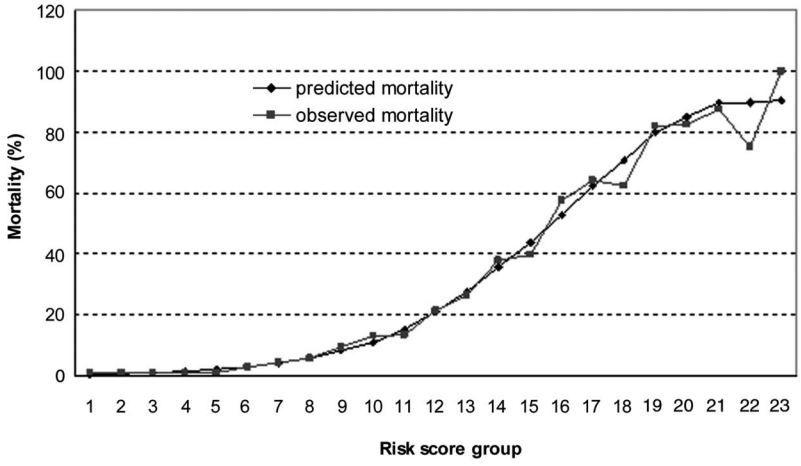
We demonstrated that simpler published risk models[23–25] including only age and stroke severity may overestimate or underestimate mortality at 30 days or 1 year after stroke (Figure III in the online-only Data Supplement). Moreover, the inclusion of additional and relevant clinical information leads to very different estimates of 30-day and 1-year mortality (Figure 3) compared with the estimates obtained when only age and stroke severity are used.[23–25,27] In particular, including additional clinical characteristics allows one to obtain meaningful differences in predicted mortality between patients of the same age and stroke severity.

Our study has strengths and limitations that deserve comment. First, our derivation cohort comprised patients admitted to stroke centers who may not be representative of patients admitted to community hospitals. However, the score was validated with a large representative sample including stroke patients admitted to all type of facilities (small community, large community, and teaching hospitals) in the province. Second, it is possible that some prognostically important variables (eg, socioeconomic status) were excluded from our final mortality prediction model. However, we took several steps (literature search, references from key articles) to ensure that the most relevant variables, including preadmission dependency, were captured in our risk model. Third, we included only hospitalized patients with an acute ischemic stroke; consequently, the risk score model may not apply to patients with cerebrovascular disease seen in the ambulatory setting or to patients with nonischemic stroke. Fourth, although several ethnic groups were included in the present study, the majority of patients were white.

The risk score had to be recalibrated in the external validation set, which suggests that individual investigators may want to recalibrate the IScore in their local data sets or to validate in other communities with different stroke patterns

A

Risk score Group	Risk Score	Observed Mortality (%)	Predicted Mortality (%)
1	59-70	1.18	0.43
2	71-80	1.02	0.73
3	81-90	1.02	0.89
4	91-100	1.23	1.33
5	101-110	1.21	1.87
6	111-120	2.94	2.58
7	121-130	4.33	3.73
8	131-140	5.95	5.03
9	141-150	9.41	7.39
10	151-160	13.3	9.78
11	161-170	13.5	13.1
12	171-180	21.6	18.0
13	181-190	26.6	24.2
14	191-200	38.0	33.0
15	201-210	39.7	39.2
16	211-220	57.5	49.2
17	221-230	64.3	57.6
18	231-240	62.5	65.7
19	241-250	82.2	80.0
20	251-260	82.6	84.2
21	261-270	87.5	90.0
22	271-280	75.0	90.2
23	281-285	100.0	90.5



B

Risk score Group	Risk Score	Observed mortality	Predicted Mortality
1	59-70	1.77	1.78
2	71-80	1.83	2.93
3	81-90	3.97	4.36
4	91-100	7.59	6.56
5	101-110	12.1	9.76
6	111-120	19.3	14.4
7	121-130	25.0	20.4
8	131-140	34.9	29.0
9	141-150	46.5	38.2
10	151-160	55.7	48.9
11	161-170	62.8	59.3
12	171-180	77.6	74.8
13	181-190	77.4	75.7
14	191-200	97.8	87.3
15	201-210	90.5	93.8
16	211-220	90.9	95.3
17	221-230	100.0	97.3
18	231-240	100.0	97.7

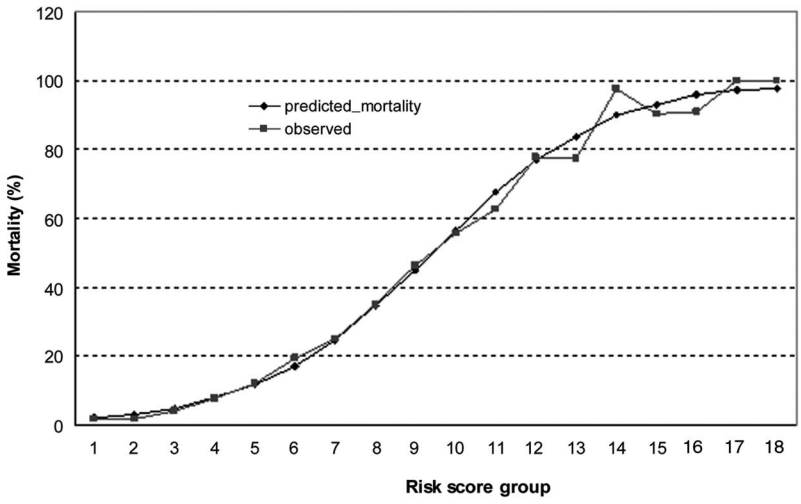


Figure 2. Observed vs predicted 30-day (A) and 1-year (B) mortality in the validation sample as a continuous function of the risk score at 10-point intervals. Overall, there was a very high correlation between observed and expected mortality (Pearson correlation coefficient=0.992 for 30-day and 0.996 for 1-year mortality), indicating excellent calibration. Note that each dot in the graph represents the mean mortality for that corresponding risk category. A more accurate estimation of the mortality for the specific risk score can be found with the Web tool (http://www.sorcan.ca/iscore).

(eg, Southeast Asia). Finally, the measure of stroke severity in this study was achieved through the application of the CNS Scale,[7] which is analogous to the more widely used NIHSS[30] for assessing neurological functioning. A recent study[31] assessed the capacity to use one of these scores and to convert it in terms of its counterpart; this study validated the ability to use the CNS and NIHSS interchangeably, finding the following results: a CNS score of 1 to 4 equals an NIHSS score of

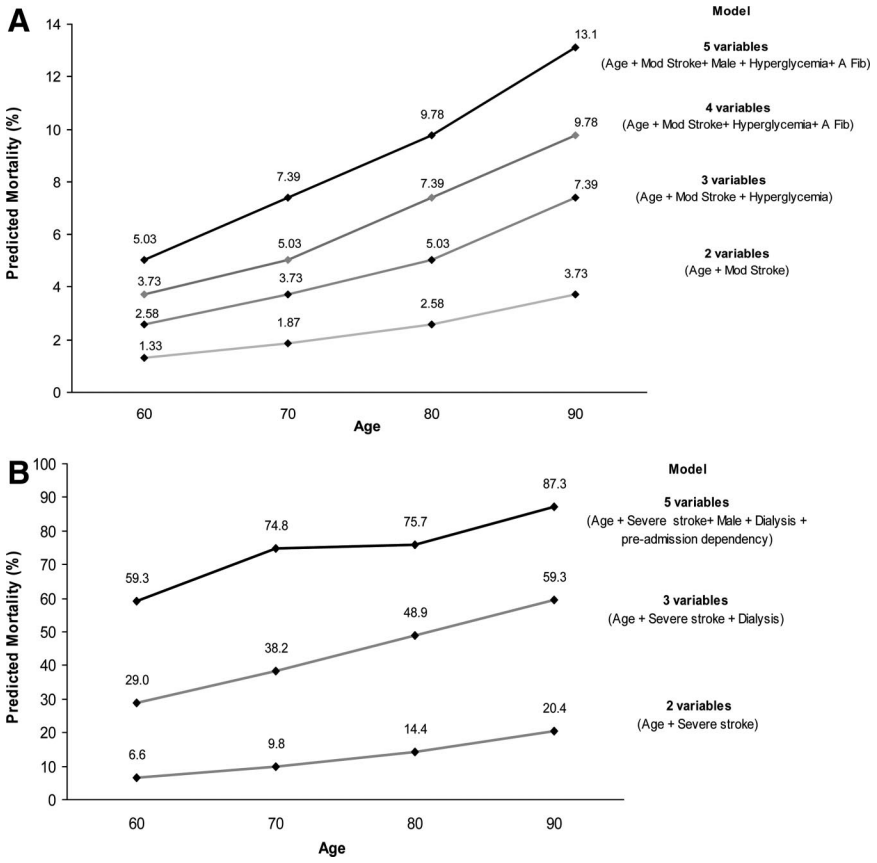


Figure 3. Comparison of predicted mortality between a 2-variable model (age and stroke severity) and the addition of other relevant variables as proposed in the current risk score. A, Comparison of 30-day mortality for patients with moderate ischemic stroke in different age groups (low-risk category). B, Comparison of 1-year mortality for patients with severe ischemic stroke in different age groups (higher-risk category). Continuous lines represent the increased mortality with the addition of other relevant variables. Fib indicates atrial fibrillation; Mod stroke, moderate stroke (CNS=5 to 7); and hyperglycemia, glucose >135 mg/dL.

14 to 22 (severe), a CNS score of 5 to 7 equals an NIHSS score of 9 to 13 (moderate), a CNS score of ≥8 equals an NIHSS score of ≤8 (mild), and a CNS score of 0 equals an NIHSS score of >22. Thus, our proposed stroke mortality prediction score may be used by healthcare providers using either one of these scales for neurological assessment.

The present model differs from other models used to predict stroke mortality in a number of important ways. Our model was designed to be independent of stroke volume, and each of the variables in the present model can be obtained easily and is independent of specialized laboratory tests or imaging evaluations because this information may be unavailable in the early hours of hospital presentation. Additionally, this may also allow its use at small centers and at community hospitals with limited resources. A caveat, however, is the need for recalibration/validation in other specific populations. Another feature unique to our new risk score model allows the individual estimation of both early (30 days) and long-term (1 year) mortality after stroke with a nearly complete ascertainment of stroke severity and follow-up. Furthermore, because of the number of variables required, it has a good face validity and greater parsimony than most other predictive risk models. Other simple models included 2 to 4 variables; however, the instrument was developed only for 30-day mortality assessment and did not account for relevant comorbid conditions, as in our model.[20,21,26,27] In addition, although several authors have developed models to predict mortality, only a few went on to develop a risk score.

Unlike acute myocardial infarction, stroke is a syndrome with several mechanisms and consequently different prognoses. Physicians may underestimate or overestimate prognosis in stroke patients, sometimes on the basis of recent or memorable clinical experiences. In contrast to anecdotal experience, our new stroke index constitutes an objective tool to stratify mortality risk. An online Web-based tool (http://www.sorcan.ca/iscore) is available for practical use to facilitate estimation of individual patient mortality at 30 days and 1 year. The index could be used as a framework to discuss prognosis and to provide evidence to support rational decision making about treatment and the difficult end-of-life care in stroke patients who are at highest risk. Besides its utility in clinical decision making, this risk score may be used in research to assist in stratifying patients into clinical risk groups or to help policymakers with standardized measures when seeking to compare facilities and/or to analyze hospital performance.

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Disclosures

Dr Tu is a HSFO career investigator and holds a Canada Research Chair in health services research.

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CLINICAL PERSPECTIVE

Stroke is a leading cause of death and adult disability. The ability to estimate prognosis in acute stroke patients directly affects treatment decisions for patients. It may also guide supportive care plan and facilitate patient and/or family counseling or discussions pertaining to end-of-life decisions. At the population level, prognostic estimations may assist policymakers in conducting fair comparisons when evaluating stroke fatality among different facilities for hospital outcomes and performance assessment. Clinicians usually rely on their own personal experience or average mortality reported in clinical trials, which do not account for valuable information available at the time of the hospital presentation. Unfortunately, few risk scores are available that include simple and relevant clinical variables, including stroke severity on admission. In this large cohort study, we created and validated a risk score model to predict 30-day and 1-year mortality early after hospitalization for patients with an acute ischemic stroke. Our model was designed to include clinical variables easily obtained in the early hours of hospital presentation and is independent of specialized laboratory tests or imaging evaluations. Additionally, this model allows estimating death at small centers and at community hospitals with limited resources. Predictors of mortality included older age, male sex, severe stroke, nonlacunar stroke subtype, glucose ≥7.5 mmol/L (135 mg/dL), history of atrial fibrillation, coronary artery disease, congestive heart failure, cancer, kidney disease on dialysis, and dependency before the stroke. Our risk score helps to estimate 30-day and 1-year mortality in individuals presenting with an acute ischemic stroke. Examples are provided in the text. An online Web-based tool (http://www.sorcan.ca/iscore) is available to estimate mortality by adding individual patient characteristics.

Supplemental Tables

Supplemental Table 1. Summary of multivariable logistic regression estimates of significant risk factors for 30 day mortality

	Derivation Cohort			Validation Cohort A			Validation Cohort B (External)		
	β Coefficient	**Standard Error**	**Wald p value**	**β Coefficient**	**Standard Error**	**Wald p value**	**β Coefficient**	**Standard Error**	**Wald p value**
Intercept	-7.6521	0.3462	< 0.0001	-6.6358	0.4414	< 0.0001	-6.229	0.5093	< 0.0001
Age (in years)	0.0376	0.0037	< 0.0001	0.0272	0.00503	< 0.0001	0.034	0.00622	< 0.0001
Gender – Male	0.1965	0.0808	0.015	--	--	NS	--	--	NS
CNS Score									
0	3.8964	0.1716	< 0.0001	3.5713	0.249	< 0.0001	3.0249	0.2922	< 0.0001
≤ 4	2.2769	0.1049	< 0.0001	2.4508	0.1433	< 0.0001	1.734	0.1602	< 0.0001
5 - 7	1.381	0.1085	< 0.0001	1.2017	0.1519	< 0.0001	0.7869	0.1428	< 0.0001
Stroke Type									
NonLacunar	0.9468	0.1847	< 0.0001	0.7267	0.2385	0.0023	0.4134	0.1952	0.0342
Undetermined etiology	1.2608	0.1824	< 0.0001	1.1139	0.2345	< 0.0001	0.5515	0.1715	0.0013
Atrial Fibrillation	0.3475	0.0941	0.0002	0.4673	0.1333	0.0005	--	--	NS
CAD	--	--	NS	0.3128	0.1218	0.0102	--	--	NS
CHF	0.2758	0.1138	0.0154	0.3659	0.1609	0.023	0.7116	0.1648	< 0.0001
Cancer	0.3523	0.1155	0.0023	0.7358	0.1557	< 0.0001	--	--	NS
Renal Dialysis	1.1518	0.3398	0.0007	--	--	NS	--	--	NS
PreAdmission Disability – Dependent	0.4453	0.0865	< 0.0001	0.4439	0.1209	0.0002	0.6195	0.1263	< 0.0001
Glucose – ≥ 7.5 mmol/L	0.4915	0.078	< 0.0001	0.4341	0.1113	< 0.0001	0.5237	0.1206	< 0.0001

NS – Not Significant, p > 0.05

Supplemental Table 2. Summary of multivariable logistic regression estimates of significant risk factors for 1 year mortality

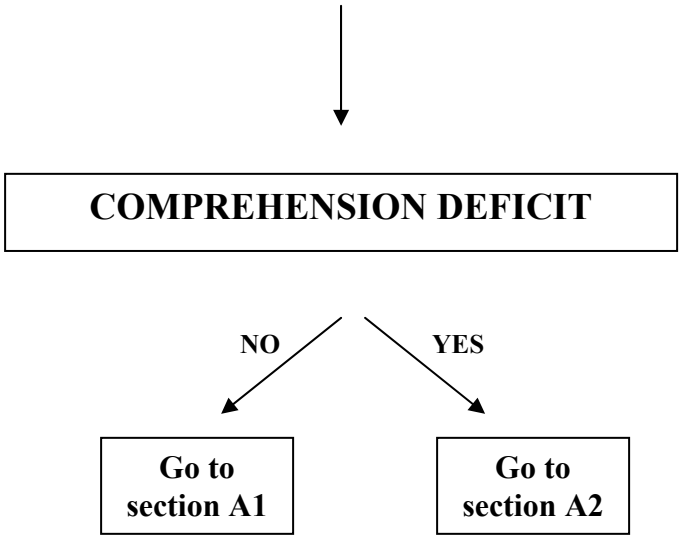
	Derivation Cohort			Validation Cohort A			Validation Cohort B (External)		
	β Coefficient	Standard Error	Wald p value	β Coefficient	Standard Error	Wald p value	β Coefficient	Standard Error	Wald p value
Intercept	-7.0429	0.2721	< 0.0001	-7.2151	0.3874	< 0.0001	-6.6458	0.4128	< 0.0001
Age (in years)	0.0494	0.0031	< 0.0001	0.0478	0.00448	< 0.0001	0.0574	0.00507	< 0.0001
Gender – Male	0.1644	0.0644	0.0107	--	--	NS	0.2932	0.0945	0.0019
CNS Score									
0	3.2853	0.1774	< 0.0001	3.414	0.2856	< 0.0001	2.5705	0.3287	< 0.0001
≤ 4	1.7497	0.0785	< 0.0001	1.8859	0.1142	< 0.0001	1.3211	0.1396	< 0.0001
5 - 7	1.0083	0.0751	< 0.0001	0.8144	0.1096	< 0.0001	0.6975	0.1039	< 0.0001
Stroke Type									
NonLacunar	0.6357	0.1125	< 0.0001	0.9331	0.1681	< 0.0001	--	--	NS
Undetermined etiology	0.77	0.111	< 0.0001	1.136	0.1673	< 0.0001	--	--	NS
Atrial Fibrillation	0.2317	0.0788	0.0033	--	--	NS	-0.259	0.1237	0.0363
Previous MI	0.216	0.0818	0.0082	--	--	NS	--	--	NS
CAD	--	--	NS	0.2492	0.1014	0.014	--	--	NS
CHF	0.4893	0.0976	< 0.0001	0.6637	0.1394	< 0.0001	0.8872	0.147	< 0.0001
Current Smoker	0.2393	0.0922	0.0094	0.354	0.1303	0.0066	--	--	NS
Cancer	0.6138	0.0923	< 0.0001	1.0985	0.1297	< 0.0001	0.7547	0.1492	< 0.0001
Renal Dialysis	1.8664	0.2851	< 0.0001	1.3932	0.4213	0.0009	1.3085	0.4203	0.0019
Dementia	--	--	NS	0.4305	0.1494	0.004	0.349	0.1513	0.0211
PreAdmission	0.7541	0.07	< 0.0001	0.7548	0.1062	< 0.0001	0.6935	0.1067	< 0.0001
Disability – Dependent									
Glucose – ≥ 7.5 mmol/L	0.3958	0.063	< 0.0001	0.4341	0.0924	< 0.0001	0.3731	0.0939	< 0.0001

NS – Not Significant, p > 0.05

Supplemental Figure 1

Canadian Neurological Scale (CNS)

M E N T A T I O N	**Level of Consciousness**	Alert 3.0	Spontaneous eye opening, normal level of consciousness
		Drowsy 1.5	When stimulated verbally patient remains awake and alert but tends to doze
	Orientation	Oriented 1.0	1. Where are you? (City and Hospital) 2. What is the month and year? Speech can be slurred but must be intelligible.
		Disoriented 0.0	Patient cannot state both place and time or cannot express answers in words or intelligible speech. It is acceptable for patient to write answer to questions of orientation
	Speech	Receptive deficit 0.0 Expressive deficit 0.5 Normal Speech 1.0	**Receptive deficit:** • Example: ask patient. 1) to close eyes; 2) Point to ceiling; 3) Does a stone sink in water? • If pt. does not complete the above 3, go to Section A2.



Section A1 No Comprehension Deficit	Face	Ask pt. to smile: • No weakness (none) – 0.5 • Weakness (present) – 0.0 (Record L or R)
	Arm: Proximal	Ask pt. to lift arms to shoulder level and apply resistance above elbows bilaterally • No weakness (none) – 1.5 • Movement to 90°, unable to oppose pressure (mild) – 1.0 • Movement < 90° (significant) – 0.5 • Absence of motion (total) – 0.0
	Arm: Distal	Ask pt. to bend wrist back. Apply pressure on back of the hand. • No weakness (none) – 1.5 • Can bend wrist, unable to oppose pressure (mild) – 1.0 • Some movement of fingers (significant) – 0.5 • Absence of movement (total) – 0.0
	Leg: Proximal	Ask pt. to flex knee to 90°. Push down on each thigh one at a time. • No weakness (none) – 1.5 • Can lift leg, unable to oppose pressure (mild) – 1.0 • Lateral movement but no power to lift leg (significant) – 0.5 • Absence of movement (total) – 0.0
	Leg: Distal	Ask pt. to point toes and feet upward. Push down on each foot one at a time. • No weakness (none)– 1.5 • Can point foot & toes upward, unable to oppose pressure (mild) – 1.0 • Some movement of toes, but cannot lift toes or foot (significant) – 0.5 • Absence of movement (total) – 0.0
Section A2 Comprehension Deficit	Face:	Ask pt. to mimic your grin (if unable, apply pressure to sternum). • Symmetrical – 0.5 • Asymmetrical – 0.0
	Arms:	Demonstrate/place pt. arms in front of pt. at 90° (if unable, apply finger nail bed pressure bilaterally and compare response) • Equal motor response – 1.5 • Unequal motor response – 0.0 (record L or R)
	Legs:	Thighs flexed to 90° (if unable, apply toenail bed pressure bilaterally and compare response) • Maintain position or withdraw equally – 1.5 • Cannot maintain position or unequal withdrawing – 0.0 (record L or R)

Note: Score Mentation Section for all patients. Then, score Section A1 OR Section A2
Total score: Score mentation + Score section A1 or A2 (Do not score both A1 & A2)

Supplemental Figure 2. Application of the Stroke Mortality Risk Score

***Illustrative Case # 1*:**

	Adding Points	
	30-Day Stroke Mortality Score/Point	1-Year Stroke Mortality Score/Point
Age - value	70	70
Sex- male	10	5
Stroke Severity- mild	0	0
Stroke Subtype- lacunar	0	0
Risk Factors		
Atrial Fibrillation -yes	10	5
CHF - no	0	0
Previous M.I.- no	-	0
Current Smoker- no	-	0
Comorbid Conditions		
Cancer - no	0	0
Renal Dialysis - no	0	0
Preadmission Disability - independent	0	0
Glucose on Admission - below 7.5	0	0
Total Score	90	80

30-Day Risk Score	
Score	**Mortality (%)**
…	…
71 - 80	0.73
81 - 90	**0.89**
91 - 100	1.33
…	…

1-Year Risk Score	
Score	**Mortality (%)**
59 – 70	1.78
71 – 80	**2.93**
81 – 90	4.36
…	…

***Illustrative Case #2*:**

	Adding Points	
	30-Day Stroke Mortality Score/Point	1-Year Stroke Mortality Score/Point
Age - value	80	80
Sex - woman	0	0
Stroke Severity – moderate	40	25
Stroke Subtype – non-lacunar	30	15
Risk Factors		
Atrial Fibrillation - no	0	0
CHF - yes	10	10
Previous M.I. - no	-	0
Current Smoker – yes	-	5
Comorbid Conditions		
Cancer - no	0	0
Renal Dialysis – yes	35	40
Preadmission Disability – independent	0	0
Glucose on Admission - > 7.5 mmol/dL	15	10
Total Score	210	185

30-Day Risk Score	
Score	**Mortality (%)**
…	…
191 – 200	33.0
201 – 210	**39.2**
211 – 220	49.2
…	…

1-Year Risk Score	
Score	**Mortality (%)**
	…
171 – 180	74.8
181 – 190	**75.7**
191 – 200	87.3
	…

Figure 3A- 30-day mortality

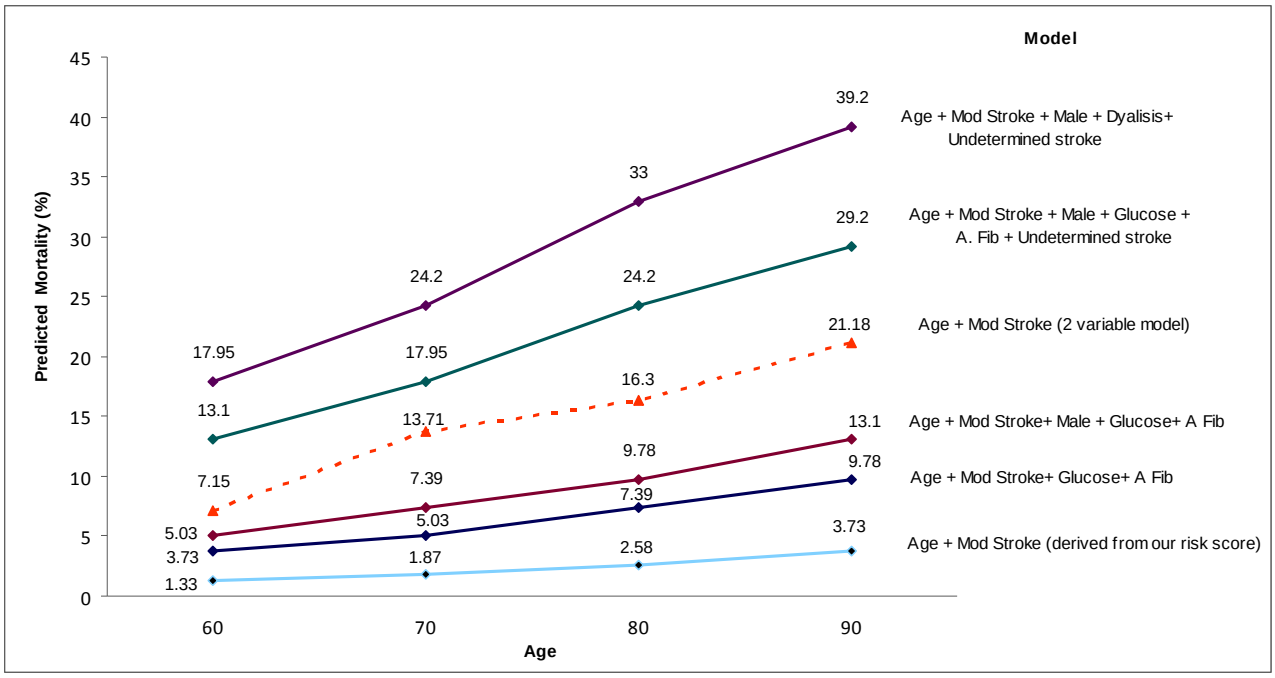
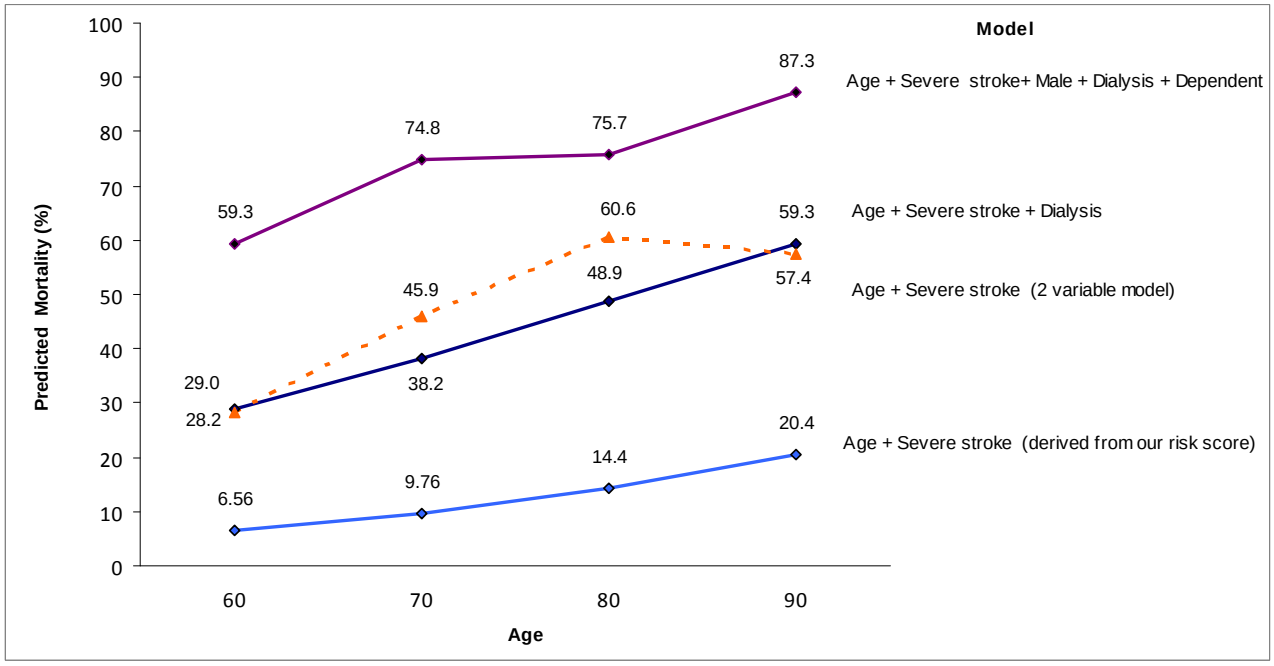


Figure 3B- 1-year mortality



Legends

Supplemental Figure 1: Canadian Neurological Scale (CNS)

Note: Score Mentation Section for all patients. Then, score Section A1 OR Section A2

Total score: Score mentation + Score section A1 or A2 (Do not score both A1 & A2)

Supplemental Figure 2: Application of the Stroke Mortality Risk Score

Case #1: For a 70 year old man, non-smoker, who was previously independent, with history of atrial fibrillation, presenting with a mild lacunar stroke, and a glucose on admission <7.5mmol/L, the 30-day risk score would be 90 and the predicted 30-day mortality would be 0.89%, while the 1-year risk score would be 80 and the mortality 2.93%.

Case #2: For a 80 year old woman, current smoker, previously independent, with history of congestive heart failure (+10) and renal failure on dialysis (+35//+40), presenting with a moderate (+40//+25) non-lacunar (+30//+15) stroke, and a glucose on admission of 12.8 mmol/L (+15//+10), her 30-day risk score would be 210 and the predicted mortality at 30 days would be ~39.2%, whereas the 1-year risk score would be 185 with an expected mortality 75.7%.

The corresponding next higher and lower risk categories are also represented.

Note: The examples included are intended to illustrate the use of the risk score. For the individual and more precise estimation of the 30-day and 1-year mortality, please go to **www.sorcan.ca/iscore/**

Supplemental Figure 3: Comparison between a 2-variable risk score and our risk score model.

Figure 3A. 30-day Mortality for patients with moderate ischemic stroke in different age groups. Dotted lines represent the mortality derived from a simple risk score model (only including age and stroke severity as in publications # 23, #24 and #25). Continuous lines represent mortality with the addition of other relevant comorbidities derived from our risk score model.

Note: The two variable models (dotted lines) shows that on average, a 70 year old with a moderate stroke would have a predicted mortality of 13.7% at 30 days. The 30-day mortality derived from our risk score for the similar age and stroke severity (but with NO other comorbidity) would be 1.87%. The addition of other comorbid conditions substantially increases the estimated mortality (continuous lines – 17.95% and 24.2%).

Figure 3B. 1-year Mortality for patients with moderate ischemic stroke in different age groups. Dotted lines represent the mortality derived from a simple risk score model (only including age and stroke severity as in publications # 23, #24 and #25). Continuous lines represent mortality with the addition of other relevant comorbidities derived from our risk score model.

Note: The two variable models (dotted lines) shows that on average, a 80 year old with a severe stroke would have a predicted mortality of 60.6% at 1-year. The estimated 1-year mortality derived from our risk score for the similar age and stroke severity (but with NO other comorbidity) would be 14.4%. The addition of other comorbid conditions substantially increases the estimated mortality (continuous lines – 48.9% and 75.7%).