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The iScore predicts health care costs early after hospitalization for acute ischemic stroke

Gustavo Saposnik

The iScore predicts total healthcare costs early after hospitalization for an acute ischemic stroke

Emmanuel M. Ewara[1], Wanrudee Isaranuwatchai[1,2], Dawn M. Bravata[3,4,5,6,7], Linda S. Williams[3,4,6,7], Jiming Fang[8], Jeffrey S. Hoch[1,2,8], and Gustavo Saposnik[9,10]* on behalf of the Stroke Outcomes Research Canada Working Group

Background **The ischemic Stroke risk score is a validated prognostic score which can be used by clinicians to estimate patient outcomes after the occurrence of an acute ischemic stroke.**

Aim **In this study, we examined the association between the ischemic Stroke risk score and patients' 30-day, one-year, and two-year healthcare costs from the perspective of a third party healthcare payer.**

Methods **Patients who had an acute ischemic stroke were identified from the Registry of Canadian Stroke Network. The 30-day ischemic Stroke risk score prognostic score was determined for each patient. Direct healthcare costs at each time point were determined using administrative databases in the province of Ontario. Unadjusted mean and the impact of a 10-point increase ischemic Stroke risk score and a patient's risk of death or disability on total cost were determined.**

Results **There were 12 686 patients eligible for the study. Total unadjusted mean costs were greatest among patients at high risk. When adjusting for patient characteristics, a 10-point increase in the ischemic Stroke risk score was associated with 8%, 7%, and 4% increase in total costs at 30 days, one-year, and two-years. The same increase was found to impact patients at low, medium, and high risk differently. When adjusting for patient characteristics, patients in the high-risk group had the highest total costs at 30 days, while patients at medium risk had the highest costs at both one and two-years.**

Conclusions **The ischemic Stroke risk score can be useful as a predictor of healthcare utilization and costs early after hospitalization for an acute ischemic stroke.**

Key words: cost, outcomes, risk scores, stroke, stroke management

Correspondence: Gustavo Saposnik*, Division of Neurology, St. Michael's Hospital, Suite 9-31, 55 Queen Street East, Toronto, Ontario, Canada M5C 1R6; Chair, Stroke Outcomes Research Working Group (http://www.sorcan.ca).
E-mail: saposnikg@smh.ca

[1]The Centre for Excellence in Economic Analysis Research, Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, ON, Canada
[2]Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, ON, Canada
[3]VHA Health Services Research and Development (HSR&D), Stroke Quality Enhancement Research Initiative (QUERI), Washington, DC, USA
[4]VHA, HSR&D Center of Innovation on Health Information and Communication, Indianapolis, IN, USA
[5]Department of Internal Medicine, Indiana University School of Medicine, Indianapolis, IN, USA
[6]Department of Neurology, Indiana University School of Medicine, Indianapolis, IN, USA
[7]Regenstrief Institute, Indianapolis, IN, USA
[8]Institute of Clinical Evaluative Sciences, Toronto, ON, Canada
[9]Department of Neurology, University of Toronto School of Medicine, Toronto, ON, Canada
[10]Division of Neurology, St. Michael's Hospital, Toronto, ON, Canada

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Introduction

Stroke, a devastating disease for patients and their families, is a leading cause of disability in adults. Up to 85% of patients experience hemiparesis immediately after stroke, and up to 75% of survivors experience lasting motor deficits after the occurrence of a stroke, diminishing patients' quality of life (1,2). The impact of stroke lasts well beyond the initial event, and results in significant costs to the healthcare payer over time. In Canada, stroke has been estimated to cost approximately $74 400 annually per patient, with costs varying by stroke severity. This results in stroke costing the Canadian economy approximately $2·8 billion annually in both direct medical and indirect costs (3), while in the United States approximately 795 000 people experience a stroke annually, at an estimated annual cost of $36·5 billion (4). Clinicians usually attempt to estimate prognosis early after an acute ischemic stroke (AIS) to counsel patients and their families. Moreover, clinical characteristics, such as stroke severity and comorbid conditions, affect treatment decisions and may directly impact the interventions a patient receives, subsequently impacting their healthcare costs.

Several prognostic scores can be used by clinicians to help estimate patient prognosis. The iScore (ischemic Stroke risk score) is a validated prognostic score which includes demographic information, clinical features (e.g., stroke severity, subtype, pre-admission status), and relevant comorbid conditions (e.g., atrial fibrillation, heart failure) to estimate a patient's probability of death, disability, and response to thrombolysis after an AIS (www.sorcan.ca/iscore). The use of the iScore has been previously validated in various ethnic groups, cohorts, and randomized trials to estimate the risk of short and long-term mortality and clinical outcomes after an AIS (5–11). This score has also been shown to provide useful risk stratification information for patients treated with thrombolytic therapy (6).

Along with helping to identify patients who may benefit from specific therapies, the use of tools like the iScore may also be helpful in guiding supportive care plans, providing useful information to facilitate discharge planning, facilitating patient and/or family counseling, and informing discussions pertaining to end-of-life decisions (10). In this study, we aimed to determine the relationship between the 30-day iScore and total healthcare costs incurred by the Ontario healthcare payer at 30 days, one-year, and two-years after a patient's initial AIS. We examined the impact of a 10-point increase in patient iScore on total costs and compared the total costs of patients deemed to be at low, medium, and high risk of death or disability as determined by the iScore.

Methods

Study population

The study population included AIS patients identified from the Ontario Stroke Registry (OSR) (formerly known as the Registry of Canadian Stroke Network). The OSR is an ongoing clinical database of more than 40 000 patients who have experienced an acute stroke or transient ischemic attack. The OSR is a 'prescribed registry' from which patient data can be collected without patient consent for the purpose of facilitating the provision of stroke care in the province of Ontario, Canada (12). The OSR involves continuous prospective data collection on all consecutive patients seen in an Emergency Department or admitted to hospital with stroke in any of the 12 participating institutions in the province of Ontario (12). Further details are available at http://www.ices.on.ca.

To be eligible for this study, patients had to be ≥18 years of age with a primary diagnosis of an AIS presenting to one of the 12 participating OSR institutions between July 1, 2003 and June 30, 2008. Patients with missing baseline characteristics (age, Canadian Neurological Scale score, glucose on admission, or date last seen 'normal' before the index event) or invalid health card numbers were excluded (<1%). Patients with transient ischemic attacks were excluded because of the expected differences in outcomes and resource utilization compared with AIS patients.

Patients who died or were discharged within 30 days were included in the analysis to provide a comprehensive description of the results according to the objectives of the study. Patient characteristics and information on poststroke mortality was obtained through linkages of the OSR data to the Ontario Registered Persons Database (RPD), a population-based database capturing all basic demographic data for residents in Ontario.

The iScore

We calculated the 30-day iScore for each eligible patient identified from the OSR. The risk scoring system used to determine the iScore is presented in the supporting information (see Table S1 and www.sorcan.ca/iscore). Details of the selection of variables for the iScore, data sources, and the creation and conceptualization of the iScore have been published elsewhere (9,10). iScore values range between 60 (low risk) and 300 (high risk). Patients were categorized into three previously determined risk groups based on their probability of death or disability according to their iScore value (11). Patients were classified as either being low risk (an iScore ≤139 with a >50% probability of a good outcome); medium risk (an iScore 140–179 with a 10–50% probability of a good outcome), or high risk (an iScore ≥180 with <10% probability of a good outcome) (11).

Healthcare costs

All cost data were obtained from Ontario administrative databases at the Institute for Clinical Evaluative Sciences (ICES). Thirty-day, one-year, and two-year total healthcare costs were determined from the date of the index ischemic stroke from the perspective of the Ontario healthcare payer. Data from the OSR and RPD were linked to data from the Canadian Institute for Health Information Discharge Abstract, Ontario Health Insurance Plan, National Ambulatory Care and Reporting System, National Rehabilitation System, Continuing Care Reporting System, Ontario Association of Community Care Access Centres Home Care, Client Profile, and Ontario Drug Benefit (ODB) databases. These datasets were linked using unique, encoded identifiers, and analyzed at ICES.

These linkages allowed for the capturing of costs due to inpatient hospitalizations, physician services, diagnostic and laboratory services, emergency department visits, rehabilitation services, complex continuing care, homecare services, long-term care, nonphysician services, and ODB drugs, respectively. Cost estimates were based on validated algorithms at ICES (Fig. 1). Each patient's 30-day, one-year, and two-year costs from the patient's index stroke date in the registry were then determined using the methodology outlined by Wodchis *et al.* (13). All costs were converted to 2013 costs by adjusting for Canadian consumer price indices, and were then converted to 2013 US$ by adjusting for purchasing power parity (14).

Statistical analysis

Chi-square tests were used to compare categorical variables, and analysis of variance or Kruskal–Wallis tests were used to compare mean and median differences for continuous variables in baseline characteristics. Unadjusted mean costs at 30 days, one-year, and two-years were determined for patients in each iScore risk group.

An increase of 10 points on the iScore is considered the minimal clinical difference to impact on stroke outcomes (10). To determine the impact of this change on patient 30-day, one-year, and two-year total cost, we utilized a multiple regression framework on the log total healthcare costs where patient iScore was treated as a continuous variable. The log of patient total healthcare cost was used to account for any skewness in the cost data. Separate models were conducted to examine the impact of a 10-point increase on total costs at each time-point. The model equation was: $C_i = \beta_{oi} + \beta_1(\text{iScore})_i + \Sigma\beta_j X_{iji} + \varepsilon_i$, where C_i is the log total cost for patient 'i', β_o is an intercept term, β_1 represents the percentage change in total cost due to a one point increase in iScore, controlling for other variables of importance. The total impact of a 10-point increase was then determined by multiplying this value by 10. As a sensitivity analysis, ordinary least squares (OLS) on unlogged costs were also explored.

We also examined the impact of a 10-point increase in 30-day, one-year, and two-year costs for patients in each risk group by treating each predictive score value as a categorical variable. High

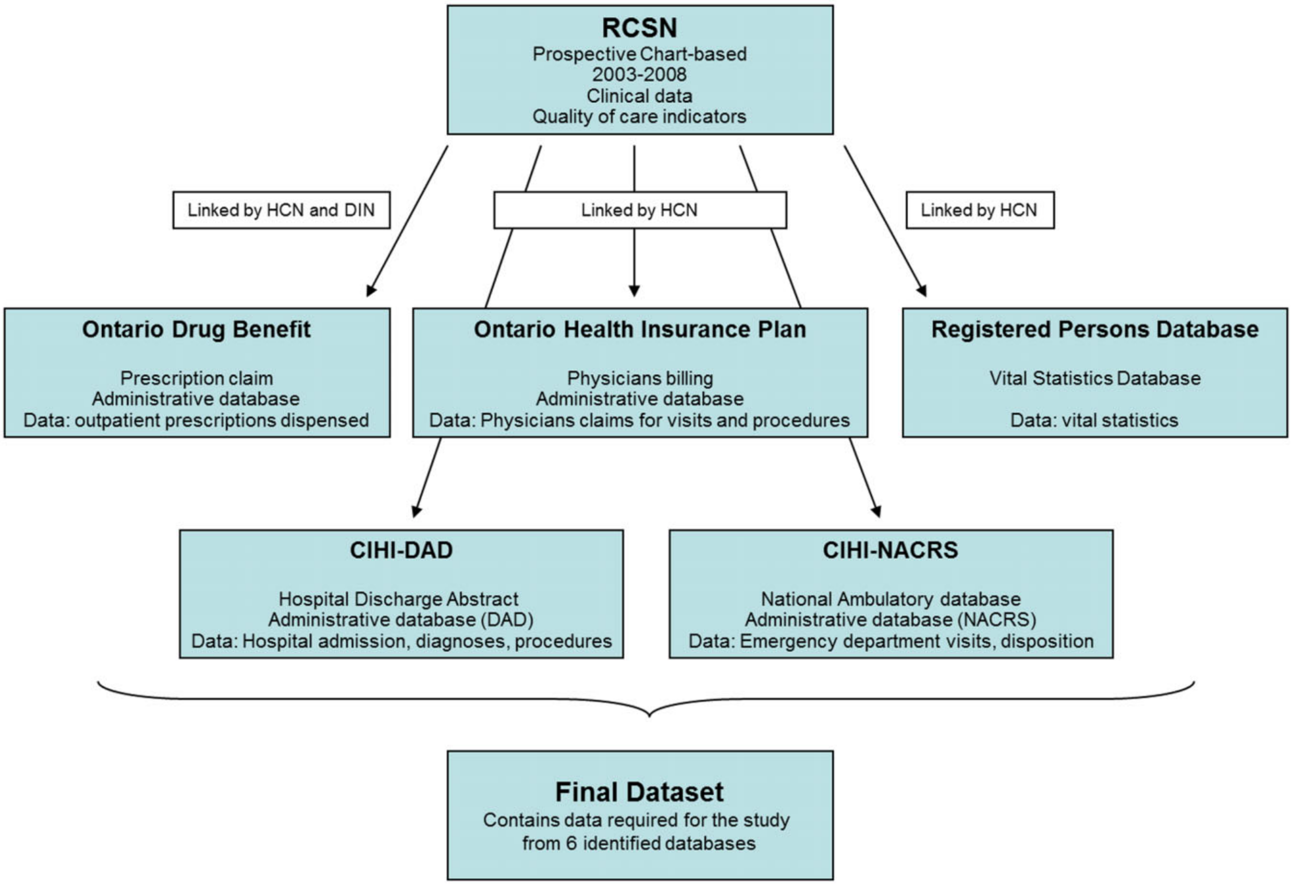

Fig. 1 Schematic of the algorithm to capture patient costs.

and medium-risk groups were distinguished through the use of dummy variables, and other variables which were found to be of importance were also added into the regression equation. The log total cost was again used to account for any skewness in the data. Separate models were conducted for each cost variable (i.e., 30-day, one-year, or two-year cost). The model equation was: $C_i = \beta_{oi} + \beta_1(M)_i + \beta_2(H)_i + \Sigma\, \beta_j X_{iji} + \varepsilon_i$, where C_i is the log cost for patient 'i', β_o is an intercept term, β_1 represents the percentage change in total cost among patients at medium risk compared with patients at low risk controlling for variables of importance, and β_2 represents the percentage change in patient cost among patients at high risk compared with patients at low risk controlling for confounding variables.

Results

Cost information was obtained for a total of 12 686 patients from the OSR. Of these patients, 7647 (60%) were classified as low risk, 2945 (23%) as medium risk, and 2094 (17%) at high risk for death and disability at 30 days. Patient characteristics can be found in Table 1.

Death at 30 days, one-year, and two-years stratified by the iScore group is shown in Fig. 2. Overall, less than one-third (29·8%; 624/2094) of patients in the high-risk iScore were alive at two-years compared with 86·6% of the low-risk group ($P < 0{\cdot}0001$).

Unadjusted mean costs

Unadjusted mean costs at each time-point were determined for patients in each risk group. Patients at high risk were found to have the highest 30-day total healthcare costs. The most significant cost driver within the first 30 days were those costs incurred for inpatient hospitalizations, representing 67%, 67%, and 73% of total costs in the low, medium, and high-risk groups, respectively (P values <0·0001). Other significant costs incurred were attributable to physician services, rehabilitation services, and Emergency Department visits (Table 2).

At one-year, patients in the medium-risk group were found to have incurred the highest total costs. Hospitalization costs remained the single most significant component for patients in all three risk groups, representing 38%, 40%, and 49% of total costs for the low, medium, and high-risk groups, respectively. Other significant cost drivers were those costs incurred for rehabilitation services, complex continuing care, long-term care, and physician services (Table 2). Similar findings were again observed at two-years (Table 2).

There were only 624 (29·8%) patients alive at two-years in the high-risk group compared with 1838 (62·4%) in the medium-risk group (Fig· 2). In these groups of patients, the mean costs were

Table 1 Patient characteristics by risk group

	iScore group			
Cost	All	Low (≤139)	Medium (140–179)	High (≥180)
n	12 686	7647	2945	2094
Mean iScore	135·4	107·8	157·3	205·8
Gender – M (%)	52·5	53·6	54·3	45·8
Mean age (SD)	72 (13·8)	68 (14·0)	76·2 (11·5)	80·8 (9·7)
Hypertension (%)	68·1	62·3	70·2	72·4
Diabetes (%)	25·5	25·9	25·7	25
Coronary artery disease (%)	24	17·6	24·8	30
Heart failure (%)	9·1	2·3	8	17·1
Atrial fibrillation (%)	17·2	3·5	18·2	30·8
Dyslipidemia (%)	35	37·6	34·9	32·4
Prior stroke (%)	21	15·3	22	26·4
Prior TIA (%)	15·1	13·9	17·4	14·4
Stroke severity, mild (CNS > 8) (%)	65·2	97·2	80·1	19
Moderate (CNS 5–7) (%)	19·7	2·7	17·9	38·9
Severe (CNS < 4) (%)	12·3	0·1	1·9	34·1
Lives with others (%)	71·9	71	72·6	74·4
Lives alone (%)	20·5	21·5	20·4	16·9
Rural (%)	10·4	11	9·9	8·8
Urban (%)	89·6	89	90·1	91·2
Income quintile 1 (%)	23·7	23·5	25	22·8
Income quintile 2 (%)	21·9	21·4	22·1	23·3
Income quintile 3 (%)	18·4	18·7	17·7	18
Income quintile 4 (%)	17·4	17·6	16·8	17·5
Income quintile 5 (%)	18·6	18·7	18·4	18·5
Median LOS (1–3 IQR)	7 (3–15)	6 (2–11)	10 (4–22)	10 (4–23)
Mean LOS	12·9	9·4	17·7	18·9

CNS, Canadian Neurological Scale; LOS, length of stay; TIA, transient ischemic attack.

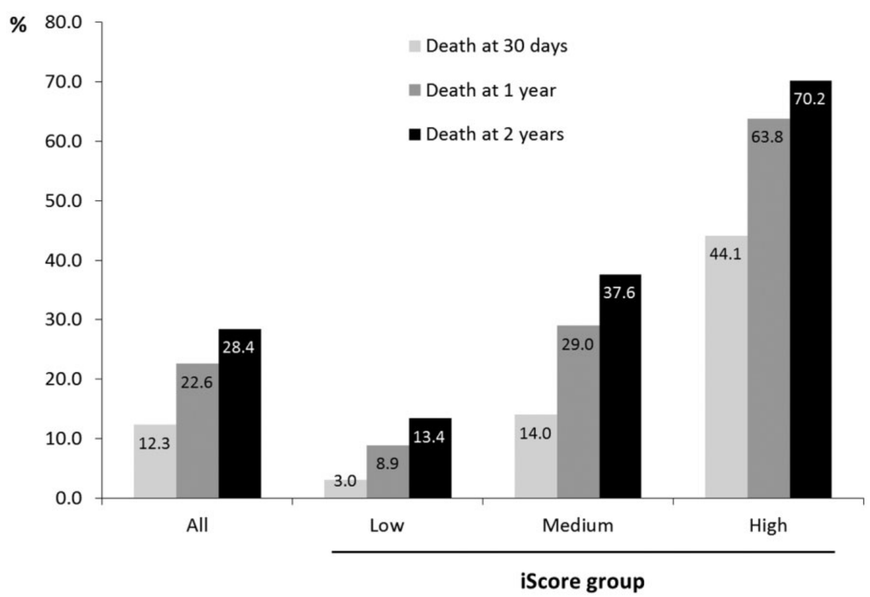

Fig. 2 Mortality at different points in time by iScore strata.

higher in the high-risk group compared with the medium-risk group ($120 354 vs. $82 021; $P < 0{\cdot}001$). Nevertheless, the average total cost among survivors in the medium-risk group ($150 754 598) double the total costs of survivors in the high-risk group ($ 75 100 896).

Adjusted mean costs: regression analyses

The iScore as a continuous variable

When the iScore was treated as a continuous variable, it was found to be an independent predictor of costs at 30 days, one-year, and

Table 2 Unadjusted mean costs at 30 days, one-year, and two-years by risk group

Cost	iScore group				
	All	Low (≤139)	Medium (140–179)	High (≥180)	*P* value
30-day costs					
Inpatient hospitalizations	$8 424·03	$6 590·05	$10 282·06	$12 508·32	<·001
Emergency department visits	$708·68	$705·79	$725·64	$695·35	0·0037
ODB drugs	$91·34	$99·12	$92·00	$62·03	<·001
Rehabilitation services	$772·22	$858·98	$846·38	$351·05	<·001
Complex continuing care	$96·02	$65·94	$135·66	$150·16	<·001
Long-term care	$65·76	$22·64	$103·26	$170·45	<·001
Homecare services	$131·11	$131·40	$146·55	$108·30	0·0008
Physician services	$1 383·65	$131·43	$1 556·54	$1 576·11	<·001
Other costs	$30·39	$33·80	$27·95	$21·35	<·001
Total cost	$13 029·47	$9 859·54	$15 397·02	$17 138·55	<·001
One-year costs					
Inpatient hospitalizations	$15 384·83	$11 476·23	$19 168·35	$21 631·81	<·001
Emergency department visits	$1 034·53	$1 035·36	$1 098·37	$941·74	<·001
ODB drugs	$1 445·01	$1 516·31	$1 604·90	$959·74	<·001
Rehabilitation services	$4 810·17	$4 577·23	$6 596·84	$3 148·08	<·001
Complex continuing care	$3 785·56	$1 921·94	$6 740·35	$6 435·59	<·001
Long-term care	$2 165·36	$1 267·73	$3 390·22	$3 720·76	<·001
Homecare services	$1 331·01	$1 121·17	$1 921·68	$1 266·58	<·001
Physician services	$3 162·15	$3 114·57	$3 504·04	$2 854·39	<·001
Other costs	$412·45	$444·48	$426·71	$275·47	<·001
Total cost	$36 130·82	$29 491·27	$47 811·09	$43 949·72	<·001
Two-year costs					
Inpatient	$17 840·45	$14 445·56	$22 629·69	$23 502·58	<·001
Emergency department visits	$1 305·47	$1 325·15	$1 394·85	$1 107·85	<·001
ODB drugs	$2 889·95	$3 056·63	$3 167·24	$1 891·31	<·001
Rehabilitation Services	$5 098·99	$4 897·65	$6 894·06	$3 309·69	<·001
Complex continuing care	$5 707·83	$2 996·17	$10 067·63	$9 478·82	<·001
Long-term care	$4 789·49	$3 038·26	$7 387·61	$7 530·76	<·001
Homecare services	$2 342·19	$1 983·01	$3 365·74	$2 214·37	<·001
Physician services	$4 307·91	$4 421·46	$4 631·12	$3 436·92	<·001
Other costs	$770·88	$827·81	$803·62	$516·97	<·001
Total cost	$49 203·51	$41 268·50	$64 785·91	$56 264·18	<·001

Other costs include those costs for outpatient laboratory testing, same-day surgeries, and nonphysician costs. ODB, Ontario Drug Benefit.

two-years after adjusting for covariates. Overall, for all patients in the cohort, a 10-point increase in the iScore was found to result in 8·2%, 6·7%, and 4·2% increases in patient's total costs at each respective time-point (Table 3) (*P* values <0·0001; *P* value for costs at 30 days in the high-risk iScore group = 0·038).

For patients in the low-risk group, a 10-point increase in iScore was associated with a 10·7%, 12·5%, and 11·8% increase in total costs at 30 days, one-year, and two-years from their initial AIS (*P* value < 0·0001). A 10-point increase in iScore was associated with 8·4%, 6·7%, and 3·8% increases in total cost for patients at medium risk at each time-point (*P*-value < 0·0001), while the same 10-point increase in iScore resulted in reductions in total cost of 1·6%, 7·8%, and 10·8% for patients at high risk (Table 3).

The iScore as a categorical variable

iScore risk group was found to be an independent predictor of total patient healthcare cost at each time-point (*P* value < ·0001). At 30 days, patients in the medium and high-risk groups had costs 48·8% and 66% higher than the patients in the low-risk group, respectively (*P* value < ·0001). At both one-year and two-years, patients in the medium-risk group were found to have the highest total costs, having costs 59·5% and 50·2% greater than patients in the low-risk group (*P* value < ·0001), while patients in the high-risk group had total costs 42·0% and 16·3% greater than patients in the low-risk group (Table 4) (*P* value < ·0001).

Discussion

Stroke care is resource intensive and a costly medical condition. Direct costs associated with stroke were found to consume up to 4% of third-party payers' total healthcare budgets (15,16). A better understanding of the expected immediate costs after surviving an initial ischemic event would allow decision makers to allocate scarce healthcare dollars more efficiently. The use of clinical prognostic scores (such as the iScore) may be a way for estimating (at the time of admission) subsequent short-term and long-term healthcare costs incurred by third-party payers. Having an understanding as to which components of costs represent significant cost drivers also fosters opportunities for innovation, as the knowledge of the areas where patients incur the greatest costs allows decision makers to highlight services or areas of need

Table 3 Results of multiple regression of cost with iScore as a continuous variable at 30 days, one-year, and two-years

	Estimate	Standard error	*t*-Value	*P* value
30-day cost				
All				
Intercept	8·61	0·051	170·22	<·0001
iScore	0·0082	0·0002	33·74	<·0001
Low risk (iScore ≤ 139)				
Intercept	8·43	0·072	117·83	<·0001
iScore	0·011	0·0006	17·29	<·0001
Medium risk (iScore 140–179)				
Intercept	8·86	0·23	39·1	<·0001
iScore	0·0084	0·0013	6·61	<·0001
High risk (iScore ≥ 180)				
Intercept	10·73	0·2	53·54	<·0001
iScore	–0·0016	0·0008	–2·07	0·0388
One-year cost				
All				
Intercept	9·09	0·059	154·53	<·0001
iScore	0·0067	0·0003	24·1	<·0001
Low risk (iScore ≤ 139)				
Intercept	8·66	0·074	117·5	<·0001
iScore	0·013	0·0006	19·69	<·0001
Medium risk (iScore 140–179)				
Intercept	9·84	0·27	36·31	<·0001
iScore	0·0067	0·0015	4·44	<·0001
High risk (iScore ≥ 180)				
Intercept	12·8	0·28	45·62	<·0001
iScore	–0·0078	0·0011	–7·05	<·0001
Two-year cost				
All				
Intercept	9·31	0·061	152·41	<·0001
iScore	0·0042	0·0003	14·71	<·0001
Low risk (iScore ≤ 139)				
Intercept	8·73	0·073	119·75	<·0001
iScore	0·012	0·0006	18·77	<·0001
Medium risk (iScore 140–179)				
Intercept	10·25	0·29	35·75	<·0001
iScore	0·0038	0·0016	2·39	0·017
High risk (iScore ≥ 180)				
Intercept	13·53	0·31	44·22	<·0001
iScore	–0·0108	0·0012	–9·08	<·0001

The parameter estimate represents the percentage change in total cost due to a one-point increase in iScore. All models were adjusted for age, gender, stroke severity, cohabitation status, rural status, and survival status for the variation of a one-point change in the iScore. The full model results can be found in Table S2.

Table 4 Results of multiple regression of cost with iScore as a categorical variable at 30 days, one-year, and two-years

Parameter	Estimate	Standard error	*t*-Value	*P* value
30-day cost				
Intercept	9·134	0·052	176·54	<·0001
Medium risk	0·488	0·02	23·9	<·0001
High risk	0·66	0·026	25·34	<·0001
Low risk	0			
One-year cost				
Intercept	9·522	0·059	161·4	<·0001
Medium risk	0·595	0·023	25·41	<·0001
High risk	0·42	0·03	14·15	<·0001
Low risk	0			
Two-year cost				
Intercept	9·567	0·061	157·37	<·0001
Medium risk	0·502	0·024	20·84	<·0001
High risk	0·163	0·03	5·42	<·0001
Low risk	0			

The parameter estimate represents the percentage change in total cost compared with patients in the low-risk group. All models were adjusted for age, gender, stroke severity, cohabitation status, rural status, and survival status for the variation of a one-point change in the iScore. The full model results can be found in Table S3.

where the implementation of new technologies or models of care could be introduced in an effort to reduce costs.

In the present study, we found that the 30-day unadjusted total healthcare costs were greatest among patients at high risk of death and disability as determined by the iScore; however, patients at medium risk had the highest healthcare costs at both one-year and two-year time-points. This increase in the total costs of the medium-risk group patients was due to these patients incurring substantially more rehabilitation services, complex continuing care, long-term care costs, and homecare costs than those patients in the high-risk group. This may be reflective of a limited number of treatment options available for patients at high risk due to the severity of their condition after their AIS. Moreover, the higher mortality of patients in the high-risk iScore strata (44% of patients died within 30 days and 70% within two-years) likely explains the lower use of resources and lower overall costs of this group.

Inpatient hospitalization costs represented the single highest component cost at all three time-points, with hospitalization costs increasing modestly over time. Hospitalization costs were greatest in those patients at high risk, likely reflecting the increased severity of their initial ischemic event. In addition to hospitalization costs, other significant costs included those incurred for physician services, complex continuing care, long-term care, physician services, and rehabilitation services.

Our findings are consistent with the findings of other cost studies conducted in this patient population (3,17). A study by Mittmann *et al.*, also conducted in Ontario, Canada, found inpatient hospitalization costs to be the major cost driver, representing approximately 46·8% of all costs incurred within the first three-months after an AIS (3). Another study which examined the direct healthcare costs of patients in 13 countries after experiencing a stroke also found inpatient hospitalization costs to be the greatest cost driver, accounting for 70% of patient's total costs, with rehabilitation, nursing care, and homecare costs being other significant cost drivers (17).

When we examined the impact of the iScore on patient's total healthcare costs adjusting for important patient characteristics, a 10-point increase in the iScore (a minimally important clinical difference) resulted in increases in total cost of approximately 8%, 7%, and 4% at 30 days, one-year, and two-years, respectively. The impact of the 10-point change in patients' iScore was found to affect each different risk groups' total costs differently over time. A 10-point increase in a patient's iScore resulted in subsequent increased healthcare costs for patients in the low and medium-risk groups, while resulting in reduced total costs for patients at high risk.

The impact of a change in iScore was also found to change over time. Patients in the low-risk group experienced a consistent approximately 12% increase in their total cost over time, while patients in the medium-risk group, increasing iScore, led to an 8% increase in total cost within the first 30 days, and dropped to a 4% increase at total costs. However, for patients in the high-risk group, a 10-point increase in iScore was associated with a steady reduction in total healthcare cost over time. These patients had the highest 30-day costs due to the severity of their AIS; however they have lower one-year and two-year healthcare costs as they may not survive this long, therefore having less opportunity to be re-hospitalized or receive long-term care. Another possible reason for this decrease is that high-risk patients' costs may be related to the lower utilization of costly resources whose use may be futile in improving a patient's condition, as well as due to a higher proportion of deaths.

We also investigated the differences in total healthcare costs among the three risk groups after adjusting for patient characteristics. Patients at high risk were found to have the highest total cost after the initial 30 days, with their cost being approximately 66% greater than patients at low risk. However, at both the one-year and two-year time-points, patients at medium risk were found to have the highest overall costs. Our manuscript provides evidence that a clinical risk score applied early after hospitalization may help predict short and long-term healthcare costs (in addition to clinical outcomes). Moreover, highest expenses are driven by the medium- risk group likely due to higher survival and need for specialized care (e.g., rehabilitation interventions) to maximize the opportunity for recovery, and its associated higher likelihood of community reengagement and productivity.

Our study has some limitations that deserve comment. First, it is possible that some potentially relevant variables (infract size and location, imaging information) not included in the initial iScore may impact treatment options and thus have an impact on subsequent patient costs; however, resources utilization (e.g., neuro-imaging, complementary studies) was accounted for in this analysis. Second, considering worldwide differences in healthcare systems and payments, caution is advised about generalizing our results.

Finally, we cannot rule out the possibility of residual confounding when evaluating the variables included in our analysis on influencing total healthcare costs. However, this study features near complete follow-up for all patients in our cohort, as well as the ability to examine relevant clinical factors influencing stroke outcomes on comprehensive patient healthcare costs.

In conclusion, the iScore is a validated risk prognostic score that can be easily applied early on after hospitalization to predict not only clinical outcomes after an AIS, but also healthcare costs. Overall, a 10-point increase in a patient's iScore resulted in increased total healthcare costs at 30 days, one-year and two-years after their initial AIS. The iScore showed differential impacts of healthcare costs between risk groups over time, with a 10-point iScore increase resulting in increasing total healthcare costs for patients at low and medium risk of death and disability, resulting in reduced healthcare cost for patients at high risk. Our results have health policy implications when considering 'by pass', 'drip-and-ship', and repatriation protocols as major healthcare costs are upfront in the first days after an AIS. Adjustments to hospital reimbursements may be needed depending on the allocation of resources to tertiary stroke centers. Further studies are being conducted to confirm our findings in other healthcare systems and hospital settings. This information can be used by case managers, health administrators, policy makers, and clinicians when discussing the discharge planning and implementing strategies to improve healthcare delivery for stroke patients.

Authors' contributions

Drs. Ewara, Wanrudee, Bravata, Williams, Fang, Hoch, and Saposnik made intellectual contributions (data interpretation and writing) to the manuscript.

Drs. Ewara, Wanrudee, Hoch, and Saposnik were responsible for the design of the study.

Drs. Ewara, Wanrudee, Hoch, and Saposnik conducted the literature review.

Dr. Fang conducted the statistical analysis.

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J. F. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. This table summarizes the iScore scoring system.

Table S2. This table summarizes the results of the multivariable regression model with the iScore as a continuous variable.

Table S3. This table summarizes the results of the multivariable regression model with the iScore as a categorical variable.