Temporal Trends in Case Fatality, Discharge Destination, and Admission to Long-term Care After Acute Stroke

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Abstract

Objective
To determine contemporary trends in case fatality, discharge destination, and admission to long-term care after acute ischemic stroke and intracerebral hemorrhage (ICH) using a large, population-based cohort.

Methods
We used linked administrative data to identify all emergency department visits and hospital admissions for first-ever ischemic stroke or ICH in Ontario, Canada, from 2003 to 2017. We calculated crude and age-/sex-standardized risk of death at 30 days and 1 year from stroke onset. We stratified crude trends by stroke type, age, and sex and used the Kendall $\tau$-b correlation coefficient to evaluate the significance of trends. We determined trends in discharge home and to rehabilitation and admission to long-term care at 1 year. We used Cox proportional hazard and logistic regression models to assess whether trends in outcomes persisted after adjustment for baseline factors, estimated stroke severity, and use of life-sustaining care.

Results
There were 163,574 people with acute ischemic stroke or ICH across the study period. Between 2003 and 2017, age-/sex-standardized 30-day stroke case fatality decreased from 20.5% to 13.2% (7.3% absolute and 36% relative reduction) while that at 1 year decreased from 32.2% to 22.8% (9.3% absolute and 29% relative reduction). Findings were consistent across age, sex, and stroke type, and after adjustment for comorbid conditions, stroke severity, and use of life-sustaining care. There was a reduction in long-term care admission after ischemic stroke and an increase in discharge home or to rehabilitation for both stroke types.

Conclusion
We observed substantial reductions in acute stroke case fatality from 2003 to 2017 with a concurrent increase in discharge to home or rehabilitation and a decrease in long-term care admissions, suggesting continuous improvements in stroke systems of care.
Stroke is the 2nd leading cause of death and 3rd leading cause of disability worldwide.1,2 Numerous studies have identified a global decrease in mortality from stroke in developed countries over the past 30 years.2,3,7 Although stroke mortality in a population can be attributable to reduced stroke incidence or reduced stroke case fatality, there is widespread evidence of decreasing case fatality after acute ischemic stroke.8-16 However, areas of uncertainty remain with regard to temporal trends in stroke case fatality. First, changes in case fatality after intensive care unit (ICU) admission or life-sustaining procedures may influence case fatality,17,18 but are typically not accounted for in studies of trends. Third, aggressive care focused on reducing early case fatality poststroke may create a trade-off by delaying death at the expense of severe disability and need for long-term care in a nursing home or complex care facility.23,24

We undertook a comprehensive and contemporary 15-year assessment of trends in acute stroke case fatality, discharge destination, and long-term care admission in Ontario, Canada, from 2003 to 2017 using population-based administrative health data, stratifying by stroke type, age, and sex, and accounting for changes in baseline characteristics and use of life-sustaining care.

**Methods**

**Setting**

The province of Ontario is Canada’s most populous province, with an adult population of approximately 11 million in 2017. The province has universal health care for residents, covering all costs for hospitalizations and emergency department (ED) visits.

**Study Sample and Data Sources**

The datasets used were linked using unique encoded identifiers and analyzed at ICES (formerly known as the Institute for Clinical Evaluative Sciences). We used the Canadian Institutes for Health Information (CIHI) Discharge Abstract Database to identify hospital admissions and the CIHI–National Ambulatory Care Reporting System to identify ED visits for acute ischemic stroke or ICH in Ontario between fiscal years 2003 (starting April 1, 2003) and 2017 (ending March 31, 2018) using International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada (ICD-10-CA) codes (ischemic stroke: I63.x [excluding I63.6], I64.x, H34.1; ICH: I61.x). These codes have excellent positive predictive value for stroke in Canada.25 All ED visits and admissions to hospital are included in these databases in Ontario by law. We excluded patients with subarachnoid hemorrhage or cerebral venous sinus thrombosis because of differing disease pathophysiology, risk factors, and care pathways. We excluded patients <18 or >104 years of age, with elective admissions, with in-hospital stroke, or with death before arrival to the ED. We excluded any individuals with prior stroke in a 12-year washout period between 1991 and 2002 (using ICD-10-CA codes above, I60 [subarachnoid hemorrhage], and ICD-9 codes 430, 431, 434, and 436).

We used the Registered Persons Database (RPDB) to obtain age (stratified as <60, 60–79 and ≥80 years), sex, and ethnicity (Chinese or South Asian) using a validated surname algorithm.26 The RPDB was also used to identify all-cause case fatality. CIHI was used to obtain the Charlson comorbidity index27 (categorized as <2 and ≥2) and intensive care unit admission. The Canadian Classification of Interventions was used to obtain instances of mechanical ventilation, percutaneous feeding tube insertion, or tracheostomy (data available from Dryad, table e-1, doi.org/10.5061/dryad.z34tmgpc7). The Canada Censuses was used to provide information on median neighborhood income and the Statistics Canada Postal Code Conversion File to provide area of residence (rural, defined as residing in a small town with population <10,000 and outside commuting zone of metropolitan areas, or urban). The National Rehabilitation Reporting System was used to identify discharges to inpatient rehabilitation. The Ontario Drug Benefits Database, the physician claims database, and ICES-specific registries (data available from Dryad, table e-2, doi.org/10.5061/dryad.z34tmgpc7) were used to obtain data on prior residence in long-term care, incident long-term care admission at 1 year after stroke, and comorbidities, including atrial fibrillation, hypertension, hyperlipidemia, diabetes, congestive heart failure, and chronic obstructive pulmonary disease, using validated algorithms. These linked administrative databases were also used to estimate stroke severity for hospitalized patients using the validated Passive Surveillance Stroke Severity Indicator, with estimated stroke severity categorized as mild, moderate, or severe using previously published thresholds.28 When estimating stroke severity, we excluded the Canadian Triage and Acuity Scale variable due to a large increase in emergency

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**Glossary**

aHR = adjusted hazard ratio; CI = confidence interval; CIHI = Canadian Institutes for Health Information; ED = emergency department; HR = hazard ratio; ICD-9 = International Classification of Diseases–9; ICD-10-CA = International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada; ICH = intracerebral hemorrhage; ICU = intensive care unit; RPDB = Registered Persons Database.
trriage for acute stroke over time, most likely driven by changes in stroke systems of care.

**Outcomes**

Our primary outcome was 30-day stroke case fatality, measured from the date of admission or ED visit for the index stroke. Secondary outcomes were 1-year case fatality after the index stroke, discharge home or to rehabilitation from acute care, and admission to long-term care within 1 year after acute care discharge.

### Table 1: Baseline Characteristics of People With Acute Ischemic Stroke and Intracerebral Hemorrhage (ICH) for 2003 and 2017

| Variable                              | Ischemic stroke | ICH |
|---------------------------------------|-----------------|-----|
|                                       | 2003 (8,967 events) | 2017 (11,812 events) | p Trend* |
| Age, y                                | 74.22 ± 12.84   | 73.16 ± 13.96   | 71.97 ± 14.08   | 71.70 ± 14.56 |
| 18–59                                 | 1,257 (14.0)    | 2,049 (17.3)    | <0.001          | 248 (18.7)     | 327 (19.7)     | 0.16 |
| 60–79                                 | 4,209 (46.9)    | 5,328 (45.1)    | <0.001          | 614 (46.2)     | 767 (46.1)     | 0.15 |
| 80+                                   | 3,501 (39.0)    | 4,435 (37.5)    | 0.08            | 466 (35.1)     | 570 (34.3)     | 0.85 |
| Women                                 | 4,542 (50.7)    | 5,680 (48.1)    | <0.001          | 666 (50.2)     | 771 (46.3)     | 0.01 |

| Variable                              | Ischemic stroke | 2017 (11,812 events) | p Trend* |
|---------------------------------------|-----------------|----------------------|----------|
| Estimated stroke severity             |                 |                      |          |
| Mild                                  | 3,560 (48.9)    | 4,910 (50.0)         | 0.14     | 415 (33.6)     | 588 (38.2)     | 0.02 |
| Moderate                              | 3,513 (48.2)    | 4,616 (47.0)         | 0.06     | 591 (47.9)     | 680 (44.2)     | 0.03 |
| Severe                                | 210 (2.9)       | 303 (3.1)            | 0.28     | 229 (18.5)     | 271 (17.6)     | 0.88 |
| Ethnicity Chinese or South Asian      | 297 (3.3)       | 635 (5.4)            | <0.001   | 74 (5.6)       | 147 (8.8)      | <0.001 |
| Lowest 2 income quintiles             |                 |                      |          |
| Hypertension                          | 2,666 (28.0)    | 3,286 (27.9)         | <0.001   | 393 (28.1)     | 471 (28.2)     | 0.18 |
| Diabetes                              | 1,286 (14.0)    | 1,669 (14.1)         | <0.001   | 173 (12.5)     | 211 (12.9)     | <0.001 |
| Dyslipidemia                          | 1,276 (14.0)    | 1,742 (14.7)         | <0.001   | 170 (12.0)     | 204 (12.3)     | <0.001 |
| CHF                                   | 1,234 (14.0)    | 1,474 (12.4)         | <0.001   | 162 (11.9)     | 204 (12.3)     | <0.001 |
| COPD                                  | 1,249 (14.0)    | 1,486 (12.5)         | <0.001   | 160 (11.9)     | 204 (12.3)     | <0.001 |
| Charlson score 2+                     | 1,270 (14.0)    | 1,620 (13.8)         | <0.001   | 170 (12.0)     | 204 (12.3)     | <0.001 |
| Care at a regional stroke center      | 1,234 (14.0)    | 1,474 (12.4)         | <0.001   | 162 (11.9)     | 204 (12.3)     | <0.001 |
| Admission to intensive care unit      | 1,276 (14.0)    | 1,742 (14.7)         | <0.001   | 170 (12.0)     | 204 (12.3)     | <0.001 |
| Mechanical ventilation                | 1,249 (14.0)    | 1,486 (12.5)         | <0.001   | 160 (11.9)     | 204 (12.3)     | <0.001 |
| Percutaneous feeding tube             | 1,270 (14.0)    | 1,620 (13.8)         | <0.001   | 170 (12.0)     | 204 (12.3)     | <0.001 |
| Tracheostomy                          | 1,234 (14.0)    | 1,474 (12.4)         | <0.001   | 162 (11.9)     | 204 (12.3)     | <0.001 |

**Analysis**

For baseline characteristics, we determined crude rates for categorical variables and means for continuous variables. For categorical variables, we used the Cochran-Armitage test to determine whether there were changes in binomial proportions over the fiscal years of the study, and for continuous variables, we used linear regression to compare changes in means over the study period.

We calculated crude case fatality by dividing the number of deaths within 30 days or 1 year after the index stroke by the
number of individuals with stroke in that year. We stratified 30-day case fatality by stroke type (ischemic stroke or ICH) and by age and sex and used the Kendall $\tau$-b correlation coefficient to evaluate the significance of trends over time. We then computed the age-/sex-standardized risk of death for each fiscal year from 2003 to 2017 using the 2003 stroke population as standard, with 95% confidence intervals (CIs). We also evaluated temporal trends in discharge destination (home or rehabilitation) and 1-year long-term care admission after stroke.

In the subset of patients admitted to hospital, we used Cox proportional hazard models to determine whether trends in 30-day and 1-year case fatality persisted after adjustment for potential confounders. We obtained hazard ratios (HRs) for 30-day or 1-year case fatality per each additional year after 2003, with adjustment for age, sex, rural residence, income quintile, Charlson index, care at a regional stroke center, estimated stroke severity, and use of life-sustaining care (ICU admission, mechanical ventilation, tracheostomy, and feeding tube placement). We performed the same analysis to obtain cause-specific HRs for 1-year long-term care admission, accounting for the competing risk of death. Lastly, among those discharged alive, we performed logistic regression to obtain the adjusted odds ratio per year for discharge home or to rehabilitation, with adjustment for the same variables above.

We conducted 2 sensitivity analyses for the 30-day and 1-year case fatality models. In the first sensitivity analysis, we added variables to the model in a stepwise fashion to assess whether the association between year and outcome was altered at any step, as follows: (1) year only; (2) year, age, and sex; (3) year, age, sex, income quintile, Charlson group, rural residence, and care at a regional stroke center; (4) variables listed in 3 plus estimated stroke severity; (5) variables listed in 3 plus life-sustaining care (ICU admission, mechanical ventilation, feeding tube, and tracheostomy); and (6) full model with all variables as reported in main analysis. In the second sensitivity analysis, to evaluate the effect of change in comorbidities over time, we removed the Charlson score from the full model and added the following variables: hypertension, diabetes, dyslipidemia, congestive heart failure, chronic obstructive pulmonary disease, coronary artery disease, and atrial fibrillation.

Analyses were conducted at ICES using SAS/STAT 14.3 (Cary, NC).
Table 2  Crude and Age-/Sex-Standardized Risk of 30-Day and 1-Year Case Fatality in Representative Years 2003, 2010, and 2017

| Outcome and fiscal year | Observed events | Number of strokes | Crude risk per 100 | Standardized risk per 100 (LCL, UCL) |
|-------------------------|----------------|------------------|-------------------|----------------------------------|
| **30-Day risk of death** |                |                  |                   |                                  |
| All strokes             |                |                  |                   |                                  |
| 2003                    | 2,110          | 10,295           | 20.5              | 20.5 (19.7, 21.3)                |
| 2010                    | 1,640          | 10,105           | 16.2              | 16.5 (15.7, 17.2)                |
| 2017                    | 1740           | 13,476           | 12.9              | 13.2 (12.6, 13.8)                |
| Absolute Δ from 2003 to 2017 |            |                  |                   | -7.6%                           |
| Relative Δ from 2003 to 2017 |            |                  |                   | -37.0%                          |
| Kendall τ-b correlation coefficient; p value |            |                  |                   | τ-b ~0.94; p < 0.001 |
| Ischemic stroke         |                |                  |                   |                                  |
| 2003                    | 1,508          | 8,967            | 16.8              | 16.8 (16.1, 17.6)                |
| 2010                    | 1,199          | 8,854            | 13.5              | 13.8 (13.0, 14.5)                |
| 2017                    | 1,231          | 11,812           | 10.4              | 10.7 (10.2, 11.4)                |
| Absolute Δ from 2003 to 2017 |            |                  |                   | -6.4%                           |
| Relative Δ from 2003 to 2017 |            |                  |                   | -38.0%                          |
| Kendall τ-b correlation coefficient; p value |            |                  |                   | τ-b ~0.96; p < 0.001 |
| ICH                     |                |                  |                   |                                  |
| 2003                    | 602            | 1,328            | 45.3              | 45.3 (42.7, 48.0)                |
| 2010                    | 441            | 1,251            | 35.3              | 35.9 (33.2, 38.5)                |
| 2017                    | 509            | 1,664            | 30.6              | 30.8 (28.6, 33.0)                |
| Absolute Δ from 2003 to 2017 |            |                  |                   | -14.7%                          |
| Relative Δ from 2003 to 2017 |            |                  |                   | -32.5%                          |
| Kendall τ-b correlation coefficient; p value |            |                  |                   | τ-b ~0.81; p < 0.001 |
| **1-Year risk of death** |                |                  |                   |                                  |
| All strokes             |                |                  |                   |                                  |
| 2003                    | 3,310          | 10,295           | 32.2              | 32.2 (31.3, 33.0)                |
| 2010                    | 2,706          | 10,105           | 26.8              | 27.2 (26.3, 28.0)                |
| 2017                    | 3,004          | 13,476           | 22.3              | 22.8 (22.1, 23.5)                |
| Absolute Δ from 2003 to 2017 |            |                  |                   | -9.9%                           |
| Relative Δ from 2003 to 2017 |            |                  |                   | -30.7%                          |
| Kendall τ-b correlation coefficient and p value |            |                  |                   | τ-b ~0.98; p < 0.001 |
| Ischemic stroke         |                |                  |                   |                                  |
| 2003                    | 2,583          | 8,967            | 28.8              | 28.8 (27.9, 29.7)                |
| 2010                    | 2,722          | 8,854            | 24.0              | 24.3 (23.5, 25.2)                |
| 2017                    | 2,348          | 11,812           | 19.9              | 20.5 (19.8, 21.2)                |
| Absolute Δ from 2003 to 2017 |            |                  |                   | -8.9%                           |
| Relative Δ from 2003 to 2017 |            |                  |                   | -31.0%                          |
| Kendall τ-b correlation coefficient and p value |            |                  |                   | τ-b ~0.94; p < 0.001 |

Continued
### Table 2 Crude and Age-/Sex-Standardized Risk of 30-Day and 1-Year Case Fatality in Representative Years 2003, 2010, and 2017 (continued)

| Outcome and fiscal year | Observed events | Number of strokes | Crude risk per 100 | Standardized risk per 100 (LCL, UCL) |
|-------------------------|------------------|------------------|-------------------|-------------------------------------|
| ICH                     |                  |                  |                   |                                     |
| 2003                    | 727              | 1,328            | 54.7              | 54.7 (52.2, 57.3)                   |
| 2010                    | 584              | 1,251            | 46.7              | 47.3 (44.6, 50.0)                   |
| 2017                    | 656              | 1,664            | 39.4              | 39.7 (37.4, 42.0)                   |
| Absolute Δ from 2003 to 2017 |                 |                  | −15.3%            | −15.1%                              |
| Relative Δ from 2003 to 2017 |                 |                  | −28.0%            | −27.6%                              |
| Kendall τ-b correlation coefficient and p value |                 |                  | r-b = 0.87; p < 0.001 |

Abbreviations: ICH = intracerebral hemorrhage; LCL = lower confidence limit; UCL = upper confidence limit.
* p Value for trend for all years from 2003 to 2017.

### Standard Protocol Approvals, Registrations, and Patient Consents

The use of data in this project was authorized under section 45 of Ontario’s Personal Health Information Protection Act, which does not require review by a research ethics board.

### Data Availability

The dataset from this study is held securely in coded form at ICES. Data sharing agreements prohibit ICES from making the dataset publicly available, but access may be granted to those who meet prespecified criteria for confidential access,

### Figure 2 Crude Rates of 30-Day and 1-Year Case Fatality for Age and Sex Subgroups of Ischemic Stroke and Intracerebral Hemorrhage (ICH) From 2003 to 2017

(A–C) 30-Day case fatality. (D–F) 1-Year case fatality. Kendall τ p value < 0.05 for all trends.
available at ices.on.ca/DAS. The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

**Results**

There were 163,574 people with acute stroke across the study period, comprising 20,328 (12.4%) with ICH and 143,246 (87.6%) with ischemic stroke (see table 1 for baseline characteristics). Between 2003 and 2017, there was an increase in the proportion of individuals aged <60 years in the ischemic stroke subgroup, and an increase in the proportion of people with hypertension and diabetes, as well as those receiving intensive care or mechanical ventilation in both the ischemic and ICH groups.

The age-/sex-standardized risk of death at 30 days decreased from 20.5% in 2003 to 13.2% in 2017 for all strokes (absolute decrease 7.3%, relative decrease 35.6%), from 16.8% to 10.7% for ischemic stroke (absolute decrease 6.1%, relative decrease 36.1%), and from 45.3% to 30.8% for ICH (absolute decrease 14.5%, relative decrease 32.0%) (figure 1 and table 2). Declines in 30-day and 1-year case fatality were seen across all age groups and in both women and men (figure 2).

Each increase in year after 2003 was associated with a lower 30-day hazard of death for both ischemic stroke and ICH and the HRs were virtually unchanged with sequential adjustment for demographics, comorbidity, and processes of care (fully adjusted HR [aHR] for ischemic stroke 0.95, 95% CI 0.95 to 0.96, and aHR for ICH 0.95, 95% CI 0.95 to 0.96; table 3 and table e-3 [data available from Dryad, doi.org/10.5061/dryad.z34tmpgc7]). Female sex was associated with higher case fatality after ischemic stroke (aHR 1.04, 95% CI 1.01 to 1.07) but lower case fatality after ICH (aHR 0.94, 95% CI 0.90 to 0.99). Older age, residence in a rural area, greater estimated stroke severity, and ICU care were associated with increased 30-day mortality after both ischemic stroke and ICH. Findings were similar for 1-year case fatality (data available from Dryad, table e-4, doi.org/10.5061/dryad.z34tmpgc7).

For both ischemic stroke and ICH, there was an increase in the proportion of people discharged to home and to rehabilitation over time (figure 3). In the fully adjusted models among those discharged alive, there was an increase in discharge to rehabilitation over time for both ischemic stroke and ICH and an increase in discharge home after ischemic stroke only (data available from Dryad, tables e-5 and e-6, doi.org/10.5061/dryad.z34tmpgc7). The rate of admission to long-term care within 1 year of index stroke decreased for those

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**Table 3** Multivariable Cox Regression Models for 30-Day Case Fatality for Patients Hospitalized With Acute Ischemic Stroke or Intracerebral Hemorrhage (ICH)

| Variable                                | Ischemic stroke |    | ICH |    |
|-----------------------------------------|-----------------|----|-----|----|
|                                        | aHR (LCL, UCL)  | p  | aHR (LCL, UCL) | p  |
| Fiscal year                             | 0.95 (0.95, 0.96) | <0.001 | 0.95 (0.95, 0.96) | <0.001 |
| Age group 60–79 y (vs <60)              | 1.83 (1.71, 1.96) | <0.001 | 1.80 (1.67, 1.93) | <0.001 |
| Age group 80+ y (vs <60)                | 4.25 (3.98, 4.54) | <0.001 | 2.81 (2.60, 3.04) | <0.001 |
| Female sex (vs male)                    | 1.04 (1.01, 1.07) | 0.01 | 0.94 (0.90, 0.99) | 0.01 |
| Lowest income quintile (vs highest)     | 1.04 (0.99, 1.09) | 0.09 | 1.03 (0.95, 1.11) | 0.5 |
| Charlson score 2+ (vs <2)               | 1.30 (1.26, 1.34) | <0.001 | 0.88 (0.84, 0.92) | <0.001 |
| Rural residence (vs urban)              | 1.32 (1.27, 1.38) | <0.001 | 1.27 (1.19, 1.37) | <0.001 |
| Care at a regional stroke centre        | 0.86 (0.83, 0.89) | <0.001 | 0.75 (0.72, 0.79) | <0.001 |
| ICU admission                           | 1.78 (1.71, 1.86) | <0.001 | 1.33 (1.25, 1.41) | <0.001 |
| Mechanical ventilation                  | 3.96 (3.68, 4.25) | <0.001 | 2.70 (2.49, 2.93) | <0.001 |
| Percutaneous feeding tube               | 0.33 (0.29, 0.36) | <0.001 | 0.13 (0.10, 0.16) | <0.001 |
| Tracheostomy                            | 0.27 (0.21, 0.34) | <0.001 | 0.23 (0.18, 0.29) | <0.001 |
| Moderate stroke (vs mild)               | 2.12 (2.04, 2.20) | <0.001 | 2.33 (2.17, 2.50) | <0.001 |
| Severe stroke (vs mild)                 | 3.40 (3.14, 4.68) | <0.001 | 4.27 (3.86, 4.72) | <0.001 |

Abbreviations: aHR = adjusted hazard ratio; ICU = intensive care unit; LCL = lower confidence limit; UCL = upper confidence limit.
with ischemic stroke over the study period, whereas for ICH there was an initial increase from 2003 to 2011 followed by a decrease from 2011 onward (figure 3). Each increase in year after 2003 was associated with a lower hazard of long-term care admission after ischemic stroke (aHR 0.96, 95% CI 0.96 to 0.96), but not after ICH (aHR 1.0, 95% CI 0.99 to 1.01). Older age, female sex, greater estimated stroke severity, Charlson score ≥ 2, feeding tube placement, and tracheostomy were associated with a higher hazard of long-term care admission for both stroke types (table 4).

**Discussion**

In this population-based study, we observed a dramatic reduction in short- and long-term case fatality between 2003 and 2017 after both acute ischemic stroke and ICH in Ontario, Canada. The decrease in case fatality was continuous, occurred in all subgroups, and persisted after adjustment for baseline factors, estimated stroke severity, and use of life-sustaining care. Over the same time period, there was an increase in the proportion of people discharged to home or rehabilitation, and, for those with ischemic stroke, a decrease in the proportion admitted to long-term care.

The observed temporal trends in case fatality for those with ischemic stroke are compatible with prior studies. However, previously published trends in ICH case fatality are less consistent, showing either stable or decreasing case fatality over time. Deferral or withdrawal of life-sustaining care predict short- and long-term mortality after ICH. Importantly, temporal trends in our study were unchanged after adjusting for ICU admission and life-sustaining procedures, indicating that case fatality reductions were not fully explained by changes in thresholds for use of life-sustaining care over time. We also showed that case fatality reductions persisted even after comprehensive adjustment for demographic and clinical characteristics and comorbid conditions, and improved in tandem with discharge destination and admission to long-term care.

Approximately one third of early deaths and poor outcomes in acute stroke are attributable to potentially modifiable early complications. Hyperacute therapies in acute stroke have improved functional outcomes, but randomized trials have not shown that thrombolysis reduces poststroke case fatality, and only 1 of 6 clinical trials demonstrated a reduction in mortality with endovascular thrombectomy. In addition, treatment rates are low and declines in case fatality in our study were occurring steadily well in advance of the widespread use of thrombectomy. In contrast, stroke unit care, established primarily in the early 2000s, has been shown to reduce the odds of death and long-term care admission, including in those with ICH. Integrated stroke systems and the use of guidelines and care processes have been associated with reductions in mortality over time. Establishing guidelines and routine processes of care have also been demonstrated to improve the use of evidence-based interventions and outcomes for hospitalized patients with ischemic stroke. Therefore, we suspect that general, broad

**Figure 3** Trends in Proportion of Acute Care Discharge to Home (Blue), Rehabilitation Facility (Red), or Admission to Long-term Care Facility at 1 Year After Stroke (Green) From 2003 to 2017 Among Patients With Ischemic Stroke and Intracerebral Hemorrhage (ICH)

(A) Ischemic stroke. (B) ICH. *Kendall \( \tau \) p value <0.05, indicating significant overall trend. For ICH long-term care admission, Kendall \( \tau \) p value = 0.001 for 2003–2011 and p = 0.003 for 2011–2017.
improvements in organized stroke care underlie the falling case fatality rate observed in this study.

Recent studies from South London, United Kingdom, and Chengdu, China, demonstrated decreases in both case fatality and functional dependence for patients with ischemic stroke from 2000 to 2016, although both studies were registry-based.\textsuperscript{14,45} In our population-based study we also observed a simultaneous reduction in both case fatality and the proportion of individuals admitted to long-term care after ischemic stroke, although there was no overall change in the rate of long-term care admission for ICH. These trends suggest that improvements in acute stroke care are not merely prolonging life at the expense of severe disability. Whereas long-term care admission at 1 year for those with ischemic stroke decreased over time, for those with ICH there was an initial increase from 2003 to 2011, followed by a decrease until 2017. The most pronounced decrease in case fatality after ICH was between 2003 and 2012, which may have initially resulted in a large increase in the number of patients with severe disability requiring long-term care. This is compatible with registry results from Dijon, France, demonstrating concurrent reductions in case fatality and increases in ambulatory disability in patients with ICH.\textsuperscript{46} However, ongoing improvements in stroke systems of care may have gradually improved functional outcomes among ICH survivors, especially after 2011, when the dissociation in trends between discharge to rehabilitation and admission to long-term care occurred.

The increase in discharge to rehabilitation and decrease in admission to long-term care after stroke may be driven by reduction in disability at discharge, or alternatively, greater access to rehabilitation services resulting in improved outcomes and lower need for full-time care in those with severe impairment. In November 2011, the Rehabilitation and Complex Continuing Care Expert Panel, commissioned by Ontario’s Ministry of Health and Long-Term Care, accepted multiple recommendations to improve stroke rehabilitation in Ontario, including more timely transfer of patients with stroke from acute facilities to rehabilitation, greater intensity therapy during inpatient rehabilitation, transfer of patients to inpatient rehabilitation rather than complex care facility for “slow-stream” rehabilitation, and timely access to outpatient/community-based rehabilitation for appropriate patients.\textsuperscript{47} Therefore, our observed changes may have been facilitated by increases in rehabilitation use post-2011, and are in the context of continuous improvements and integration of stroke systems of care in Ontario and Canada.\textsuperscript{29,43}

| Variable                               | Ischemic stroke aHR (LCL, UCL) | p Value | ICH aHR (LCL, UCL) | p Value |
|----------------------------------------|-------------------------------|---------|-------------------|---------|
| Fiscal year                            | 0.96 (0.96, 0.96)             | <0.001  | 1.00 (0.99, 1.01)  | 0.61    |
| Age group 60–79 (vs <60)               | 2.01 (1.89, 2.14)             | <0.001  | 1.49 (1.34, 1.66)  | <0.001  |
| Age group 80+ (vs <60)                 | 3.90 (3.68, 4.15)             | <0.001  | 2.13 (1.90, 2.38)  | <0.001  |
| Female sex (vs male)                   | 1.22 (1.19, 1.26)             | <0.001  | 1.20 (1.12, 1.29)  | <0.001  |
| Lowest income quintile (vs highest)    | 1.11 (1.06, 1.16)             | <0.001  | 1.10 (0.99, 1.23)  | 0.07    |
| Charlson score 2+ (vs <2)              | 1.44 (1.40, 1.48)             | <0.001  | 1.32 (1.23, 1.41)  | <0.001  |
| Rural residence (vs urban)             | 1.00 (0.96, 1.04)             | 0.97    | 0.89 (0.79, 0.99)  | 0.04    |
| Care at a regional stroke center       | 0.81 (0.79, 0.84)             | <0.001  | 0.97 (0.90, 1.04)  | 0.36    |
| ICU admission                          | 0.88 (0.84, 0.92)             | <0.001  | 0.75 (0.69, 0.82)  | <0.001  |
| Mechanical ventilation                 | 0.95 (0.85, 1.06)             | 0.33    | 0.77 (0.67, 0.89)  | <0.001  |
| Percutaneous feeding tube              | 3.43 (3.26, 3.62)             | <0.001  | 3.46 (3.08, 3.88)  | <0.001  |
| Tracheostomy                           | 1.53 (1.32, 1.79)             | <0.001  | 2.16 (1.82, 2.55)  | <0.001  |
| Moderate stroke (vs mild)              | 1.70 (1.65, 1.76)             | <0.001  | 1.64 (1.51, 1.78)  | <0.001  |
| Severe stroke (vs mild)                | 1.63 (1.46, 1.81)             | <0.001  | 1.21 (1.04, 1.41)  | 0.01    |

Abbreviations: aHR = adjusted hazard ratio; ICU = intensive care unit; LCL = lower confidence limit; UCL = upper confidence limit.
substantially higher risk of death at the end of the study period compared to those with ischemic stroke (30.8% vs 10.7% in 2017), as well as at higher risk of long-term care admission. These persistent differences support the urgent need for further therapies to improve outcome after ICH.

Our study has limitations. We used administrative coding to identify strokes and did not have imaging data. However, the codes used have high validity in Canada.23 We could not obtain a clinical stroke severity measure or measure of disability from administrative data. Instead, we were able to derive a validated estimate of stroke severity from administrative data and used long-term care admission as a surrogate of severe disability and care needs. We may have overestimated case fatality throughout the study period by not including outpatients diagnosed with minor stroke, although our main goal was to identify trends across time in acute stroke, and specificity is poor for outpatient claims.39 Increased detection of minor stroke over time in the ED and during hospitalization could have accounted for some of the observed reductions in case fatality, although this applies predominantly to ischemic stroke and would not explain the large reductions in ICH case fatality. In addition, the lower hazard of death over time persisted for both stroke types after adjustment for estimated stroke severity. Despite these limitations, our study is strengthened by reliable linkages, a large population with a single payer health care system, and complete ascertainment of events requiring hospitalization or ED care as well as incident long-term care admission.

Our study confirms ongoing substantial declines in case fatality for both acute ischemic stroke and ICH in the first 2 decades of the 21st century. The reductions were observed for all age groups and sexes, persisted after adjustment for baseline patient factors and use of life-sustaining interventions, and were not associated with an increase in long-term care admissions. Discharge to home and rehabilitation increased in tandem with case fatality reductions, supporting global improvements in stroke outcomes. Further work is warranted to ensure the trends continue into subsequent years and to determine the factors most responsible for these observed patterns.

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**Appendix**

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| Name                     | Location                                                                 | Contribution                                                                 |
|--------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Raed A. Joundi, MD, DPhil | Department of Clinical Neurosciences, Cumming School of Medicine, University of Calgary; ICES, Toronto | Drafting/revision of the manuscript for content, study concept or design, analysis or interpretation of data |
| Eric E. Smith, MD, MPH    | Department of Clinical Neurosciences, Cumming School of Medicine, University of Calgary | Drafting/revision of the manuscript for content, including medical writing for content, study concept or design, analysis or interpretation of data |
| Amy Y.X. Yu, MD, MSc      | ICES, Toronto; and the Department of Medicine, Division of Neurology, University of Toronto, Canada | Drafting/revision of the manuscript for content, including medical writing for content, study concept or design, analysis or interpretation of data |
| Mohammed Rashid, MSc      | ICES, Toronto                                                             | Major role in the acquisition of data; study concept or design, analysis or interpretation of data |
| Jiming Fang, PhD          | ICES, Toronto                                                             | Major role in the acquisition of data; study concept or design, analysis or interpretation of data |
| Moira K. Kapral, MD, MSc   | ICES, Toronto; General Internal Medicine, University of Toronto, Canada; Institute of Health Policy, Management, and Evaluation, University of Toronto, Canada | Drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data; study concept or design, analysis or interpretation of data |

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