Age-Specific and Sex-Specific Trends in Life-Sustaining Care After Acute Stroke

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BACKGROUND: Temporal trends in life-sustaining care after acute stroke are not well characterized. We sought to determine contemporary trends by age and sex in the use of life-sustaining care after acute ischemic stroke and intracerebral hemorrhage in a large, population-based cohort.

METHODS AND RESULTS: We used linked administrative data to identify all hospitalizations for acute ischemic stroke or intracerebral hemorrhage in the province of Ontario, Canada, from 2003 to 2017. We calculated yearly proportions of intensive care unit admission, mechanical ventilation, percutaneous feeding tube placement, craniotomy/craniectomy, and tracheostomy. We used logistic regression models to evaluate the association of age and sex with life-sustaining care and determined whether trends persisted after adjustment for baseline factors and estimated stroke severity. There were 137,358 people with acute ischemic stroke or intracerebral hemorrhage hospitalized during the study period. Between 2003 and 2017, there was an increase in the proportion receiving care in the intensive care unit (12.4% to 17.7%) and mechanical ventilation (4.4% to 6.6%). There was a small increase in craniotomy/craniectomy, a decrease in percutaneous feeding tube use, and no change in tracheostomy. Trends were generally consistent across stroke types and persisted after adjustment for comorbid conditions, stroke-center type, and estimated stroke severity. After adjustment, women and those aged ≥80 years had lower odds of all life-sustaining care, although the disparities in intensive care unit admission narrowed over time.

CONCLUSIONS: Use of life-sustaining care after acute stroke increased between 2003 and 2017. Women and those at older ages had lower odds of intensive care, although the differences narrowed over time. Further research is needed to determine the reasons for these findings.

Key Words: acute stroke ■ epidemiology ■ intensive care unit ■ temporal trends
Second, although there are no major disparities in the provision and quality of acute stroke care between age groups, the use of life-sustaining care has not been adequately studied by age in stroke. In a study of Canadian administrative data from 2003 to 2004, the rates of admission to ICU after stroke decreased with older age. Yet because of the projected dramatic increase in the number of people with stroke in North America from an aging population, a contemporary understanding of the association between age and aggressive care after stroke is needed. Third, little information is present on whether any age or sex-related disparities in aggressive care for stroke are changing over time. An evaluation of trends in ICU admission and life-sustaining procedures in the 20th century and whether disparities persist over time is important for resource and capacity planning and optimizing the quality of care for all patients with acute stroke.

We sought to evaluate temporal trends and the association of age and sex with life-sustaining care using administrative data from the entire population of the province of Ontario, Canada, from 2003 to 2017.

METHODS

Data Access

The data set from this study is held securely in coded form at ICES. Data sharing agreements prohibit ICES from making the data set publicly available, but access may be granted to those who meet prespecified criteria for confidential access, available at ices.on.ca/DAS. The full data set 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.

Study Sample and Data Sources

All patients with ischemic stroke and ICH admitted to an acute care hospital in Ontario, Canada between April 1, 2003 and March 31, 2018 were included. The province has universal health care for residents, covering all costs for hospitalizations and emergency department visits. The data sets 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 Discharge Abstract Database to ascertain cases of hospital admissions for acute stroke 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; ICH: I61.x). These codes have excellent positive predictive value for stroke in Canada, with positive predictive values of 97.3% for ischemic stroke and 91.9% for ICH. All admissions to the hospital are included in this database in Ontario by law with a waiver of consent. Patients with subarachnoid hemorrhage and cerebral venous sinus thrombosis were excluded. We excluded patients aged <18 or >104 years, those with elective admissions, and those with in-hospital stroke. We excluded any individuals with prior stroke in a 12-year period between 1991 and 2002 (including aforementioned ICD-10-CA codes and I60 [subarachnoid hemorrhage] and International Classification of Diseases, Ninth Revision [ICD-9] codes 430, 431, 434, and 436).

We used the Registered Persons Database to obtain age (divided into <60, 60–79 and ≥80 years). We chose the lower age threshold of 60 years as this is generally considered “stroke in the young” in line with recent randomized controlled trials and the upper threshold of age 80 years as it is a common threshold of elderly in stroke studies. The Canadian Institutes for Health

Nonstandard Abbreviations and Acronyms

| Abbreviation | Definition |
|--------------|------------|
| ICD-10-CA    | International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada |
| ICH          | intracerebral hemorrhage |
| PaSSV        | Passive Surveillance Stroke Severity Indicator |
| RPDB         | Registered Persons Database |
Information Discharge Abstract Database was used to obtain the Charlson comorbidity index, identify episodes of care in the ICU, and median days in the ICU. The Canadian Classification of Interventions was used to obtain instances of mechanical ventilation, percutaneous feeding tube, or tracheostomy (Table S1). Canada Census was used to provide information on median neighborhood income, and the Statistics Canada Postal Code Conversion File was used to provide area of residence (rural, defined as residing in a small town with population <10,000 and outside a commuting zone of metropolitan areas, or urban). The Ontario Drug Benefits Database, the physician claims database, and ICES-specific registries were used to obtain data on prior residence in long-term care and comorbidities, including atrial fibrillation, hypertension, hyperlipidemia, diabetes, congestive heart failure, and chronic obstructive pulmonary disease using validated algorithms (Table S2). These linked administrative databases were also used to estimate stroke severity for hospitalized patients using the validated Passive Surveillance Stroke Severity Indicator (PaSSV), with estimated stroke severity categorized as mild, moderate, or severe using previous published thresholds. When determining PaSSV, we excluded the Canadian Triage and Acuity Scale variable because of a large increase in emergency triage for acute stroke during the study period, most likely driven by changes in stroke systems of care.

Outcomes
Our primary outcome was receiving care in an ICU during the index admission for acute stroke. Our secondary outcomes were receipt of mechanical ventilation, percutaneous feeding tubes, tracheostomy, and craniotomy/craniectomy.

Statistical Analysis
All analyses were stratified by stroke type. We displayed crude rates for categorical variables and means for continuous variables. For categorical variables, we divided the study period into fiscal years and used the Cochran–Armitage test to determine whether there were changes in binomial proportions of baseline patient characteristics across the study period. For continuous variables, linear regression was used to compare changes in means, and median regression was used for medians. We evaluated trends in yearly proportions of all outcomes from 2003 to 2017 with the Cochran–Armitage test and stratified all outcomes by age and sex.

We used separate multivariable logistic regression models to determine whether temporal trends in ICU care, mechanical ventilation, percutaneous feeding tubes, and tracheostomy persisted after adjustment for potential confounders. We tested the linearity assumption for continuous covariates year and age using restricted cubic splines. The assumption was not satisfied for age, so we categorized age as <60, 60 to 79, and ≥80 years. We obtained the odds of each outcome per additional year since 2003, with adjustments for age, sex, rural residence, income quintile, Charlson index, care at a regional stroke center, and estimated stroke severity. We reported the adjusted odds ratios (AORs) for female sex and age groups from the same models. Lastly, for the primary outcome of ICU admission, we included interaction terms in the logistic model to assess for modification of trends over time by age (year×age) and sex (year×sex) and to assess whether the association of female sex with ICU admission is modified by age (age×sex).

We conducted multiple sensitivity analyses. First, to address the potential impact of early mortality on receipt of intensive care, the models for ICU admission were repeated excluding those who died within 72 hours of arrival to a hospital. Second, we repeated the trends analysis and models for ICU admission including those with prior stroke. Third, although practice in Ontario is variable, some patients may be admitted to a non-ICU, step-down unit after thrombolysis or thrombectomy. Therefore, we included step-down units in the definition of ICU. Fourth, we included hospital size as a variable in the model.

We computed the c-statistic as a measure of goodness of fit for all models. There were no missing data because of the complete capture of age, sex, and postal code, and the binary nature of administrative data coding indicating the presence or absence of a baseline characteristic or outcome. Analyses were conducted at ICES using SAS EG 7.1 (Cary, NC). 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.

RESULTS
There were 137,358 patients with acute stroke hospitalized during the study period, including 18,831 (13.7%) with ICH. Trends in baseline characteristics and use of life-sustaining care for the overall cohort are shown in Table 1 for the years 2003, 2010, and 2017. Throughout the study period, there was an increase in the proportion of individuals with acute stroke who were admitted to the ICU (12.4% in 2003 to 17.7% in 2017; P<0.001) and who received mechanical ventilation (4.4%–6.6%; P<0.001). The pattern of change was similar for ischemic stroke and ICH, although patients with ICH had substantially higher use of ICU care and mechanical ventilation throughout the study period (Figure). Women and those at older ages had lower crude rates of ICU care and mechanical ventilation for both stroke types, although the proportion receiving
ICU care and mechanical ventilation increased over time for all subgroups (Figure; Table S3). Among those admitted to the ICU, the days spent in the ICU did not change in the overall cohort (median, 2.0–2.0; P=0.8), decreased slightly for ischemic stroke (median, 2.0–1.9; P=0.005), and increased for ICH (median, 2.0–2.7; P<0.001).

Use of percutaneous feeding tubes decreased during the study period (3.7% to 2.5%; P<0.001), driven by a decrease in those with ischemic stroke (3.4% to 2.2%; P<0.001), with no significant change in those with ICH (5.7% to 4.4%; P=0.24; Table S3). Use of tracheostomy was uncommon and trended minimally upward for ischemic stroke (0.3%–0.5% for ischemic stroke; P=0.02), but not significantly for ICH (2.7%–3.1% for ICH; P=0.39). Craniotomy/craniectomy was also uncommon and increased from 0.1% to 0.3% in patients with ischemic stroke (P<0.001) and from 0.8% to 1.9% in patients with ICH (P<0.001). In the multivariable model, each year after 2003 was associated with higher odds of ICU admission for ischemic stroke (AOR, 1.04; 95% CI, 1.04–1.11), lower odds of feeding tube placement (AOR, 0.96; 95% CI, 0.96–0.97), and no change in tracheostomy use for ischemic stroke. The associations were similar for those with ICH (Table 2).

Female sex was associated with lower odds of ICU admission in ischemic stroke (AOR, 0.80; 95% CI, 0.77–0.84) and ICH (AOR, 0.81; 95% CI, 0.76–0.88; Table 2). This association was consistent in all age groups and after excluding those who died within 72 hours of arrival to hospital, except among those aged <60 years with ICH where the association was not significant (Tables S4 and S5). However, there was a significant interaction between year and sex (P interaction <0.001) for ischemic stroke, in which women had a greater increase in odds of ICU admission per year (AOR, 1.05; 95% CI, 1.05–1.06) compared with men (AOR, 1.04; 95% CI, 1.03–1.04), narrowing the gap in ICU admissions (Table S6; Figure [B]). Female sex was also associated with lower odds of mechanical ventilation (AOR, 0.57; 95% CI, 0.53–0.62), percutaneous feeding tube (AOR, 0.77; 95% CI, 0.72–0.82), and tracheostomy (AOR, 0.60; 95% CI, 0.50–0.71; Table 2).

Older age was associated with lower odds of ICU admission for ischemic stroke (AOR, 0.41 for

| Variable | Ischemic stroke or intracerebral hemorrhage | 2003 | 2010 | 2017 | P trend |
|----------|-------------------------------------------|------|------|------|---------|
| N        |                                           | 8518 | 8511 | 10 147 |         |
| Age, y   |                                           | 74.5±12.88 | 73.29±13.86 | 73.38±13.96 | <0.001 |
| 18–59 y  |                                           | 1143 (13.5) | 1453 (17.1) | 1913 (16.8) | <0.001 |
| 60–79 y  |                                           | 3935 (46.2) | 3673 (43.2) | 5088 (44.8) | 0.57    |
| ≥80 y    |                                           | 3435 (40.3) | 3385 (39.8) | 4367 (38.4) | <0.001 |
| Women    |                                           | 4329 (50.8) | 4392 (52.5) | 4342 (51.1) | <0.001 |
| PaSSV indicator* |                         | 3975 (46.7) | 3924 (46.1) | 5498 (48.4) | 0.02    |
| Mild     |                                           | 4104 (48.2) | 4130 (48.5) | 5296 (46.6) | 0.012   |
| Moderate |                                           | 439 (5.2) | 457 (5.4) | 574 (5.0) | 0.84    |
| Severe   |                                           | 3807 (44.7) | 3720 (43.7) | 5338 (47.0) | <0.001 |
| Rural residence |                                    | 1298 (15.2) | 1138 (13.4) | 1461 (12.9) | <0.001 |
| Hypertension |                                         | 6474 (76.0) | 6868 (80.7) | 9275 (81.6) | <0.001 |
| Diabetes |                                           | 2498 (29.3) | 2875 (33.8) | 4247 (37.4) | <0.001 |
| Dyslipidemia |                                       | 735 (8.6) | 868 (10.2) | 903 (7.9) | <0.001 |
| CHF      |                                           | 1224 (14.4) | 1044 (12.3) | 1205 (10.8) | <0.001 |
| Atrial fibrillation |                                   | 765 (9.0) | 936 (11.0) | 982 (8.6) | 0.89    |
| CAD      |                                           | 1288 (15.1) | 1378 (16.2) | 1743 (15.3) | 0.17    |
| Care at a regional stroke center |                        | 2021 (23.7) | 2065 (24.3) | 4661 (41.0) | <0.001 |

P for trends are for entire study period from 2003 to 2017. Data are provided as number, number (percentage), or mean±SD. CAD indicates coronary artery disease; CHF, congestive heart failure; and PaSSV, Passive Surveillance Stroke Severity Indicator.

*Estimated stroke severity (PaSSV indicator) was derived using linked administrative data. Mild PaSSV has an estimated National Institutes of Health Stroke Scale of <5, moderate PaSSV from 5 to <15, and severe PaSSV ≥15. Model for PaSSV from Table S7 in Yu et al.22
There was a significant interaction between year and age ($P_{interaction} < 0.001$), in which older individuals had greater increases in ICU admissions per year for ischemic stroke (AOR, 1.06 for those aged $\geq 80$ years; 1.04 for those aged 60–79 years; and 1.03 for those aged <60 years; Table S4), with a similar pattern for ICH. Older age was also associated with lower odds of mechanical ventilation (AOR, 0.26 for $\geq 80$ versus <60 years; 95% CI, 0.23–0.29) tracheostomy (AOR, 0.31 for $\geq 80$ versus <60 years; 95% CI, 0.24–0.41) and craniotomy/craniectomy (AOR 0.01 for $\geq 80$ versus <60 years; 95% CI, 0.01–0.03), but higher odds of feeding tube placement (AOR, 1.56 for $\geq 80$ versus <60 years; 95% CI, 1.38–1.76) after ischemic stroke. The pattern was similar for ICH with the exception of lower odds of feeding tube insertion in the oldest age group (Table 2).

When incorporating those with prior stroke, the percentage of patients with multiple ICU admissions after recurrent stroke during the study period was 1.5% for ischemic stroke and 1.0% for ICH. The associations of year, sex, and age with ICU admission were consistent when including those with prior stroke (Table S7). The associations were also similar when including step-down units and adjusting for hospital size (Figure S1 and Tables S8, S9).

**DISCUSSION**

Our study found an increase in the rate of ICU admission, mechanical ventilation, and craniotomy/craniectomy between 2003 and 2017 for patients with acute ischemic stroke and ICH, whereas the use of percutaneous feeding tubes decreased in those with ischemic stroke. Women and elderly individuals had overall lower rates of intensive care, although the difference narrowed over time because of the relatively greater increases in these subgroups. The temporal trends observed in our study persisted after adjustment for baseline factors and estimated stroke severity.

There is evidence of increasing rates of ICU admission from the emergency department over time in the
### Table 2. Logistic Regression Models Showing Association of Year, Age, and Sex With ICU Admission, Mechanical Ventilation, Percutaneous Feeding, Tracheostomy, and Craniotomy/Craniectomy for Ischemic Stroke and Intracerebral Hemorrhage

| Outcome                     | Ischemic stroke | Intracerebral hemorrhage |
|-----------------------------|-----------------|--------------------------|
|                             | AOR 95% LCL 95% UCL P value | AOR 95% LCL 95% UCL P value | C-statistic  | C-statistic |
| ICU care                    |                 |                          | 0.70         | 0.78        |
| Per additional year since 2003 | 1.04 1.04 1.05 <0.001 | 1.04 1.03 1.05 <0.001 | 0.70         | 0.78        |
| Female vs male sex          | 0.80 0.77 0.84 <0.001 | 0.81 0.76 0.88 <0.001 | 0.80 0.77 0.84 <0.001 | 0.81 0.76 0.88 <0.001 |
| Age 60–79 vs <60 y          | 0.74 0.70 0.77 <0.001 | 0.62 0.57 0.68 <0.001 | 0.74 0.70 0.77 <0.001 | 0.62 0.57 0.68 <0.001 |
| Age ≥80 vs <60 y            | 0.41 0.39 0.44 <0.001 | 0.26 0.23 0.29 <0.001 | 0.41 0.39 0.44 <0.001 | 0.26 0.23 0.29 <0.001 |
| Mechanical ventilation     |                 |                          | 0.90         | 0.93        |
| Per additional year since 2003 | 1.05 1.04 1.06 <0.001 | 1.09 1.07 1.10 <0.001 | 0.90         | 0.93        |
| Female vs male sex          | 0.57 0.53 0.62 <0.001 | 0.70 0.63 0.78 <0.001 | 0.57 0.53 0.62 <0.001 | 0.70 0.63 0.78 <0.001 |
| Age 60–79 vs <60 y          | 0.57 0.51 0.64 <0.001 | 0.55 0.48 0.62 <0.001 | 0.57 0.51 0.64 <0.001 | 0.55 0.48 0.62 <0.001 |
| Age ≥80 vs <60 y            | 0.26 0.23 0.29 <0.001 | 0.18 0.15 0.20 <0.001 | 0.26 0.23 0.29 <0.001 | 0.18 0.15 0.20 <0.001 |
| Percutaneous feeding tube   |                 |                          | 0.71         | 0.73        |
| Per additional year since 2003 | 0.96 0.96 0.97 <0.001 | 0.98 0.97 1.00 0.01 | 0.71         | 0.73        |
| Female vs male sex          | 0.77 0.72 0.82 <0.001 | 0.73 0.64 0.83 <0.001 | 0.77 0.72 0.82 <0.001 | 0.73 0.64 0.83 <0.001 |
| Age 60–79 vs <60 y          | 1.47 1.30 1.66 <0.001 | 1.07 0.92 1.26 0.39 | 1.47 1.30 1.66 <0.001 | 1.07 0.92 1.26 0.39 |
| Age ≥80 vs <60 y            | 1.56 1.38 1.76 <0.001 | 0.67 0.56 0.82 <0.001 | 1.56 1.38 1.76 <0.001 | 0.67 0.56 0.82 <0.001 |
| Tracheostomy                |                 |                          | 0.88         | 0.86        |
| Per additional year since 2003 | 1.00 0.99 1.03 0.36 | 1.0 0.98 1.02 0.65 | 0.88         | 0.86        |
| Female vs male sex          | 0.60 0.50 0.71 <0.001 | 0.69 0.58 0.82 <0.001 | 0.60 0.50 0.71 <0.001 | 0.69 0.58 0.82 <0.001 |
| Age 60–79 vs <60 y          | 0.82 0.66 1.00 0.05 | 0.65 0.55 0.78 <0.001 | 0.82 0.66 1.00 0.05 | 0.65 0.55 0.78 <0.001 |
| Age ≥80 vs <60 y            | 0.31 0.24 0.41 <0.001 | 0.13 0.09 0.18 <0.001 | 0.31 0.24 0.41 <0.001 | 0.13 0.09 0.18 <0.001 |
| Cranietomy/craniectomy      |                 |                          | 0.92         | 0.83        |
| Per additional year since 2003 | 1.07 1.04 1.11 <0.001 | 1.05 1.02 1.08 <0.001 | 0.92         | 0.83        |
| Female vs male sex          | 0.80 0.62 1.05 0.11 | 1.08 0.86 1.36 0.51 | 0.80 0.62 1.05 0.11 | 1.08 0.86 1.36 0.51 |
| Age 60–79 vs <60 y          | 0.21 0.16 0.27 <0.001 | 0.57 0.45 0.72 <0.001 | 0.21 0.16 0.27 <0.001 | 0.57 0.45 0.72 <0.001 |
| Age ≥80 vs <60 y            | 0.01 0.01 0.03 <0.001 | 0.11 0.06 0.18 <0.001 | 0.01 0.01 0.03 <0.001 | 0.11 0.06 0.18 <0.001 |

Model includes year, age, sex, income quintile, Charlson score, rural residence, care in a regional stroke center, and estimated stroke severity. AOR indicates adjusted odds ratio; C-statistic, concordance statistic, or area under the curve; LCL, lower confidence limit; and UCL, upper confidence limit.
United States, although studies in stroke are lacking. Our data may parallel these general ICU trends or indicate a tendency toward more intensive care specifically in patients with stroke. Although a relatively small proportion of patients receive thrombolysis or thrombectomy in clinical practice, the development of hyperacute treatments in the past 2 decades may have influenced the use of more intensive care or admissions to ICU for neurological monitoring. Further potential reasons for increasing monitoring include publication of clinical trials for hemicraniectomy in malignant ischemia and intensive blood pressure reduction in ICH. In contrast, there was a decrease in the use of feeding tubes for both ischemic stroke and ICH, consistent with a US study that showed decreased feeding tube usage from 2002 to 2012. The dissociation in trends between ICU care and feeding tube use may be attributed to improvements in acute stroke care and subsequent disability, reducing the prevalence of severe dysphagia at 2 to 3 weeks, when feeding tubes are typically placed in Canada, or an increase in the use of palliative care or care limitations. Importantly, we observed an approximate doubling in the absolute numbers of patients with first acute stroke requiring ICU care across the 15-year study period, from 1054 per year to 2017 per year, highlighting the increasing resource need for ICU and post-ICU care among patients with stroke.

The association between elderly age and less intensive care is consistent with prior studies and may reflect decision-making surrounding baseline function, poor prognosis, or withdrawal of life-sustaining care. Although decisions to withhold life-sustaining care in the elderly may represent appropriate matching of treatment to care goals, there is also the possibility of false prognostic pessimism. However, the increase in ICU admissions over time was relatively greatest in the elderly, potentially reflecting a shift in practices or preferences toward more intensive care at older age. Consistent with this, older individuals with ischemic stroke were more likely to have feeding tube placement, potentially attributed to survival with higher levels of disability.

The lower likelihood of intensive care among women is in line with prior studies on sex differences in patients who are critically ill. In studies of intensive care in Ontario, Canada, women were found to have lower odds of admission to an ICU, receipt of mechanical ventilation, dialysis, feeding tube placement, tracheostomy, and cardiopulmonary resuscitation after adjustment for baseline factors. Our findings are also in line with a pooled analysis of 19,000 individual patients from 5 acute stroke randomized trials, which found that women were less likely to have ICU admission and intubation. There are multiple potential explanations for the observed sex differences. Sex-specific biological factors may influence the likelihood of having an indication for ICU admission and intensive treatment such as neurological deterioration or airway compromise. Sociocultural factors that influence decision-making could differ by sex, including sex bias in medical decision-making and individual preferences on intensive care and survival with disability.
on discussions surrounding the use of end-of-life-care, withdrawal of life-sustaining care, use of palliation, or timing of palliative care decisions. Fourth, we could not account for providers of intensive care (ie, general intensivists versus neurointensivists), which may influence determination of prognosis. Fifth, we did not have comprehensive information on race or ethnicity. Sixth, we could not accurately capture the use of thrombolysis or thrombectomy using administrative data. Because of the retrospective, observational nature of the study and the aforementioned limitations, we were unable to establish causal relations, and our results may not be generalizable to other jurisdictions. Nevertheless, our findings in a large population were consistent across multiple outcomes and support prior findings of lower intensity of care among women and the elderly.

In conclusion, our study identifies age-specific and sex-specific temporal trends in poststroke intensive care from 2003 to 2017. Use of intensive care is increasing overall after acute stroke. Women and elderly have lower rates of ICU care, although the gaps are narrowing over time. Future work will need to determine the reasons for these observed trends.

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Supplementary Material
Tables S1–S9
Figures S1

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SUPPLEMENTAL MATERIAL
Table S1. Variables for life-sustaining interventions.

| Variable                     | Definition                                              | Source       | Code |
|------------------------------|---------------------------------------------------------|--------------|------|
| Percutaneous feeding tube    | Proportion received during admission                    | CCI-DAD      |      |
|                              |                                                         |              |      |
| ICU admission                | Proportion admitted to ICU at any time                  | CIHI-DAD     |      |
|                              |                                                         |              |      |
| Mechanical ventilation       | Proportion received during admission                    | CCI-DAD      |      |
|                              |                                                         |              |      |
| Tracheostomy                 | Proportion received during admission                    | CCI-DAD      |      |
|                              |                                                         |              |      |
| Craniotomy/craniectomy       | Proportion receiving craniotomy/craniectomy during admission | CCI-DAD |      |
|                              |                                                         |              |      |

CCI-DAD = Canadian Classification of Interventions-Discharge Abstract Database, ICU = Intensive Care Unit, CIHI-DAD = Canadian Institute of Health Information - Discharge Abstract Database, SCU = special care unit
Table S2. Additional data sources and variable definitions.

| Variable                                      | Data Source                                                                 |
|-----------------------------------------------|-----------------------------------------------------------------------------|
| Seen at or transferred to a Regional Stroke Centre | Link to year-specific file of regional stroke centre institutions IDs.       |
| Hypertension                                 | HYPER database<sup>19</sup>.                                                |
| Atrial fibrillation                          | 1 hospitalization or 1 ED visit or 4 Ontario Health Insurance Plan (OHIP) claims within 1-year with a diagnosis of atrial fibrillation, using a 5-year lookback window prior to index stroke, using code I48 for DAD/NACRS and 427 for OHIP. |
| Hyperlipidemia                               | 2 OHIP claims with a diagnosis of hyperlipidemia (code 272) in 2 years, using a 5-year look-back window prior to index stroke. |
| Diabetes                                     | Ontario Diabetes Database<sup>20</sup>.                                    |
| Congestive Heart Failure                     | Congestive Heart Failure Database<sup>21</sup>.                             |
| Coronary Artery Disease                      | 5-year lookback for previous hospitalization for myocardial infarction (ICD-10 code I21, I22 from DAD), percutaneous coronary intervention (Canadian Classification of Interventions code 1IJ50, 1IJ57GQ, 1IJ54 from DAD and Same Day Surgery Database), or coronary artery bypass graft (intervention code 1IJ76 from DAD). |

*References included in main text*
Table S3. Proportion receiving ICU admission, mechanical ventilation, percutaneous feeding tubes and tracheostomy in years 2003 and 2017, stratified by age, sex, and stroke type

| Subgroup        | Ischemic stroke | ICH |
|-----------------|-----------------|-----|
|                 | 2003 N          | 2017 N | 2003 2017 p-trend* | 2003 N | 2017 N | 2003 2017 p-trend* |
| **ICU care**    |                 |      |                     |       |       |                     |
| Overall         | 700/7283        | 1.459/9829 | 14.8 <.001 354/1235 | 28.7 | 558/1539 | 36.3 <.001 |
| Sex             |                 |      |                     |       |       |                     |
| Women           | 296/3712        | 681/4739 | 14.4 <.001 161/617 | 26.1 | 241/709 | 34.0 <.001 |
| Men             | 404/3712        | 778/5090 | 15.3 <.001 193/618 | 31.2 | 217/830 | 38.2 <.001 |
| Age             |                 |      |                     |       |       |                     |
| Age <60         | 136/920         | 300/1606 | 18.7 <.001 103/228 | 45.2 | 156/307 | 50.8 0.05 |
| Age 60-79       | 368/3364        | 694/4377 | 15.9 <.001 188/571 | 32.9 | 275/711 | 38.7 <.001 |
| Age 80+         | 196/2999        | 465/3846 | 12.1 <.001 63/436 | 14.5 | 127/521 | 24.4 <.001 |
| **Mechanical ventilation** | | | | | | |
| Overall         | 181/7283        | 387/9829 | 3.9 <.001 91/617 | 14.8 | 147/709 | 20.7 <.001 |
| Sex             |                 |      |                     |       |       |                     |
| Women           | 74/3712         | 161/4739 | 3.40 <.001 91/617 | 14.8 | 147/709 | 20.7 <.001 |
| Men             | 107/3571        | 226/5090 | 4.44 <.001 105/618 | 17.0 | 218/830 | 26.3 <.001 |
| Age             |                 |      |                     |       |       |                     |
| Age <60         | 50/920          | 95/1606 | 5.92 <.001 62/228 | 27.2 | 117/307 | 38.1 <.001 |
| Age 60-79       | 92/3364         | 191/4377 | 4.36 <.001 98/571 | 17.2 | 189/711 | 26.6 <.001 |
| Age 80+         | 39/2999         | 101/3846 | 2.63 <.001 36/436 | 8.26 | 59/521 | 11.3 0.01 |
| **Percutaneous feeding** | | | | | | |
| Overall         | 245/7283        | 217/9829 | 2.2 <.001 70/1235 | 5.7 | 67/1539 | 4.4 0.24 |
| Sex             |                 |      |                     |       |       |                     |
| Women           | 114/3712        | 90/4739 | 1.9 <.001 24/617 | 3.89 | 18/709 | 2.54 0.09 |
| Men             | 131/3571        | 127/5090 | 2.5 0.002 46/618 | 7.44 | 49/830 | 5.90 0.54 |
| Age             |                 |      |                     |       |       |                     |
| Age <60         | 13/920          | 30/1606 | 1.87 0.74 14/228 | 6.14 | 20/307 | 6.51 0.65 |
| Age 60-79       | 120/3364        | 108/4377 | 2.47 0.001 38/571 | 6.65 | 38/711 | 5.34 0.08 |
| Age 80+         | 112/2999        | 79/3846 | 2.05 <.001 18/436 | 4.13 | 9/521 | 1.73 0.18 |
| **Tracheostomy** |                 |      |                     |       |       |                     |
| Overall         | 20/7283         | 52/9829 | 0.5 0.02 33/1235 | 2.7 | 47/1539 | 3.1 0.55 |
| Sex             |                 |      |                     |       |       |                     |
| Women           | 2-6**/3712      | 17/4739 | 0.36 0.03 9/617 | 8.77 | 11/709 | 6.84 0.42 |
| Men             | 14-18/3571      | 35/5090 | 0.69 0.16 24/618 | 2.10 | 26/830 | 3.66 0.007 |
| Age             |                 |      |                     |       |       |                     |
| Age <60         | 1-5/920         | 12/1606 | 0.75 0.75 20/228 | 8.77 | 21/307 | 6.80 0.004 |
| Age 60-79       | 14-3364         | 30/4377 | 0.69 0.23 8-12/571 | 1.40-2.10 | 26/711 | 3.66 0.12 |
| Age 80+         | 1-5/2999        | 10/3846 | 0.26 0.05 1-5/436 | 0.23-1.15 | 0/521 | 0 0.04 |

*P-trend from Cochrane-Armitage test for all years 2003-2017; **Ranges provided to maintain confidentiality for cells with <6 patients as per ICES policy. Craniotomy/craniectomy was not stratified by age and sex due to small cells.
Table S4. Logistic regression models showing association of year and sex with ICU admission for ischemic stroke and intracerebral hemorrhage, stratified by age group

| Outcome and group | Ischemic stroke | Intracerebral hemorrhage |
|-------------------|-----------------|--------------------------|
| ICU care          |                 |                          |
| Age <60 years     |                 |                          |
| Per additional year since 2003 | 1.03 1.02 1.04 <.001 | 1.02 1.01 1.04 0.01 |
| Female sex versus male | 0.76 0.69 0.83 <.001 | 0.91 0.79 1.05 0.20 |
| Age 60-79 years   |                 |                          |
| Per additional year since 2003 | 1.04 1.04 1.05 <.001 | 1.04 1.03 1.05 <.001 |
| Female sex versus male | 0.78 0.74 0.83 <.001 | 0.76 0.69 0.85 <.001 |
| Age 80+ years     |                 |                          |
| Per additional year since 2003 | 1.06 1.05 1.06 <.001 | 1.06 1.05 1.08 <.001 |
| Female sex versus male | 0.84 0.78 0.89 <.001 | 0.77 0.67 0.88 <.001 |

*aOR indicates adjusted odds ratio. Model includes year, age, sex, income quintile, Charlson score, rural residence, care in a regional stroke centre, and estimated stroke severity. LCL indicates lower confidence limit; UCL upper confidence limit; C-statistic indicates concordance statistic for the model, or area under the curve. P-interaction for age*year<.001; age*sex = 0.21.
Table S5. Logistic regression models showing association of year and sex with ICU admission for ischemic stroke and intracerebral hemorrhage, stratified by age group and excluding those who died in the first 72 hours

| Outcome and group  | Ischemic stroke | Intracerebral hemorrhage |
|--------------------|-----------------|--------------------------|
|                    | aOR 95% LCL 95% UCL P-value | aOR 95% LCL 95% UCL P-value |
| ICU care           |                 |                          |
| Age <60 years      |                 |                          |
| Per additional year since 2003 | 1.03 1.02 1.04 <.001 | 1.02 1.01 1.04 0.01 |
| Female sex versus male | 0.77 0.71 0.85 <.001 | 0.92 0.79 1.07 0.26 |
| Age 60-79 years    |                 |                          |
| Per additional year since 2003 | 1.04 1.04 1.05 <.001 | 1.04 1.03 1.05 <.001 |
| Female sex versus male | 0.79 0.73 0.83 <.001 | 0.75 0.66 0.84 <.001 |
| Age 80+ years      |                 |                          |
| Per additional year since 2003 | 1.06 1.05 1.06 <.001 | 1.06 1.04 1.08 <.001 |
| Female sex versus male | 0.84 0.79 0.90 <.001 | 0.76 0.65 0.89 0.001 |
Table S6. Logistic regression models showing association of year and age with ICU admission for ischemic stroke and intracerebral hemorrhage, stratified by sex

| Outcome and group | Ischemic stroke | Intracerebral hemorrhage |
|-------------------|-----------------|--------------------------|
|                   | aOR  | 95% LCL | 95% UCL | P-value | C-statistic | aOR  | 95% LCL | 95% UCL | P-value | C-statistic |
| ICU care          |      |         |         |         |            |      |         |         |         |            |
| Female            |      |         |         |         |            |      |         |         |         |            |
| Per additional year since 2003 | 1.05 | 1.05 | 1.06 | <.001 | 0.72 | 1.04 | 1.03 | 1.05 | <.001 | 0.80 |
| Age 60-79 vs. <60 | 0.71 | 0.65 | 0.76 | <.001 | 0.55 | 0.48 | 0.63 | <.001 | 0.67 | 0.60 | 0.75 | <.001 |
| Age 80+ vs. <60  | 0.41 | 0.38 | 0.44 | <.001 | 0.23 | 0.20 | 0.27 | <.001 | 0.28 | 0.24 | 0.32 | <.001 |
| Male              |      |         |         |         |            |      |         |         |         |            |
| Per additional year since 2003 | 1.04 | 1.03 | 1.04 | <.001 | 0.69 | 1.04 | 1.03 | 1.05 | <.001 | 0.77 |
| Age 60-79 vs. <60 | 0.76 | 0.71 | 0.81 | <.001 | 0.67 | 0.60 | 0.75 | <.001 | 0.28 | 0.24 | 0.32 | <.001 |
| Age 80+ vs. <60  | 0.42 | 0.39 | 0.45 | <.001 | 0.28 | 0.24 | 0.32 | <.001 | 0.28 | 0.24 | 0.32 | <.001 |
Table S7. Logistic regression models showing association of year, age, and sex with ICU admission for ischemic stroke and intracerebral hemorrhage, including those with prior stroke

| Outcome                          | Ischemic stroke | Intracerebral hemorrhage |
|----------------------------------|-----------------|--------------------------|
|                                  | aOR  | 95% LCL | 95% UCL | P-value | C-statistic | aOR  | 95% LCL | 95% UCL | P-value | C-statistic |
| ICU care                         |      |         |         |         |            |      |         |         |         |            |
| Per additional year since 2003   | 1.05 | 1.05    | 1.05    | <.001   | 0.70        | 1.05 | 1.04    | 1.05    | <.001   | 0.78        |
| Female sex versus male           | 0.81 | 0.78    | 0.84    | <.001   | 0.79        | 0.79 | 0.74    | 0.84    | <.001   | 0.78        |
| Age 60-79 vs. <60                | 0.73 | 0.70    | 0.76    | <.001   | 0.60        | 0.60 | 0.56    | 0.65    | <.001   | 0.78        |
| Age 80+ vs. <60                  | 0.42 | 0.40    | 0.44    | <.001   | 0.26        | 0.26 | 0.23    | 0.28    | <.001   | 0.78        |
Table S8. Logistic regression models showing association of year, age, and sex with ICU admission for ischemic stroke and intracerebral hemorrhage, including step-down units

| Outcome                              | Ischemic stroke          | Intracerebral hemorrhage | C-statistic | C-statistic |
|--------------------------------------|--------------------------|--------------------------|-------------|-------------|
|                                      | aOR  95% LCL  95% UCL P-value | aOR  95% LCL  95% UCL P-value |             |             |
| ICU care                             |                          |                          | 0.70        | 0.77        |
| Per additional year since 2003       | 1.05 1.05 1.06 <.001     | 1.05 1.04 1.06 <.001     |             |             |
| Female sex versus male               | 0.81 0.78 0.83 <.001     | 0.83 0.78 0.89 <.001     |             |             |
| Age 60-79 vs. <60                    | 0.75 0.72 0.78 <.001     | 0.60 0.55 0.65 <.001     |             |             |
| Age 80+ vs. <60                      | 0.44 0.41 0.46 <.001     | 0.26 0.24 0.29 <.001     |             |             |
Table S9. Logistic regression models showing association of year, age, and sex with ICU admission for ischemic stroke and intracerebral hemorrhage, adjusting for hospital size

| Outcome                              | Ischemic stroke |                 | Intracerebral hemorrhage |                 |
|--------------------------------------|-----------------|-----------------|--------------------------|-----------------|
|                                      | aOR             | 95% LCL         | 95% UCL                  | aOR             | 95% LCL         | 95% UCL                  | P-value       | C-statistic | aOR             | 95% LCL         | 95% UCL                  | P-value       | C-statistic |
| ICU care                             |                 |                 |                          |                 |                 |                          |              |             |                 |                 |                          |              |             |
| Per additional year since 2003       | 1.04            | 1.04            | 1.05                     | <.001           | 1.04            | 1.03            | 1.05                     | <.001         | 1.04         | 1.03            | 1.05                     | <.001         |
| Female sex versus male               | 0.80            | 0.77            | 0.83                     | <.001           | 0.81            | 0.76            | 0.87                     | <.001         | 0.81         | 0.76            | 0.87                     | <.001         |
| Age 60-79 vs. <60                    | 0.72            | 0.69            | 0.76                     | <.001           | 0.61            | 0.56            | 0.66                     | <.001         | 0.61         | 0.56            | 0.66                     | <.001         |
| Age 80+ vs. <60                      | 0.40            | 0.38            | 0.43                     | <.001           | 0.25            | 0.22            | 0.28                     | <.001         | 0.25         | 0.22            | 0.28                     | <.001         |
| Hospital size (number of acute care beds; reference category >500 beds) |                 |                 |                          |                 |                 |                          |              |             |                 |                 |                          |              |             |
| <=50 beds                            | 1.18            | 1.07            | 1.31                     | 0.002           | 1.17            | 0.83            | 1.46                     | 0.17          | 1.17         | 0.83            | 1.46                     | 0.17          |
| 51-150 beds                          | 1.94            | 1.79            | 2.11                     | <.001           | 1.70            | 1.46            | 1.99                     | <.001         | 1.70         | 1.46            | 1.99                     | <.001         |
| 151-250 beds                         | 1.20            | 1.11            | 1.30                     | <.001           | 1.17            | 1.01            | 1.35                     | 0.03          | 1.17         | 1.01            | 1.35                     | 0.03          |
| 251-350 beds                         | 0.93            | 0.87            | 1.00                     | 0.06            | 0.87            | 0.77            | 0.99                     | 0.03          | 0.87         | 0.77            | 0.99                     | 0.03          |
| 351-500 beds                         | 0.79            | 0.74            | 0.83                     | <.001           | 0.86            | 0.77            | 0.96                     | 0.008         | 0.86         | 0.77            | 0.96                     | 0.008         |
Figure S1. Trends in ICU admission between 2003-2017 stratified by age and sex for ischemic stroke (A-B) and ICH (C-D), including those with prior stroke. Outlines indicate 95% confidence intervals of binomial proportions.