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ORIGINAL RESEARCH

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

Critical care needs are common after acute stroke, typically attributed to disturbance of consciousness or cardiorespiratory complications or to monitor patients who are unstable or who received hyperacute treatment.[1] One in 15 patients with stroke require mechanical ventilation on admission, with a higher rate among those with intracerebral hemorrhage (ICH).[2,3] Admission to the intensive care unit (ICU) after stroke carries significant cost and is associated with worse outcomes and high long-term mortality.[4–6] Life-sustaining care also includes the use of percutaneous feeding tubes or tracheostomy for a small proportion of patients with severe dysphagia or prolonged ventilation.[7,8] Although rates of feeding tube insertion in the United States are decreasing over time,[9] tracheostomy use is increasing.[8] However, contemporary patterns and trends for ICU admission, mechanical ventilation, percutaneous feeding tubes, and tracheostomy after stroke are not well understood.

First, sex differences in life-sustaining care after stroke are not well defined. Although female sex is associated with lower intensive care use overall in patients who are critically ill,[10] whether a similar association exists specifically after stroke is unknown.

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CLINICAL PERSPECTIVE

What Is New?

- The rate of intensive care unit admission and mechanical ventilation after acute stroke increased between 2003 and 2017.
- Women and older individuals had lower odds of intensive care unit admission after adjustment for estimated stroke severity and other factors, although the differences narrowed during the study period.

What Are the Clinical Implications?

- Knowledge of the observed trends in critical care after stroke could assist in resource planning and understanding disparities and access to appropriate intensive care among women and the elderly with acute stroke.

Nonstandard Abbreviations and Acronyms

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

Second, although there are no major disparities in the provision and quality of acute stroke care between age groups,[11] 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.[12] Yet because of the projected dramatic increase in the number of people with stroke in North America from an aging population,[13] 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, H34.1; 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.[14] 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[15] and the upper threshold of age 80 years as it is a common threshold of elderly in stroke studies.[16,17] The Canadian Institutes for Health

Information Discharge Abstract Database was used to obtain the Charlson comorbidity index,[18] 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).[19–21] 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.[22] 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

Table 1. Baseline Characteristics and Life-Sustaining Care in Patients Hospitalized After Acute Ischemic Stroke or Intracerebral Hemorrhage for Representative Years 2003, 2010, and 2017

Variable	Ischemic stroke or intracerebral hemorrhage			
	2003	2010	2017	*P* trend
N	8518	8511	10 147	
Age, y	74.53±12.88	73.29±13.86	73.38±13.96	<0.001
18–59 y	1148 (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*				<0.001
Mild	3975 (46.7)	3924 (46.1)	5498 (48.4)	0.02
Moderate	4104 (48.2)	4130 (48.5)	5296 (46.6)	0.012
Severe	439 (5.2)	457 (5.4)	574 (5.0)	0.84
Lowest 2 income quintiles	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 (10.6)	<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]

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, 1.04–1.05) and ICH (AOR, 1.04; 95% CI, 1.03–1.05; Table 2). Each year after 2003 was associated with higher odds of mechanical ventilation (AOR, 1.05; 95% CI, 1.04–1.06), higher odds of craniotomy/craniectomy (AOR, 1.07; 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

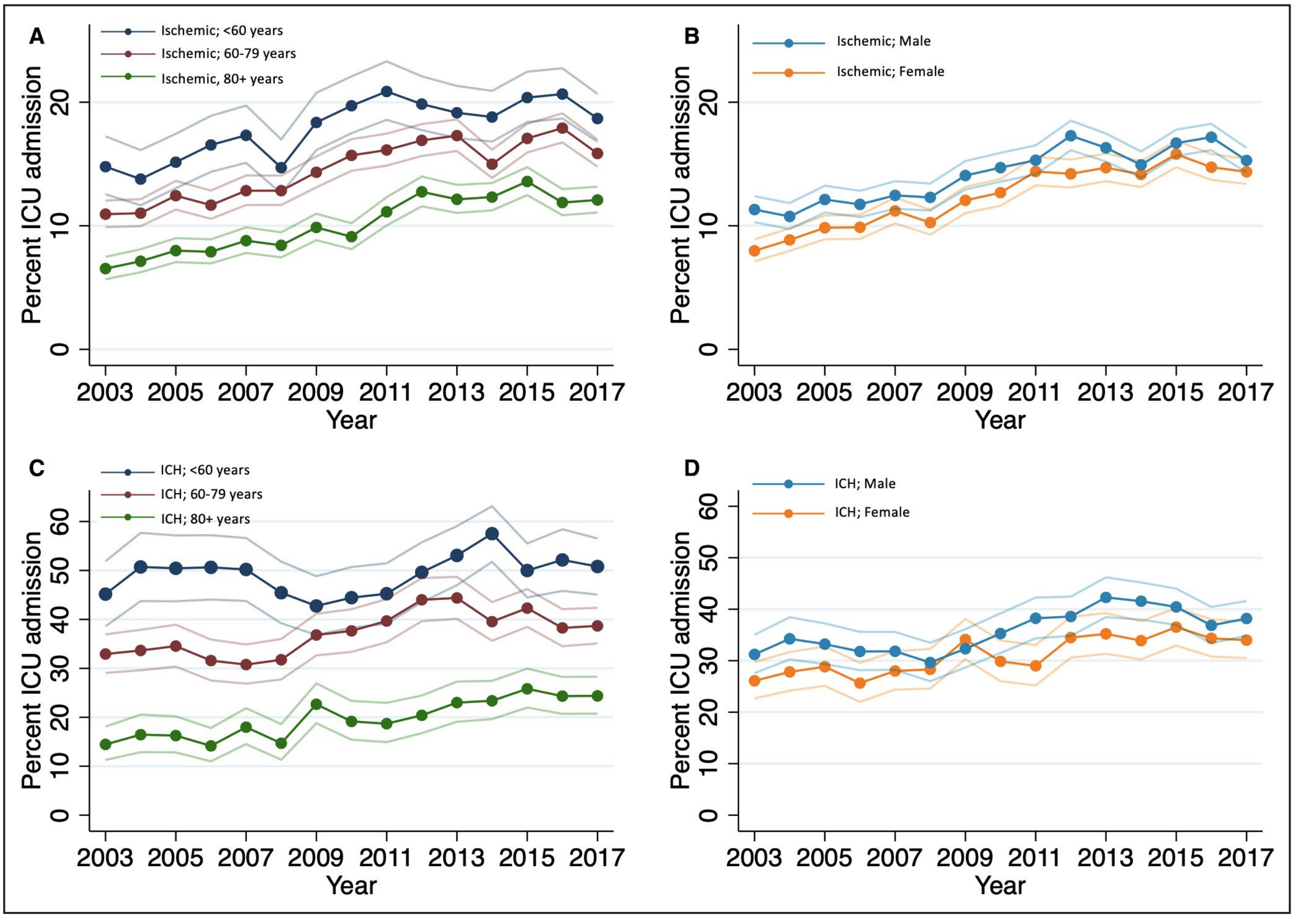

Figure. Trends in ICU admission between 2003 and 2017 stratified by age and sex for ischemic stroke (A and B) and ICH (C and D).

Outlines indicate 95% CIs of binomial proportions. ICH indicates intracerebral hemorrhage; and ICU, intensive care unit.

≥80 versus <60 years; 95% CI, 0.39–0.44) and ICH (Table 2). 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 ≥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 ≥80 versus <60 years; 95% CI, 0.23–0.29) tracheostomy (AOR, 0.31 for ≥80 versus <60 years; 95% CI, 0.24–0.41) and craniotomy/craniectomy (AOR 0.01 for ≥80 versus <60 years; 95% CI, 0.01–0.03), but higher odds of feeding tube placement (AOR, 1.56 for ≥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	C-statistic	AOR	95% LCL	95% UCL	*P* value	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	
Female vs male sex	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	
Age ≥80 vs <60 y	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	
Female vs male sex	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	
Age ≥80 vs <60 y	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	1.0	0.01	
Female vs male sex	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	
Age ≥80 vs <60 y	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	
Female vs male sex	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	
Age ≥80 vs <60 y	0.31	0.24	0.41	<0.001		0.13	0.09	0.18	<0.001	
Craniotomy/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	
Female vs male sex	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	
Age ≥80 vs <60 y	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,[23] 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,[24,25] 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.[26,27] 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.[9] 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,[28] 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.[29,30] 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.[31] 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.[32,33] 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.[10,29,30] 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.[34] 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.[10,35] Women are more likely to be widowed and therefore may have less decisional support and advocacy when they are critically ill, which may decrease the tendency to receive aggressive care.[36,37] Among community-dwelling elderly individuals, women had a higher relative risk of refusal of a hypothetical scenario of future critical illness requiring life-sustaining treatments.[38] Women are also more likely to have had discussions with friends and family regarding advanced care planning, which may result in lower levels of aggressive care.[39] Although these studies suggest that community-dwelling elderly women may be more likely than men to have advanced care plan discussions and express wishes for lower levels of aggressive care after critical illness, this is less understood in the context of stroke.[1,9] We did not have access to data on advanced care plans, but the changes in temporal trends for life-sustaining care suggest that this could be changing. Lastly, lower odds of intensive care may be attributed to higher early mortality rates among women. Prior studies have shown higher mortality rates in women who are critically ill,[10,32,40] but studies are conflicting after stroke, and sex differences in mortality are often attenuated after adjustment for stroke severity and other baseline factors.[41–44] However, our results were consistent after excluding those who died within 72 hours of arrival to hospital. Our study also showed that the sex disparity in ICU admission for those with ischemic stroke became narrower over time.

Our study had limitations. There is the risk of misclassification with the use of administrative data for identification of stroke cases; however, the codes used have high validity in Canada.[14] We did not have a clinical assessment of stroke severity, but we included a validated estimate of stroke severity from the administrative data.[22] As our results were based on the secondary use of administrative data, we acknowledge the potential for measured and unmeasured confounding, which may have impacted the reported associations. First, although we accounted for multiple baseline characteristics, there is the possibility of residual confounding from changes in baseline characteristics, stroke severity, comorbidities, socioeconomic status, and geographic distribution of patients during the study period. Second, shifts in clinical decision-making, societal and patient preferences, province-level and hospital-level policies, resource allocation, and access to acute stroke care could not be accounted for. Third, we did not have information 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.[45] 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.

ARTICLE INFORMATION

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Disclosures

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Supplementary Material

Tables S1–S9
Figure 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	*Gastrostomy*: 1NF53BTQB 1NF53BTTS 1NF53DAQB 1NF53DATS 1NF53HATS *Jejunostomy*: 1NK53BTTS 1NK53DATS 1NK53HATS
ICU admission	Proportion admitted to ICU at any time	CIHI-DAD	Where SCU = '10', '20', '25', '30', '35', '40', '45', '60', '80'
Mechanical ventilation	Proportion received during admission	CCI-DAD	1.GZ.31.CA-ND 1.GZ.31.CA-EP 1.GZ.31.CA-PK
Tracheostomy	Proportion received during admission	CCI-DAD	1.GJ.77.HA 1.GJ.77.LA 1.GJ.77.LA-LG 1.GJ.77.QB 1.GZ.31.CR-ND 1.GZ.31.GP-ND
Craniotomy/craniectomy	Proportion receiving craniotomy/craniectomy during admission	CCI-DAD	1.EA.87 1.EA.72 1.AP.72 1.EA.92 1.AN.87.SZ 1.JW.57.SZ

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[19].
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[20].
Congestive Heart Failure	Congestive Heart Failure Database[21].
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

	Ischemic stroke					ICH				
Subgroup	**2003 N**	**2003 crude rate (%)**	**2017 N**	**2017 crude rate (%)**	**p-trend* (%)**	**2003 N**	**2003 crude rate (%)**	**2017 N**	**2017 crude rate (%)**	**p-trend (%)**
ICU care										
Overall	700/7283	9.6	1,459/9829	14.8	<.001	354/1235	28.7	558/1539	36.3	<.001
Sex										
Women	296/3712	7.97	681/4739	14.4	<.001	161/617	26.1	241/709	34.0	<.001
Men	404/3571	11.3	778/5090	15.3	<.001	193/618	31.2	217/830	38.2	<.001
Age										
Age <60	136/920	14.8	300/1606	18.7	<.001	103/228	45.2	156/307	50.8	0.05
Age 60-79	368/3364	10.9	694/4377	15.9	<.001	188/571	32.9	275/711	38.7	<.001
Age 80+	196/2999	6.54	465/3846	12.1	<.001	63/436	14.5	127/521	24.4	<.001
Mechanical ventilation										
Overall	181/7283	2.5	387/9829	3.9	<.001	196/1235	15.9	365/1539	23.7	<.001
Sex										
Women	74/3712	1.99	161/4739	3.40	<.001	91/617	14.8	147/709	20.7	<.001
Men	107/3571	3.0	226/5090	4.44	<.001	105/618	17.0	218/830	26.3	<.001
Age										
Age <60	50/920	5.43	95/1606	5.92	<.001	62/228	27.2	117/307	38.1	<.001
Age 60-79	92/3364	2.73	191/4377	4.36	<.001	98/571	17.2	189/711	26.6	<.001
Age 80+	39/2999	1.30	101/3846	2.63	<.001	36/436	8.26	59/521	11.3	0.01
Percutaneous feeding										
Overall	245/7283	3.4	217/9829	2.2	<.001	70/1235	5.7	67/1539	4.4	0.24
Sex										
Women	114/3712	3.07	90/4739	1.9	<.001	24/617	3.89	18/709	2.54	0.09
Men	131/3571	3.67	127/5090	2.5	0.002	46/618	7.44	49/830	5.90	0.54
Age										
Age <60	13/920	1.41	30/1606	1.87	0.74	14/228	6.14	20/307	6.51	0.65
Age 60-79	120/3364	3.57	108/4377	2.47	0.001	38/571	6.65	38/711	5.34	0.08
Age 80+	112/2999	3.73	79/3846	2.05	<.001	18/436	4.13	9/521	1.73	0.18
Tracheostomy										
Overall	20/7283	0.3	52/9829	0.5	0.02	33/1235	2.7	47/1539	3.1	0.55
Sex										
Women	2-6**/3712	0.05-0.16	17/4739	0.36	0.13	9/617	8.77	11/709	6.84	0.42
Men	14-18/3571	0.39-0.50	35/5090	0.69	0.16	24/618	2.10	26/830	3.66	0.007
Age										
Age <60	1-5/920	0.11-0.54	12/1606	0.75	0.75	20/228	8.77	21/307	6.80	0.004
Age 60-79	14/3364	0.42	30/4377	0.69	0.23	8-12/571	1.40-2.10	26/711	3.66	0.12
Age 80+	1-5/2999	0.03-0.16	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

	Ischemic stroke					Intracerebral hemorrhage				
Outcome and group	**aOR***	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**
ICU care										
Age <60 years					0.70					0.73
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					0.69					0.75
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					0.70					0.76
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

	Ischemic stroke					**Intracerebral hemorrhage**				
Outcome and group	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**
ICU care										
Age <60 years					0.68					0.69
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					0.68					0.70
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					0.68					0.70
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

	Ischemic stroke					Intracerebral hemorrhage				
Outcome and group	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**
ICU care										
Female					0.72					0.80
Per additional year since 2003	1.05	1.05	1.06	<.001		1.04	1.03	1.05	<.001	
Age 60-79 vs. <60	0.71	0.65	0.76	<.001		0.55	0.48	0.63	<.001	
Age 80+ vs. <60	0.41	0.38	0.44	<.001		0.23	0.20	0.27	<.001	
Male					0.69					0.77
Per additional year since 2003	1.04	1.03	1.04	<.001		1.04	1.03	1.05	<.001	
Age 60-79 vs. <60	0.76	0.71	0.81	<.001		0.67	0.60	0.75	<.001	
Age 80+ vs. <60	0.42	0.39	0.45	<.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

	Ischemic stroke					Intracerebral hemorrhage				
Outcome	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**
ICU care					0.70					0.78
Per additional year since 2003	1.05	1.05	1.05	<.001		1.05	1.04	1.05	<.001	
Female sex versus male	0.81	0.78	0.84	<.001		0.79	0.74	0.84	<.001	
Age 60-79 vs. <60	0.73	0.70	0.76	<.001		0.60	0.56	0.65	<.001	
Age 80+ vs. <60	0.42	0.40	0.44	<.001		0.26	0.23	0.28	<.001	

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

	Ischemic stroke					Intracerebral hemorrhage				
Outcome	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**
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

	Ischemic stroke					Intracerebral hemorrhage				
Outcome	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**	**aOR**	**95% LCL**	**95% UCL**	**P-value**	**C-statistic**
ICU care					0.72					0.79
Per additional year since 2003	1.04	1.04	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	
Age 60-79 vs. <60	0.72	0.69	0.76	<.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	
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	
51-150 beds	1.94	1.79	2.11	<.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	
251-350 beds	0.93	0.87	1.00	0.06		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	

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.