ORIGINAL ARTICLE

Temporal and Age-Specific Trends in Acute Stroke Incidence: A 15-Year Population-Based Study of Administrative Data in Ontario, Canada

Raed A. Joundi, Eric E. Smith, Amy Y.X. Yu, Mohammed Rashid, Jiming Fang, Moira K. Kapral

ABSTRACT: ***Background:*** Contemporary data on temporal trends in acute stroke incidence, specific to stroke type and age, are lacking. We sought to evaluate temporal trends in incidence of ischemic stroke and intracerebral hemorrhage over 15 years in a large population. ***Methods:*** We used linked administrative data to identify all emergency department visits and hospital admissions for first-ever ischemic stroke or intracerebral hemorrhage in Ontario, Canada from 2003–2017. We evaluated annual age-/sex-standardized incidence per 100,000 person-years for ischemic stroke and intracerebral hemorrhage across the study period. We used negative binomial regression to determine incidence rate ratios for each year compared to 2003, with assessment of modification by age, sex, or stroke type. ***Results:*** Our cohort had 163,574 people with stroke (88% ischemic stroke). For ischemic stroke and intracerebral hemorrhage combined, age-/sex-standardized incidence decreased between 2003 and 2011 (standardized rate 109.4 to 85.8 per 100,000; 22%), then increased until 2017 (standardized rate 96.8 per 100,000; 13%). The pattern of change was similar for ischemic stroke and intracerebral hemorrhage, and for men and women, but was modified by age. For those aged 60 and above, adjusted incidence rate ratios decreased from 2003 to 2011 then subsequently increased, whereas for those aged <60 years incidence rate ratios increased throughout the entire study time period, particularly after 2011. ***Conclusions:*** Acute stroke incidence decreased from 2003 to 2011 but subsequently increased until 2017. Among those aged <60, incidence increased continuously from 2003 to 2017 but especially after 2011. The underlying reasons for these changes should be determined.

RÉSUMÉ : Tendances relatives à l'âge et dans le temps en ce qui concerne l'incidence d'AVC aigus : une étude populationnelle de 15 ans reposant sur des données administratives ontariennes. ***Contexte et objectif*** **:** Il nous manque, à l'heure actuelle, des données portant sur l'incidence dans le temps des AVC aigus, notamment le type d'AVC qui surviennent ainsi que l'âge des personnes qui en sont victimes. Pour une période de 15 ans, nous avons donc cherché à évaluer les tendances portant sur l'incidence des accidents ischémiques et des hémorragies intracérébrales au sein d'une population importante. ***Méthodes*** **:** Pour ce faire, nous avons utilisé des données administratives interreliées afin de comptabiliser de 2003 à 2017 toutes les visites à un service des urgences et toutes les hospitalisations pour tout accident ischémique ou toute hémorragie cérébrale survenant une première fois en Ontario (Canada). Pour ces mêmes accidents ischémiques et hémorragies cérébrales, nous avons ensuite évalué tout au long de la période à l'étude l'incidence annuelle standardisée en fonction de l'âge et du sexe pour chaque tranche de 100 000 personnes. À cet égard, nous avons fait appel à un modèle de régression binomiale négative afin de déterminer, pour chaque année à l'étude, les ratios de taux d'incidence et de les comparer à 2003, l'année de référence. Nous avons ensuite été en mesure d'analyser l'évolution des tendances selon l'âge, le sexe ou le type d'AVC. ***Résultats*** **:** Notre cohorte rassemblait 163 574 personnes victimes d'un AVC. De ce nombre, 88 % d'entre elles avaient été victimes d'un accident ischémique. En tenant compte de tous les cas d'accident ischémique et d'hémorragie cérébrale combinés, l'incidence standardisée en fonction de l'âge et du sexe a diminué entre 2003 et 2011. En effet, le taux standardisé par 100 000 personnes est passé de 109,4 à 85,8, ce qui représente une diminution de 22 %. Ce taux a ensuite augmenté jusqu'en 2017 pour s'établir à 96,8 par 100 000 personnes, soit 13 % d'augmentation. Si le profil de changement s'est révélé semblable pour les accidents ischémiques et les hémorragies cérébrales ainsi que pour les hommes et les femmes, il a toutefois varié selon l'âge des personnes. Pour ceux et celles âgés de plus de 60 ans, les ratios de taux d'incidence ajustés ont diminué de 2003 à 2011 et ont ultérieurement augmenté tandis que ceux et celles âgés de moins de 60 ans ont au contraire vu leurs ratios de taux d'incidence augmenter tout au long de la période à l'étude, surtout après l'année 2011. ***Conclusions*** **:** Les taux d'incidence des accidents ischémiques ont certes diminué de 2003 à 2011 mais ont par la suite augmenté jusqu'en 2017. Parmi ceux et celles âgés de 60 ans et moins, ce taux a augmenté de façon continue entre 2003 et 2017, plus particulièrement après 2011. Les raisons sous-jacentes de cette évolution devraient être déterminées.

Keywords: Acute stroke, Incidence, Temporal trends, Epidemiology, Ischemic stroke, Intracerebral hemorrhage, Administrative data

doi:10.1017/cjn.2020.257 Can J Neurol Sci. 2021; 48: 685–689

From the Department of Clinical Neurosciences, Cumming School of Medicine, University of Calgary, Calgary, Canada (RAJ, EES); ICES, Toronto, Canada (RAJ, EES, AYXY, MR, JF, MKK); Department of Medicine, Division of Neurology, University of Toronto, Toronto, Canada (AYXY); Department of Medicine, Division of General Internal Medicine, University of Toronto, Toronto, Canada (MKK); and Institute of Health Policy, Management, and Evaluation, University of Toronto, Toronto, Canada (MKK)

Received October 16, 2020. Date of Acceptance November 15, 2020.

Correspondence to: Moira K. Kapral, University of Toronto, Toronto General Hospital, 200 Elizabeth St. 14EN-215, Toronto, ON M5G 2C4, Canada. Email: moira.kapral@uhn.ca

Background

Aggregate global data from high-income countries have shown a significant decline in incidence for both ischemic and hemorrhagic stroke between 1990 and 2010.[1,2] However, there is variability among individual countries, as well as concerning reports of rising stroke incidence in younger individuals in recent years.[1,3-5] We aimed to evaluate recent temporal trends in acute stroke incidence over a 15-year period from an entire province in Canada.

Methods

Study Sample and Data Sources

The province of Ontario had an adult population of approximately 9.5 million in 2003 and 11.3 million in 2017. The province has universal healthcare for residents, covering all costs for hospitalizations and emergency department (ED) visits. We used administrative data to identify all patients with ischemic stroke and intracerebral hemorrhage (ICH) admitted to an acute care hospital or seen in the ED in Ontario, Canada between fiscal years 2003 (starting April 1, 2003) and 2017 (ending March 31, 2018). The datasets were linked using unique encoded identifiers and analyzed at ICES (formerly known as the Institute for Clinical Evaluative Sciences). Cases were ascertained with the Canadian Institutes for Health Information - Discharge Abstract Database for hospital admissions and the Canadian Institutes for Health Information - National Ambulatory Care Reporting System for ED visits 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; intracerebral hemorrhage: I61.x]. The transition from ICD-9 to ICD-10 was complete in 2002 in Ontario. These codes have been validated through duplicate chart abstraction, with excellent positive predictive value for stroke in Canada.[6] By law, all ED visits and admissions to hospital are included in these databases. We excluded patients with subarachnoid hemorrhage and cerebral venous sinus thrombosis, those <18 or >104 years of age, with elective admissions, and death before arrival to the ED. We also excluded those with in-hospital stroke due to substantial differences in baseline characteristics and stroke severity compared to community-onset stroke.[7] We identified transfers between institutions to link together the same episodes of care and avoid duplication of records. We established a 12-year wash-out period between 1991 and 2002 and excluded any individuals with prior stroke in that time (using ICD-10-CA codes above in addition to I60 [subarachnoid hemorrhage], and ICD-9 codes 430, 431, 434, and 436).

We estimated stroke severity for hospitalized patients using linked administrative data according to previously described methods for the PaSSV indicator (excluding the Canadian Triage and Acuity Scale as it may not generalize to other jurisdictions).[8] See Supplementary Table for additional data sources and algorithms used.[9-13]

Analysis

We assessed for trends in baseline characteristics across the study period using the Cochrane–Armitage test for proportions and linear regression for means. We computed crude and age-/sex-standardized acute stroke incidence rates per 100,000 person-years for each fiscal year from 2003 to 2017 using the 2003 Ontario population as the standard, overall and stratified by stroke type. We also computed age-standardized incidence rates in women and men, and sex-standardized rates stratified by age group (<60, 60–79, and 80+ years). We evaluated the statistical significance of trends in standardized rates using the Kendall τ-b correlation coefficient, with a threshold of $p = 0.05$. We used negative binomial regression to assess the association between year since 2003 and incidence, assessing for modification by age, sex, and stroke type. Due to significant modification by age, we fit models to obtain annual incidence rate ratios (IRRs) separately for each age group, adjusting for sex and stroke type. We performed an additional analysis also adjusting for estimated stroke severity among hospitalized patients. Analyses were conducted using SAS Enterprise Guide 7.1 (Cary, NC) and Stata 16.0 (College Station, TX).

Results

There were 163,574 people with incident acute stroke in the final cohort, 87.6% of whom had ischemic stroke. Baseline characteristics across years in the whole cohort are shown in Table 1. There were increases in the proportions of people aged <60 years, those with hypertension and diabetes, and a decrease in the proportion of women over the study period. The number of incident strokes remained stable from 2003 to 2011 (10,295 to 10,148), then rose by approximately 33% until 2017 (13,476).

Among all strokes, there was a gradual decrease in age-/sex-standardized incidence by 21.6% between 2003 and 2011 (standardized rate 109.4 to 85.8 per 100,000), followed by a reversal and continuous increase of 12.7% between 2011 and 2017 (standardized rate 96.8 per 100,000; Kendall τ-b correlation coefficient −0.33, $p = 0.08$). The pattern was similar for ischemic stroke and ICH, men and women, and those aged 60 years and over (Figure 1A-C and Supplementary Figure 1 A-D). In contrast, there was a continuous rise in incidence for individuals <60 years from 2003 to 2017 (Kendall τ-b 0.89, $p < 0.001$; Figure 1D and Supplementary Figure 1E-F).

Yearly trends in acute stroke incidence were modified by age ($p < 0.001$ for interaction), but not sex or stroke type. While adjusted IRRs for those aged over 60 years declined from 2003 to 2011 then stabilized and increased, IRRs for individuals <60 increased throughout the entire study period and especially after 2011 (Figure 2). The IRR trends were unchanged after adjustment for estimated stroke severity among hospitalized patients. Patterns were also similar for men and women (Supplementary Figure 2).

Discussion

In this population-based study, we found that a decline in stroke incidence between 2003 and 2011 was followed by an increase in incidence between 2011 and 2017, for both ischemic stroke and ICH and for men and women. Stroke incidence increased over the entire study period among those aged under 60 years.

The decreasing incidence of ischemic stroke and ICH in the first half of our study period is consistent with many prior studies.[2,14] However, the increase in incidence between 2011 and 2017 is an unexpected finding, and there are few population-based studies for comparison due to the recency of the

https://doi.org/10.1017/cjn.2020.257 Published online by Cambridge University Press

Table 1: Baseline characteristics of whole cohort for representative years 2003, 2011, and 2017

Variable	Ischemic stroke or ICH			
Year (N events)	2003 (10,295)	2011 (10,148)	2017 (13,476)	*p*-trend
Age (mean ± SD)	73.93 ± 13.02	72.98 ± 13.94	72.98 ± 14.04	<0.001
18–59 (n, %)	1,505 (14.6%)	1,785 (17.6%)	2,376 (17.6%)	<0.001
60–79	4,823 (46.8%)	4,471 (44.1%)	6,095 (45.2%)	<0.001
80+	3,967 (38.5%)	3,892 (38.4%)	5,005 (37.1%)	0.11
Women	5,208 (50.6%)	4,983 (49.1%)	6,451 (47.9%)	<0.001
PaSSV indicator (mean + SD)	7.64 ± 1.82	7.65 ± 1.69	7.72 ± 1.69	<0.001
Ethnicity Chinese or South Asian	371 (3.6%)	537 (5.3%)	782 (5.8%)	<0.001
Lowest two income quintiles	4,579 (44.5%)	4,283 (42.2%)	6,277 (46.6%)	<0.001
Rural residence	1,576 (15.3%)	1,372 (13.5%)	1,773 (13.2%)	<0.001
Hypertension	7,620 (74.0%)	8,105 (79.9%)	10,752 (79.8%)	<0.001
Diabetes	2,952 (28.7%)	3,462 (34.1%)	4,944 (36.7%)	<0.001
Dyslipidemia	933 (9.1%)	970 (9.6%)	1,104 (8.2%)	<0.001
CHF	1,356 (13.2%)	1,224 (12.1%)	1,365 (10.1%)	<0.001
Atrial fibrillation	876 (8.5%)	1,068 (10.5%)	1,114 (8.3%)	0.27
CAD	1,494 (14.5%)	1,652 (16.3%)	2,022 (15.0%)	0.07
Care at a regional stroke center	2,427 (23.6%)	3,545 (34.9%)	5,365 (39.8%)	<0.001

SD indicates standard deviation, CHF congestive heart failure, CAD coronary artery disease. Estimated severity (PaSSV indicator) was derived using linked administrative data, with higher score indicating lower probability of severe stroke.

observation window. An update from the Atherosclerosis Risk in Communities Cohort in the United States demonstrated a continuous drop in overall stroke incidence from 1990 to 2017, although the study had no individuals <65 years old after 2010.[15]

Possible explanations for our findings include improved detection of minor stroke, or differences in care-seeking behavior over the study time period. However, we included both stroke hospitalizations and ED visits, and there was no change in trends after adjustment for estimated stroke severity among hospitalized patients, reducing the likelihood that our findings were due to changes in admission thresholds[16,17] and raising the possibility of a true increase in stroke incidence. Rates of vascular risk factors, particularly diabetes and obesity, are increasing in Canada overall but especially among younger individuals.[18,19] The rise in stroke incidence in our study was particularly striking among young adults, confirming and extending prior observations.[3,4,20] The possibility of changes in other stroke risk factors characteristic of young age, such as recreational drug use, exogenous hormone use, or cervical artery dissection, should also be considered. Although strokes in individuals less than 60 years of age accounted for only 17% of all strokes in our cohort, our finding of a consistent increase in incidence over 15 years is concerning given the potential for greater number of years lived with disability.

Limitations of our study include those inherent to the use of administrative data. We did not have imaging confirmation or physician adjudication of stroke, although the case definitions used have high validity in Canada.[6] We could not assess outpatient visits for stroke due to low specificity of outpatient claims data for stroke[21]; although this would reduce ascertainment of minor stroke it would not explain the pattern of change we observed. We did not include out-of-hospital deaths from stroke due to inability to differentiate ischemic stroke from ICH and we could not determine stroke etiology. Despite these limitations, our study is strengthened by the complete ascertainment of events requiring hospitalization or ED care in a large population.

The observed increase in stroke incidence between 2011 and 2017 suggests the need for research to understand the underlying drivers of this finding, especially among younger individuals, and to determine if these changes are occurring in other jurisdictions.

Acknowledgements

This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care. The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by ICES or the Ontario Ministry of Health and Long-Term Care is intended or should be inferred. Parts of this material are based on data and/or information compiled and provided by the Canadian Institute for Health Information. However, the analyses, conclusions, opinions and statements expressed in the material are those of the author(s), and not necessarily those of the Canadian Institute for Health Information.

RAJ is supported by a Fellowship Grant from the Canadian Institutes of Health Research. AYXY is supported by the Heart & Stroke Foundation of Canada National New Investigator Award. MKK is supported by a Mid-Career Investigator Award from the Heart and Stroke Foundation of Canada and holds the Lillian

https://doi.org/10.1017/cjn.2020.257 Published online by Cambridge University Press

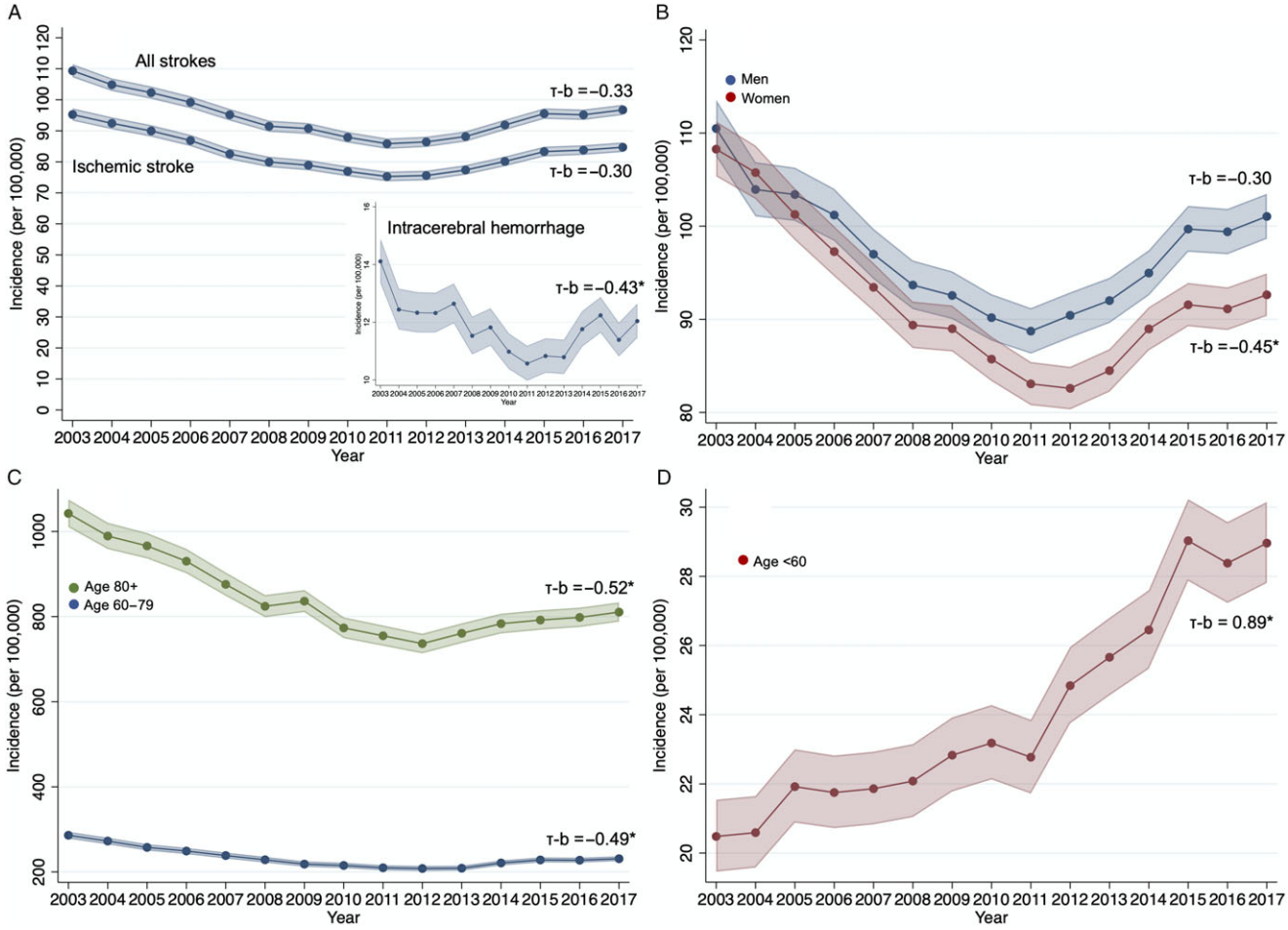

Figure 1: *Age/sex-standardized acute stroke incidence per 100,000 population with 95% CI for overall and for each stroke type (A; inset showing ICH incidence magnified); Age-standardized incidence of men and women for all acute strokes (B); Sex-standardized incidence for those 60–79 or ≥80 years old for all acute strokes (C); Sex-standardized incidence for those < 60 years old for all acute strokes (D). τ-b indicates Kendall τ-b correlation coefficient, * indicates* $p < 0.05$.

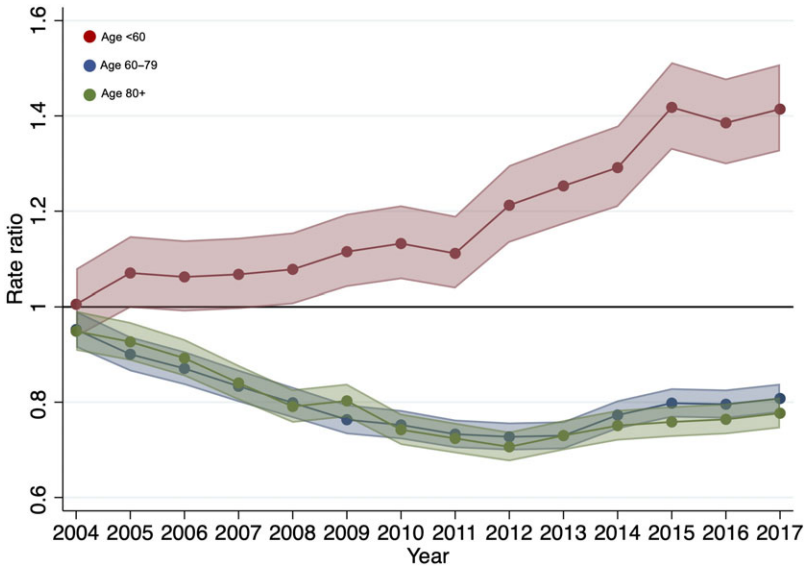

Figure 2: *Age-specific acute stroke incidence rate ratios with 95% CIs for each year compared to 2003, adjusted for stroke type and sex.*

https://doi.org/10.1017/cjn.2020.257 Published online by Cambridge University Press

Love Chair in Women's Health from the University Health Network/University of Toronto.

Funding

The study was supported by the Physicians' Services Incorporated Foundation.

Disclosures

EES reports royalties from UpToDate, consulting fees from Alnylam, Biogen, and Javelin. The remaining authors have no conflicts of interest to declare.

Statement of Authorship

RAJ was involved with conception, design, analysis, interpretation, and drafting the manuscript.

EES was involved with conception, design, interpretation, and critical revision of the manuscript.

AYXY was involved with design, interpretation and critical revision of the manuscript.

MR and JF were involved with data acquisition and analysis.

MKK was involved with conception, design, interpretation, and critical revision of the manuscript.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/cjn.2020.257.

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