Association of Neighborhood-Level Material Deprivation With Health Care Costs and Outcome After Stroke

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Abstract

Background and Objectives
To determine the association between material deprivation and direct health care costs and clinical outcomes following stroke in the context of a publicly funded universal health care system.

Methods
In this population-based cohort study of patients with ischemic and hemorrhagic stroke admitted to the hospital between 2008 and 2017 in Ontario, Canada, we used linked administrative data to identify the cohort, predictor variables, and outcomes. The exposure was a 5-level neighborhood material deprivation index. The primary outcome was direct health care costs incurred by the public payer in the first year. Secondary outcomes were death and admission to long-term care.

Results
Among 90,289 patients with stroke, the mean (SD) per-person costs increased with increasing material deprivation, from $50,602 ($55,582) in the least deprived quintile to $56,292 ($59,721) in the most deprived quintile (unadjusted relative cost ratio and 95% confidence interval 1.11 [1.08, 1.13] and adjusted relative cost ratio 1.07 [1.05, 1.10] for least compared to most deprived quintile). People in the most deprived quintile had higher mortality within 1 year compared to the least deprived quintile (adjusted hazard ratio [HR] 1.07 [1.03, 1.12]) as well as within 3 years (adjusted HR 1.09 [1.05, 1.13]). Admission to long-term care increased incrementally with material deprivation and those in the most deprived quintile had an adjusted HR of 1.33 (1.24, 1.43) compared to those in the least deprived quintile.

Discussion
Material deprivation is a risk factor for increased costs and poor outcomes after stroke. Interventions targeting health inequities due to social determinants of health are needed.

Classification of Evidence
This study provides Class II evidence that the neighborhood-level material deprivation predicts direct health care costs.
The effect of social determinants of health on stroke incidence, care, and outcomes is increasingly recognized. Socioeconomic disadvantage is a social determinant of health that has been shown to be associated with increased mortality after stroke. However, this association is less clear in regions with comprehensive, publicly funded health care. For example, this association was not seen in studies conducted in England (South London Stroke Register) or Italy, but researchers in Canada and other parts of England (Sentinel Stroke National Audit Programme) have found that socioeconomic disadvantage is associated with higher mortality after stroke.

It is not known whether socioeconomic disadvantage is associated with higher direct health care costs following stroke. Whereas universal health care access may address some barriers to affordability of care, higher disability is consistently reported in patients with stroke who are disadvantaged compared to those who are less disadvantaged. A better understanding of the relationship between socioeconomic status and costs may provide additional motivation to invest in programs to promote health equity through action on social determinants of health.

Socioeconomic status is a concept that encompasses many variables, such as education, housing, income, and food security, and it can be measured at an individual or area-based level. The current study's objective was to determine the association between neighborhood-level material deprivation and direct health care costs as well as clinical outcomes following stroke in the context of Canada’s health care system. We hypothesized that socioeconomic disadvantage will be associated with higher costs and morbidity after stroke.

### Methods

#### Cohort Identification

We conducted a population-based retrospective cohort study to evaluate the association between neighborhood-level material deprivation and direct health care costs and clinical outcomes following stroke (Class II evidence). We identified all community-dwelling adults admitted to an acute care hospital with a most responsible diagnosis of ischemic stroke or intracerebral hemorrhage between April 1, 2008, and March 31, 2017, in Ontario, Canada, using validated administrative data algorithms. We excluded patients without valid health insurance numbers, for example non-Canadian visitors, as they are not covered under the provincial health plan. We also excluded patients with subarachnoid hemorrhage because they tend to be younger, to have different disease pathophysiology, and are usually treated under the care of a neurosurgical service. We only included the first event in individuals with multiple events during the study period to derive the cohort.

#### Setting

Residents of Ontario (14 million people) have access to publicly funded, broadly accessible health care programs under the provincial health plan, which includes costs related to hospital fees, drugs prescribed in-hospital, surgical procedures, physician fees, rehabilitation, and long-term care homes. Access is universal, but the extent of the coverage has limits. For example, stroke rehabilitation is generally capped at 12 weeks, outpatient prescription drugs are only universally covered for people over age 65 years, and home care services for people living in the community and requiring assistance with activities of daily living are limited, generally up to a few hours a day, depending on patient needs. Medications and services not covered by the provincial plan are paid for out-of-pocket or by private insurance. Long-term care institutions, which are skilled nursing facilities providing around-the-clock nursing care and assistance for activities of daily living, are publicly funded.

#### Exposure

We used a neighborhood-level exposure variable, a previously developed material deprivation index, as a proxy for socioeconomic status. This index is categorized into 5 quintiles (Q), from the least deprived (Q1) to the most deprived (Q5), and has been shown to be closely related to poverty and is associated with general health outcomes and costs. The elements of this index are obtained from the Canadian census of the population, and include the proportion of the population aged 20 years and older without a high-school diploma, the proportion of families who are lone parent families, the proportion of total income from government transfer payments for the population aged 15 years and older, the proportion of total income from government transfer payments for the population aged 15 years and older who are unemployed, the proportion of the population considered low income, and the proportion of households living in dwellings that are in need of major repair. Census data for individuals are not disclosed. The index was derived in the smallest geographic area for which aggregated census data are disseminated (a dissemination area), and which contains on average 400–700 people.

#### Outcomes

The primary outcome was the direct person-level cumulative costs, calculated from the perspective of the government payer in the first 365 days after the date of the index hospital admission using Ontario’s guidelines on person-level costing calculations using administrative data. Direct costs to the Ontario Ministry of Health and Long-Term Care for physician billings for health services, prescription drugs in patients

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**Glossary**

CI = confidence interval; HR = hazard ratio.

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aged 65 and over, and outpatient diagnostic or laboratory services were calculated for each patient. Home care costs were estimated using the average cost per hour. Long-term care costs were calculated based on the government’s per diem payment rate. Given that costs of encounters in the emergency department, hospital, and inpatient rehabilitation settings depend on the intensity of resource utilization, each encounter in these settings was assigned a resource intensity weight associated with its case mix group, allowing for the calculation of the weighted cost for each visit based on the intensity of use of drugs, procedures, tests, and personnel. Resource intensity weights were calculated using standard methods from the Canadian Institute for Health Information. Costs were adjusted to 2018 Canadian dollars using the Statistics Canada Consumer Price Index for Health.

Secondary outcomes included death within 1 year after stroke, death within 3 years, and long-term care admission within 1 year. We used administrative data to identify the study cohort, covariates, and outcomes. The datasets have been validated and extensively used for research and are housed at ICES (previously the Institute for Clinical Evaluative Sciences; see eTable 1, available from Dryad, doi.org/10.5061/dryad.8kprr4xnt). We present 3 models: unadjusted, adjusted for age and sex, and adjusted for all covariates deemed to be clinically relevant potential confounders, including age, sex, home location (rural vs urban), stroke type (ischemic vs hemorrhagic), vascular comorbidity (diabetes, hypertension, dyslipidemia, atrial fibrillation, prior stroke, coronary artery disease, peripheral arterial disease), frailty using the hospital frailty risk score, and stroke severity using the Passive Surveillance Stroke Severity indicator (eTable 2, available from Dryad, doi.org/10.5061/dryad.8kprr4xnt). Home location and neighborhood income quintile were obtained from the Canadian census and Postal Code Conversion File. We tested the linearity assumption for continuous explanatory covariates in the regression models using restricted cubic splines. The assumption was not satisfied for age, which was categorized as follows in the models: 18–45, 46–65, 66–75, 76–85, and over 85 years. To give further context, we calculated the differences in mean marginal costs between the least deprived quintile and each of the other deprivation quintiles and computed 95% confidence intervals (CIs) using bootstrap percentile intervals with 1,000 bootstrap samples. We used Cox proportional hazard models to evaluate the association between deprivation and death unadjusted, partially adjusted, and fully adjusted for the same covariates as above. For 1-year long-term care admission, we accounted for the competing risk of death by using unadjusted, partially adjusted, and fully adjusted cause-specific hazard models. We present hazard ratios (HRs) and 95% CIs. Robust variance estimators were used to account for the clustering of patients in neighborhoods for all outcomes. All data analyses were performed using SAS Enterprise Guide version 7.1 (SAS Institute Inc.).

Statistical Methods

Descriptive analyses were performed using the $\chi^2$ test to compare categorical variables and Kruskal-Wallis (median) and analysis of variance (mean) tests to compare continuous variables. We assessed the association between material deprivation and costs using a generalized linear model with a gamma distribution and a log link function. The interpretation of the exponentiated regression coefficient, the relative cost ratio, is the relative change in mean cost in each deprivation quintile compared to the least deprived quintile. We present 3 models: unadjusted, adjusted for age and sex, and adjusted for all covariates deemed to be clinically relevant potential confounders, including age, sex, home location (rural vs urban), stroke type (ischemic vs hemorrhagic), vascular comorbidity (diabetes, hypertension, dyslipidemia, atrial fibrillation, prior stroke, coronary artery disease, peripheral arterial disease), frailty using the hospital frailty risk score, and stroke severity using the Passive Surveillance Stroke Severity indicator (eTable 2, available from Dryad, doi.org/10.5061/dryad.8kprr4xnt). Home location and neighborhood income quintile were obtained from the Canadian census and Postal Code Conversion File. We tested the linearity assumption for continuous explanatory covariates in the regression models using restricted cubic splines. The assumption was not satisfied for age, which was categorized as follows in the models: 18–45, 46–65, 66–75, 76–85, and over 85 years. To give further context, we calculated the differences in mean marginal costs between the least deprived quintile and each of the other deprivation quintiles and computed 95% confidence intervals (CIs) using bootstrap percentile intervals with 1,000 bootstrap samples. We used Cox proportional hazard models to evaluate the association between deprivation and death unadjusted, partially adjusted, and fully adjusted for the same covariates as above. For 1-year long-term care admission, we accounted for the competing risk of death by using unadjusted, partially adjusted, and fully adjusted cause-specific hazard models. We present hazard ratios (HRs) and 95% CIs. Robust variance estimators were used to account for the clustering of patients in neighborhoods for all outcomes. All data analyses were performed using SAS Enterprise Guide version 7.1 (SAS Institute Inc.).

Standard Protocol Approvals, Registrations, and Patient Consents

Data were linked using unique encoded identifiers and analyzed at ICES, an independent, nonprofit research institute. The use of data in this project was authorized under section 45 of Ontario’s Personal Health Information Protection Act without the requirement for research ethics board approval.

Data Availability

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

Results

We identified 90,289 patients and describe their characteristics by material deprivation quintile in Table 1. Patients in higher deprivation quintiles were more likely to be younger, be female, live in nonrural regions, have vascular comorbidities except for atrial fibrillation, dyslipidemia, and peripheral artery disease, and have higher frailty scores compared to those in lower deprivation quintiles.

The mean (SD) direct total health care costs in the year following stroke were $53,001 ($57,053) in the overall cohort. Mean costs were lowest in the Q1 (least deprived) group, $50,602 ($55,582), and highest in the Q5 (most deprived) group, $56,292 ($59,721), as shown in Figure 1. The detailed costs by material deprivation quintile in the year preceding and following stroke, stratified by health care setting, can be found in Table 2. The higher costs in the more deprived groups did not appear to be driven by care in a particular health care setting.

Compared to the Q1 (least deprived) group, unadjusted mean costs incurred in the Q4 (very deprived group) were 5% higher (relative cost ratio 1.05, 95% CI [1.03, 1.08]) and those in the Q5 (most deprived) group were 11% higher (relative cost ratio 1.11, 95% CI [1.08, 1.13]). This relationship was attenuated but still present after adjustment for all covariates (Table 3). Mean costs in the first 3 deprivation quintile groups were similar. The estimated marginal difference in mean cost comparing each level of material deprivation group to the Q1 (least deprived) group are in eTable 4, available from Dryad (doi.org/10.5061/dryad.8kprr4xnt).
Unadjusted mortality within 1 year after stroke was similar in all deprivation quintiles. However, once adjusted for age and sex, the hazard of death was higher in the Q5 (most deprived) group compared to the Q1 (least deprived) group (HR 1.08, 95% CI [1.04, 1.13]) and this remained true in the fully adjusted model (HR 1.07, 95% CI [1.03, 1.12]; Figure 2). The increased hazard of death in the most deprived group compared to the least deprived group was still present after 3 years (Figure 2, Table 4).

We observed a gradient of increasing need for long-term care admission within the first year after stroke with increasing deprivation. Compared to the Q1 (least deprived) group, the unadjusted hazard of long-term care admission was 18% higher in the Q3 (slightly deprived) group (HR 1.18, 95% CI [1.09, 1.27]), 22% higher in the Q4 (very deprived) group (HR 1.22, 95% CI [1.13, 1.31]), and 30% higher in the Q5 (most deprived) group (HR 1.30, 95% CI [1.21, 1.40]). These observations remained true in the partially and fully adjusted models (Figure 2, Table 4). In Figure 3, we show the cumulative incidence of admission to long-term care in the first year after stroke for each deprivation group using Fine-Gray models.

### Discussion

In this cohort of patients hospitalized with stroke, we found that socioeconomic disadvantage, measured by a neighborhood-level material deprivation index, was associated with higher direct health care costs and worse clinical outcomes, including more admission to long-term care and

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Table 1 Baseline Characteristics by Material Deprivation Quintile

|                        | Q1: Least deprived (n = 14,609) | Q2: Less deprived (n = 16,042) | Q3: Slightly deprived (n = 17,490) | Q4: Very deprived (n = 19,529) | Q5: Most deprived (n = 22,619) | Total (n = 90,289) | p Value |
|------------------------|---------------------------------|---------------------------------|-----------------------------------|---------------------------------|---------------------------|------------------|--------|
| Median age, y (Q1, Q3) | 75 (64, 83)                     | 75 (64, 83)                     | 75 (64, 83)                       | 74 (63, 83)                     | 73 (61, 82)               | 74 (63, 83)     | <0.0001 |
| Female sex             | 6,583 (45.1)                    | 7,329 (45.7)                    | 8,056 (46.1)                      | 9,239 (47.3)                    | 10,747 (47.5)            | 41,954 (46.5)   | <0.0001 |
| Rural                  | 1,326 (9.1)                     | 2,463 (15.4)                    | 3,115 (17.8)                      | 3,083 (15.8)                    | 1,941 (8.6)              | 11,928 (13.2)   | <0.0001 |
| Hypertension           | 11,718 (80.2)                   | 12,939 (80.7)                   | 14,292 (81.7)                     | 16,024 (82.1)                   | 18,521 (81.9)            | 73,494 (81.4)   | <0.0001 |
| Diabetes               | 4,526 (31.0)                    | 5,373 (33.5)                    | 6,229 (35.6)                      | 7,308 (37.4)                    | 9,059 (40.1)             | 32,495 (36.0)   | <0.0001 |
| Atrial fibrillation    | 1,488 (10.2)                    | 1,651 (10.3)                    | 1,764 (10.1)                      | 1,991 (10.2)                    | 2,166 (9.6)              | 9,060 (10.0)    | 0.1153  |
| Dyslipidemia           | 4,530 (31.0)                    | 4,930 (30.7)                    | 5,200 (29.7)                      | 5,942 (30.4)                    | 6,435 (28.4)             | 27,037 (29.9)   | <0.0001 |
| History of stroke      | 907 (6.2)                       | 1,069 (6.7)                     | 1,160 (6.6)                       | 1,331 (6.8)                     | 1,620 (7.2)              | 6,087 (6.7)     | 0.0086  |
| Coronary artery disease| 2,376 (16.3)                    | 2,842 (17.7)                    | 3,153 (18.0)                      | 3,439 (17.6)                    | 4,101 (18.1)             | 15,911 (17.6)   | <0.0001 |
| Peripheral artery disease| 795 (5.4)                      | 897 (5.6)                       | 964 (5.5)                         | 1,098 (5.6)                     | 1,313 (5.8)              | 5,067 (5.6)     | 0.6031  |
| Frailty risk score      |                                 |                                 |                                   |                                 |                          |                 | <0.0001 |
| High                   | 1,415 (9.7)                     | 1,557 (9.7)                     | 1,703 (9.7)                       | 2,004 (10.3)                    | 2,586 (11.4)             | 9,265 (10.3)    |        |
| Intermediate           | 5,305 (36.3)                    | 5,911 (36.8)                    | 6,489 (37.1)                      | 7,282 (37.3)                    | 8,892 (39.3)             | 33,879 (37.5)   |        |
| Low                    | 7,889 (54.0)                    | 8,574 (53.4)                    | 9,298 (53.2)                      | 10,243 (52.5)                   | 11,141 (49.3)            | 47,145 (52.2)   |        |
| Stroke type            |                                 |                                 |                                   |                                 |                          |                 | 0.0002  |
| Hemorrhage             | 2,014 (13.8)                    | 2,165 (13.5)                    | 2,334 (13.3)                      | 2,537 (13.0)                    | 2,781 (12.3)             | 11,831 (13.1)   |        |
| Ischemia               | 12,595 (86.2)                   | 13,877 (86.5)                   | 15,156 (86.7)                     | 16,992 (87.0)                   | 19,838 (87.7)            | 78,458 (86.9)   |        |
| Stroke severity        |                                 |                                 |                                   |                                 |                          |                 | 0.0012  |
| Mild                   | 7,268 (49.8)                    | 8,055 (50.2)                    | 8,973 (51.3)                      | 10,070 (51.6)                   | 11,620 (51.4)            | 45,986 (50.9)   |        |
| Moderate               | 6,568 (45.0)                    | 7,139 (44.5)                    | 7,635 (43.7)                      | 8,501 (43.5)                    | 9,756 (43.1)             | 39,599 (43.9)   |        |
| Severe                 | 773 (5.3)                       | 848 (5.3)                       | 882 (5.0)                         | 958 (4.9)                       | 1,243 (5.5)              | 4,704 (5.2)     |        |

Values are n (%).
death, in the year following stroke. The association between socioeconomic disadvantage and poor outcomes after stroke has been consistently reported, but the relationship between deprivation, costs of care, and clinical outcomes in the context of a publicly funded health care system is less understood. Although a publicly funded system is expected to promote fair access to care, our findings suggest that health inequities are nevertheless present.

There are several potential explanations for our findings. First, while access to the public health care system is universal, it is not comprehensive. Patients with stroke may require services that are beyond the public system, such as extended rehabilitation, prescription drug costs for most people under age 65 years, and the daily home care needs of some community-dwelling stroke survivors may exceed the public home care capacity. Wealthier people may have more economic or social capital to access additional services, such as hiring private personal support workers or paying for supplementary therapy. These privately purchased services may relieve the government payer of direct costs, while also potentially decreasing mortality and lowering the need for long-term care admission. In addition, material deprivation often coexists with other social determinants of health, including race-

Table 2 Mean (SD) Direct Health Care Costs by Material Deprivation Quintile Before and After Stroke, Total Costs and Categorized by Health Care Setting

|                        | Q1: Least deprived (n = 14,609) | Q2: Less deprived (n = 16,042) | Q3: Slightly deprived (n = 17,490) | Q4: Very deprived (n = 19,529) | Q5: Most deprived (n = 22,619) | p Value   |
|------------------------|---------------------------------|---------------------------------|----------------------------------|---------------------------------|---------------------------------|-----------|
| Prestroke total cost   | $10,368 (21,056)                | $10,725 (21,642)                | $10,580 (21,541)                 | $10,696 (21,588)                | $11,415 (22,580)                | <0.0001   |
| Poststroke total cost  | $50,602 (55,582)                | $51,452 (55,351)                | $51,720 (55,681)                 | $53,404 (57,395)                | $56,292 (59,721)                | <0.0001   |
| Prestroke acute care cost | $3,212 (11,036)                | $3,498 (11,901)                | $3,565 (12,390)                 | $3,514 (11,447)                | $3,833 (12,353)                | <0.0001   |
| Poststroke acute care cost | $20,681 (30,688)               | $21,056 (30,434)                | $21,556 (31,990)                | $22,515 (33,634)                | $23,810 (34,674)                | <0.0001   |
| Prestroke outpatient care cost | $5,658 (11,995)               | $5,653 (10,980)                | $5,522 (11,045)                 | $5,645 (11,595)                | $5,971 (12,502)                | 0.0019    |
| Poststroke outpatient care cost | $9,959 (10,976)               | $9,869 (10,438)                | $9,842 (10,661)                 | $10,126 (11,538)                | $10,434 (11,517)                | <0.0001   |
| Pre-stroke rehabilitation cost | $337 (2,877)                 | $391 (3,348)                   | $334 (3,055)                    | $355 (3,227)                    | $312 (2,713)                    | 0.1382    |
| Poststroke rehabilitation cost | $9,575 (15,907)               | $9,826 (16,663)                | $9,986 (16,443)                 | $9,829 (16,340)                 | $10,367 (16,939)                | <0.0001   |
| Prestroke home care cost | $1,160 (4,373)                 | $1,183 (4,367)                 | $1,159 (3,994)                  | $1,182 (4,263)                  | $1,300 (4,614)                  | 0.0042    |
| Poststroke home care cost | $2,731 (6,731)                 | $2,749 (6,446)                 | $2,831 (6,741)                  | $2,850 (6,659)                  | $2,836 (6,521)                  | 0.3238    |
| Prestroke long-term care cost | —                              | —                               | —                               | —                               | —                               |           |
| Poststroke long-term care cost | $7,656 (27,010)               | $7,952 (26,942)                | $7,505 (25,671)                 | $8,084 (26,117)                 | $8,846 (28,151)                 | <0.0001   |

eTable 3, available from Dryad (doi.org/10.5061/dryad.8kprr4xnt), provides mean direct health care costs and 95% confidence intervals.
ethnicity, immigration status, and language proficiency, which may result in additional challenges in advocating for care needs as well as navigating the health system.  

Second, socioeconomic status, education, and health-related behaviors are closely related.  

Although all patients in Canada theoretically have equal access to acute revascularization treatments, such as IV thrombolysis or endovascular thrombectomy, delays in stroke recognition or arrival to hospital due to differences in awareness of stroke symptoms may affect eligibility for these treatments and outcomes. Differences in health knowledge and health-seeking behavior may lead to worse outcomes and higher costs after stroke.

Third, secondary stroke management in outpatient clinics is covered by public health care, but people who experience material deprivation may have more difficulties attending

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**Table 3** Relative Cost Ratio (95% Confidence Intervals) Comparing Each Material Deprivation Quintile to the Least Deprived Group

| Quintile                | Unadjusted modela | Partially adjusted modelb | Fully adjusted modelc |
|-------------------------|-------------------|---------------------------|-----------------------|
| Q1: Least deprived (n = 14,609) | Ref 1.01 (0.99,1.04) | 1.02 (1.00,1.05) | 1.05 (1.03,1.08) |
| Q2: Less deprived (n = 16,042)     | 1.02 (0.99,1.04) | 1.02 (1.00,1.05) | 1.06 (1.03,1.09) |
| Q3: Slightly deprived (n = 17,490)  | 1.02 (0.99,1.04) | 1.02 (1.00,1.05) | 1.05 (1.03,1.08) |
| Q4: Very deprived (n = 19,529)      | Ref 1.01 (0.99,1.04) | 1.02 (1.00,1.05) | 1.05 (1.03,1.08) |
| Q5: Most deprived (n = 22,619)      | 1.01 (0.99,1.04) | 1.02 (1.00,1.05) | 1.07 (1.05,1.10) |

* Unadjusted linear regression model in gamma distribution using log link function.
  a Model adjusted for sex only.
  b Model adjusted for age, sex, rural home location, hypertension, diabetes, atrial fibrillation, dyslipidemia, coronary artery disease, peripheral arterial disease, prior history of stroke, stroke type, and stroke severity.

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**Figure 2** Hazard Ratios (95% Confidence Intervals) Comparing Each Material Deprivation Quintile to the Least Deprived Group (Quintile 1) Using Cox Proportional Hazard Models for Death and Cause-Specific Hazard Models for Long-term Care Admission

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these appointments due to language barriers, restrictions in mobility, or limited caregiver support, leading to potential missed opportunities for secondary stroke prevention and screening for complications after stroke.\(^2^\) In addition, health outcomes are affected by non-health policies, such as paid work leave. Although physician fees are covered by the public health system, our data suggest that there may be additional barriers to care.

Finally, consistent with other studies, we found that the direct health care costs in the year following stroke were high (mean per-person cost of $53,001),\(^2^\)\(^9\) higher than caring for people in the first year after diagnosis of cancer ($25,914)\(^3^\)\(^0\) or coronary artery disease ($23,000–26,000)\(^3^\)\(^1\) in Canada. The mean per-person cost increments by material deprivation quintiles were modest, about $5,000 higher in the most deprived group compared to the least deprived group. Nevertheless, from the public payer’s perspective, given that we identified 22,619 patients categorized as most deprived during the 9-year study period, a small increment in mean per-person cost translates to a large amount (22,619 × $5,000 = $113,095,000). Importantly, higher costs did not eliminate the disparities in outcomes. Further work on the health needs of people with stroke and material deprivation, such as informal caregiving needs, indirect costs, and other barriers to health care access, are needed to achieve equitable health outcomes and potentially reduce overall public health expenditures.

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**Table 4** Crude Proportions of Death and Admission to Long-term Care by Neighborhood-Level Material Deprivation Quintile and Hazard Ratio (95% Confidence Interval) From the Cox Proportional Hazard Models (Death) and Cause-Specific Hazard Models (Long-term Care Admission)

| Death within 1 y, n (%) | Q1: Least deprived (n = 14,609) | Q2: Less deprived (n = 16,042) | Q3: Slightly deprived (n = 17,490) | Q4: Very deprived (n = 19,529) | Q5: Most deprived (n = 22,619) |
|--------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Death within 3 y, n (%)   | 4,852 (33.2)                   | 5,548 (34.6)                   | 5,958 (34.1)                   | 6,677 (34.2)                   | 7,735 (34.2)                   |

**Figure 3** Cumulative Incidence of Admission to Long-term Care (LTC) in the First Year after Stroke for Each Deprivation Group

Shaded area represents 95% confidence bands. Deprivation quintile 1 is least deprived and 5 is most deprived.
Our study has several strengths, including its large sample size, prolonged follow-up time, and the use of validated administrative data codes to identify a population-based cohort of patients hospitalized with stroke as well as a validated proxy for stroke severity, which is often absent from administrative health data. There are nevertheless limitations worth discussing. First, we used a neighborhood-level measure of material deprivation as a proxy for individual-level socioeconomic status and our results must be interpreted in the context of potential ecologic fallacy. However, this area-level measure allowed us to evaluate outcomes in a population-based cohort with a long follow-up time, and we showed a gradient between deprivation quintiles and the outcomes of costs and long-term care admission, suggesting that this association is biologically plausible. Second, we evaluated direct health care costs from the perspective of the payer, the government, but do not include costs from the patient’s perspective, such as loss in income and services acquired privately. Third, we did not include people with TIA or minor strokes who were not hospitalized. However, given the universal health care context, we expect that we have captured clinically significant strokes during the study period. We also could not evaluate treatment with IV thrombolysis or endovascular thrombectomy. Fourth, this is an observational study using population-based administrative data and, despite adjustment for many factors, residual confounding cannot be excluded. Finally, we were unable to evaluate the quality of care. Future studies on the association and causal pathways between deprivation and quality of stroke care and outcomes are needed.

Material deprivation is associated with higher health care costs, mortality, and morbidity after stroke, and it should be recognized as a risk factor for poor outcomes even in a setting with universal access to health care services. Investments targeting health inequities related to social determinants of health have potential to optimize the cost-effectiveness of public health care and improve outcomes.

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Appendix (continued)

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