

# Time Trends and Geographic Disparities in Acute Complications of Diabetes in Ontario, Canada

GILLIAN L. BOOTH, MD, MSc<sup>1,2,3</sup>  
 JANET E. HUX, MD<sup>1,3,4,5</sup>

JIMING FANG, PHD, MSc<sup>3</sup>  
 BENJAMIN T.B. CHAN, MD, MPH, MPA<sup>3,4,6,7</sup>

**OBJECTIVE** — This study examines whether acute diabetes complication rates have fallen in recent years and whether geographic factors influence these trends.

**RESEARCH DESIGN AND METHODS** — A population-based time-trend analysis of acute complications of diabetes was conducted using linked administrative and census data from Ontario, Canada. The study population included all adults identified through a province-wide electronic diabetes registry between 1994 and 1999 ( $n = 577,659$ ). The primary outcome was hospitalizations for hyper- and hypoglycemia and emergency department visits for diabetes.

**RESULTS** — Between 1994 and 1999, rates of hospitalization for hyper- and hypoglycemic emergencies decreased by 32.5 and 76.9%, respectively; emergency department visits for diabetes fell by 23.9%. On multivariate analysis, fiscal year was an independent predictor of acute diabetes complications, with individuals in our cohort experiencing a decline in risk of ~6% per year for either being hospitalized with hyper- or hypoglycemia or requiring an emergency department visit for diabetes. After accounting for variation in physician service use, diabetic individuals living in rural areas or Aboriginal communities were nearly twice as likely to have an acute complication, whereas those residing in remote areas of the province were nearly three times as likely to experience an event.

**CONCLUSIONS** — Although our findings suggest an overall improvement in diabetes care in Ontario, certain subgroups of the population continue to experience higher rates of complications that are potentially preventable through good ambulatory care. Measures to improve access to timely and effective outpatient care may further reduce rates of acute complications among the diabetic population.

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**R**esults of randomized trials published over the past decade have proven the importance of tight glycemic control in preventing chronic complications of diabetes (1,2). However, despite these advances in knowledge, there remains a considerable gap between the level of care recommended by evi-

From the <sup>1</sup>Department of Medicine, University of Toronto, Ontario, Canada; <sup>2</sup>St. Michael's Hospital, Toronto, Ontario, Canada; the <sup>3</sup>Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada; the <sup>4</sup>Department of Health Policy, Management, and Evaluation, University of Toronto, Ontario, Canada; the <sup>5</sup>Sunnybrook and Women's College Health Sciences Centre, Toronto, Ontario, Canada; the <sup>6</sup>Department of Family and Community Medicine, University of Toronto, Ontario, Canada; and the <sup>7</sup>Health Quality Council, Saskatoon, Saskatchewan, Canada.

Address correspondence and reprint requests to Gillian L. Booth, MD, Division of Endocrinology and Metabolism, St. Michael's Hospital, 61 Queen St. East, 6-147, Toronto, Ontario, Canada M5C 2T2. E-mail: boothg@smh.toronto.on.ca.

B.T.B.C. is currently affiliated with the Department of Community Health and Epidemiology, College of Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

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**Abbreviations:** GEE, generalized estimating equation; ODD, Ontario Diabetes Database.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

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dence-based guidelines and actual practice (3,4). A broad range of provider factors have been identified as barriers to adopting evidence into practice (5,6). Reduced access to health services can also impede the optimal delivery of care, contributing to gaps between outcomes in the general population and those achieved in clinical trials.

Because hospitalizations for acute diabetic emergencies should be largely avoidable, these episodes provide one measure of the quality of diabetes care provided in the ambulatory setting. The translation of evidence regarding tight glycemic control into clinical practice could result in lower rates of hospitalizations for hyperglycemia but might also lead to a rise in the use of acute care services to manage severe hypoglycemia. Studies from several countries have failed to identify a decline in acute hyperglycemic admissions on a per capita basis. However, such trends might have been masked by a concomitant rise in the prevalence of diabetes (7,8), or increasing barriers to accessing timely and effective outpatient care. In Canada, both outpatient and in-hospital medical services are universally covered through provincial health insurance plans. However, variations in health outcomes related to diabetes have been observed across geographic regions, favoring urban over rural areas (9–11). Disparities in access to outpatient services could explain these findings. Increasing physician supply shortages over the past decade may have created further constraints to providing care to patients with diabetes and other chronic diseases in rural areas of the country (12).

We conducted a population-based time-trend analysis of avoidable hospitalizations and emergency department visits related to hyper- or hypoglycemia in Ontario, Canada between 1994 and 1999 — a period during which a number of studies were published regarding the benefit of tight glycemic control. The primary purpose of this study was to examine whether the quality of diabetes care, as

reflected in rates of acute complications, improved over this period of time. Secondary objectives were to examine whether these trends were consistent in all areas of the province and whether patients living in rural or geographically remote areas experience higher rates of these complications.

## RESEARCH DESIGN AND METHODS

The Ontario Diabetes Database (ODD), a validated electronic registry created from administrative data sources, was used to identify all adults  $\geq 20$  years of age with diabetes in the province of Ontario between 1 April 1994 and 31 March 1999 ( $n = 577,659$ ). Creation of the database is described in full elsewhere (13). Briefly, hospital discharge abstracts prepared by the Canadian Institute for Health Information were used to identify patients admitted to a hospital with a new or preexisting diagnosis of diabetes based on the presence of an ICD-9 code of 250.x on any one of 16 diagnostic fields. Physicians' service claims records were used to identify visits for diabetes (diagnostic code "250"). Any individuals having at least one hospitalization or two physicians' service claims bearing a diagnosis of diabetes within a 2-year period were included in the ODD. All subjects entering the ODD remain in the database until death or migration out of province. The ODD has been well validated and shown to have a high sensitivity (86%) and specificity (97%) for identifying individuals in whom diabetes was recorded in primary care charts (13). Records for individuals in the ODD were linked to other administrative data sets using a unique and confidential patient identifier. These records were also linked to census data to derive neighborhood-level variables using the individuals' postal code of residence.

The number of acute complications experienced by individuals in this cohort was assessed on a yearly basis. Hospitalizations for hyperglycemia were identified from the Canadian Institute for Health Information records listing diabetic ketoacidosis, hyperosmolar nonketotic coma, or a mixed case of ketoacidosis and hyperglycemic coma (ICD-9 codes 250.1–250.3) as one of the primary diagnoses leading to hospitalization, whether or not it was felt to be the most responsible diagnosis accounting for the length of stay in hospital. Similar methods were used to identify admissions for hypoglycemic/insulin coma (ICD-9 code 251.0). Diabetes-related emergency

department visits were derived from physicians' service claims bearing a diagnostic code for diabetes (250) or hypoglycemia (251) and indicating that the encounter occurred in an emergency department. These claims list only a single diagnosis and contain only the first three digits of the ICD-9 code, diminishing the ability to distinguish between visits related to hyperglycemia and those related to hypoglycemia. Thus, emergency department visits for these diagnoses were pooled to create a category that reflects both aspects of glucose control.

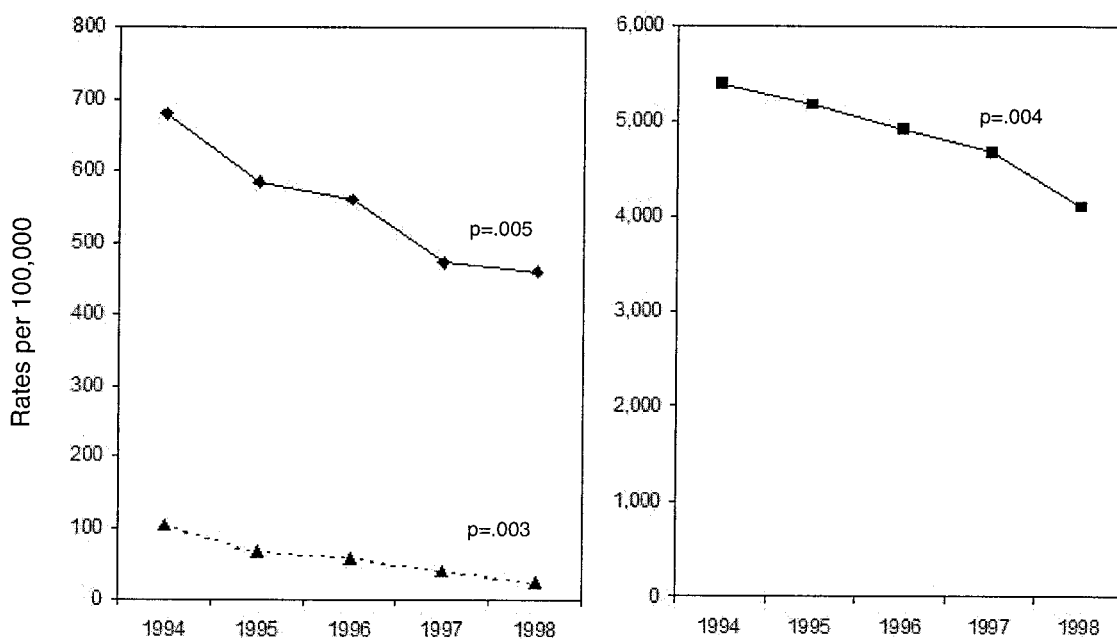
We examined whether rates of hospitalization for hyperglycemia and hypoglycemia or emergency department visits for diabetes changed significantly between fiscal 1994 (1 April 1994–31 March 1995) and fiscal 1998 (1 April 1998–30 March 1999). Age- and sex-adjusted rates for each of these three outcomes were calculated for each fiscal year. The numerator was the total number of episodes in a given year and the denominator was the total number of persons with diabetes who were in the ODD during the same time frame. Simple linear regression was used to calculate the crude rate of change in complication rates over time in the entire province and within two separate geographic regions: Southern Ontario, which contains the largest concentration of urban areas in the province, and Northern Ontario, comprised largely of smaller and more isolated communities. Southern Ontario contains six distinct health planning regions, but previous data demonstrated significantly less variation in acute diabetes complication rates among southern regions than between southern and northern regions. Therefore, for these regression analyses, rates were pooled for all areas in Southern Ontario (9). To assess whether temporal trends were consistent in these two areas of the province, multiple linear regression was used to identify interactions between fiscal year and geographic region.

Generalized estimating equations (GEEs) with a repeated measures analysis were then used to evaluate whether fiscal year was an independent predictor of the total annual number of acute events (defined either as a hospitalization for hyper- or hypoglycemia or an emergency department visit for diabetes) after accounting for changes in health care utilization and population demographics over the 5-year period. A Poisson link function was used and an autoregressive error term was

modeled to account for serial autocorrelation of the time series data.

Geographic location of residence was an important covariate that was accounted for in the GEE model. Residential location was categorized by: 1) proximity to medical care, with remote locations defined as those  $> 100$  km (or a minimum of 1 h away) from the nearest emergency department; 2) urban (population  $\geq 10,000$ ) versus rural status; and 3) planning region, as defined by Ontario's Ministry of Health and Long-Term Care. The model also adjusted for age, sex, annual number of visits to a primary care physician, endocrinologist and general internist, and community-level measures of income, aboriginal status, and education. Level of comorbidity was determined using the Johns Hopkins Adjusted Clinical Group case-mix assignment software (Sun Sparc/Solaris version 4.52) to create distinct case-mix categories (collapsed ambulatory diagnostic groups) based on diagnostic codes listed in hospitalization and physicians' services claims records from each year during the study period (14,15). Physicians' service claims were used to identify all office visits for patients in our cohort over the same period of time. These records were linked to the Corporate Provider Database, which includes information on areas of specialization for all physicians in the province, using a unique and confidential physician identifier common to these databases. Socioeconomic status was assigned to individuals in our cohort based on the median household income level of their neighborhood of residence as reported in the 1996 Canadian Census (16). Education level was also estimated using community-level census data; those residing in neighborhoods where  $> 20\%$  of the population did not attend high school were categorized as having a low level of education compared with all other groups. Aboriginal status was assigned to individuals in our cohort if they lived in a community where  $\geq 85\%$  of residents identified themselves as being of First Nations status on census records (17). Clinical details, such as diabetes subtype and glycemic control, are not available in administrative data sources and therefore were not included in the model. Predictor variables were allowed to vary by year.

Because many individuals in our cohort ( $n = 577,659$ ) had multiple outcome events over the 5-year period, the dataset for the GEE analysis was quite large (2,160,572 observations). Therefore, the



**Figure 1**—Temporal trends in hospitalizations and emergency department visits. ◆, hospitalizations for hyperglycemia; ▲, hospitalizations for hypoglycemia; ■, emergency department visits for diabetes.

GEE analysis was performed on a randomly selected sample (15% of the cohort). This procedure was repeated 10 times; only variables in which  $\geq 9$  of 10 tests had  $P < 0.05$  were considered to be statistically significant.

We also examined the impact of fiscal year, geographic location, and other covariates on the likelihood of having any acute diabetes complication over the 5-year period among members of our cohort ( $n = 577,659$ ). In this analysis, a logistic regression model was used to evaluate the effect of each factor on the development of either a hospitalization for hyper- or hypoglycemia or an emergency department visit for diabetes between fiscal 1994 and 1998. All analyses were performed using SAS 8.2.

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## RESULTS

### Temporal trends in acute complications

Between 1994 and 1999, hospital admissions for hyperglycemic emergencies in

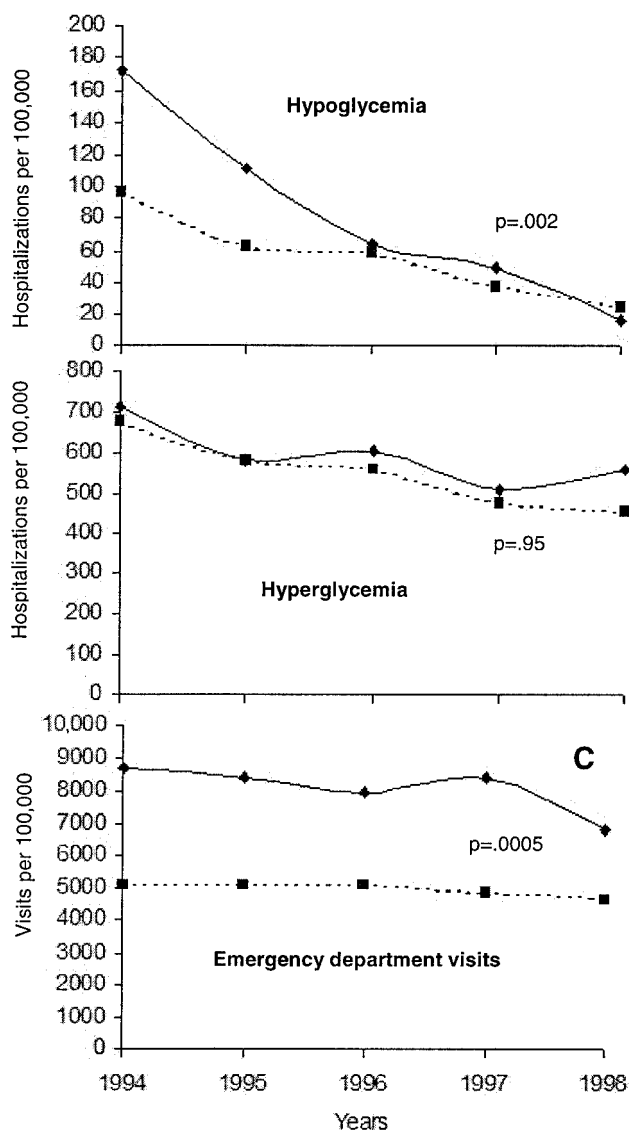
Ontario fell by 33% ( $-55.1$  per 100,000 persons with diabetes/year) (Fig. 1). There was also a marked decline in hospital admissions for hypoglycemia ( $-18.7$  per 100,000/year) and a concomitant fall in emergency department visits for diabetes ( $-307.8$  per 100,000/year) over the 5-year period. These changes were observed across the province, although the rate and magnitude of decline varied by region (Fig. 2). More remote, northern areas had higher rates of admission for hypoglycemia and emergency department visits for diabetes throughout the period of study but experienced comparable or even greater declines in rates as areas in southern Ontario. On multivariate analysis, fiscal year was an independent predictor of the total number of acute diabetes complications and of the likelihood that individuals in our cohort experienced any of these events (Table 1). After adjusting for measures of health care utilization, geographic location, and demographic factors, the odds of having a hospitalization for hyper- or hypoglycemia or an emergency department visit for diabetes fell by  $\sim 6\%$  per year.

### Predictors of acute complications

Diabetic individuals at risk for reduced access to care were more likely to suffer from an acute complication of diabetes (Table 1). Even after accounting for dif-

ferences in service use, individuals living in rural areas of the province or in Aboriginal communities were up to 1.8 times more likely to visit an emergency department or be admitted to a hospital for management of diabetes than those living in urban or nonaboriginal communities. Furthermore, those residing in remote areas of the province were nearly three times as likely to suffer from one of these complications. In contrast, individuals residing in Toronto, where the greatest density of diabetes services is found, were only 50% as likely to have an acute complication as those living in northern regions of the province, where substantially fewer diabetes services are available. In general, logistic regression and GEE analyses yielded similar results. The only exception was that residence in an aboriginal community did not significantly predict the number of acute complications suffered when region was included in the GEE model. Low income remained an important predictor after adjusting for geographic indicators.

**CONCLUSIONS** — Between 1994 and 1999, we observed a substantial decline in acute diabetes complication rates in Ontario. Hospitalizations for hyperglycemia fell by 33% and hospitalizations for hypoglycemia decreased by 75%. Reduced access to in-hospital beds has con-



**Figure 2**—Temporal trends in acute complications by region. ♦, northern Ontario; ■, southern Ontario (mean rate for six southern health planning regions). P values are for comparisons between northern (more remote) and southern (less remote) Ontario. Significant interaction between year and region only for trend in hospitalizations for hypoglycemia (P = 0.08).

tributed to lower admission rates for other chronic conditions as well (18). However, we noted a concomitant fall in emergency department visits over the same time period, suggesting that the lower rates of hospitalization represent a true decline in complications rather than a rise in the threshold for admission. In fact, the fall in emergency department visits surpassed a general decline in emergency department use per capita in Ontario throughout the 1990s (19). These trends occurred in the wake of large-scale studies promoting tighter control of blood glucose levels (1,2) and suggest that practice patterns

changed over the period of study, leading to better outcomes for patients with diabetes throughout Ontario.

Our data also showed that geographic factors strongly influence the risk of avoidable complications related to diabetes, highlighting the importance of non-insurance barriers in delivering care to this population. Individuals living in remote areas were at particularly high risk, being three times as likely to use acute care services for management of diabetes. Greater distances to primary care may cause patients living in remote settings to delay seeking medical attention in the

early stages of a diabetic emergency, when further deterioration in glycemic control could have been avoided through outpatient management. An alternate explanation is that those living in remote areas are more inclined to use emergency services for less severe episodes. Detailed clinical information is not available in administrative data; however, case severity as measured by in-hospital mortality appears to be comparable in different regions of the province, suggesting that the regional differences are not merely due to a lower threshold for use of hospital services in remote areas (9).

Imbalances in physician supply may contribute to geographic variation in outcomes. From previous data, persons with diabetes living in rural, underserved areas of Ontario have comparable access to primary care as those living in areas where the number of full time physicians per capita is higher (20). However, areas with a lower supply of primary care physicians may have higher patient volumes per practice. Providers may therefore face greater time constraints in delivering comprehensive diabetes care. In Ontario, the use of endocrinologists and internal medicine specialists by patients with diabetes is highly contingent on physician supply (20). Although we adjusted for variations in the use of these services, the local supply of specialists may indirectly influence the quality of care provided by family/general practitioners by providing opportunities for educational interactions between physician groups. Furthermore, there may be substantial regional variations in access to and use of nonphysician services, which cannot be tracked using administrative data. Diabetes education programs have been shown to reduce short-term outcomes of diabetes (21,22) and their use may be highly correlated with access to specialist services.

Inherent differences between populations living in various regions might also contribute to disparities in acute complication rates across areas of the province. A previous study showed that socially isolated aboriginal communities experience proportionately more preventable hospitalizations for ambulatory care-sensitive conditions (such as infection, congestive heart failure, and asthma) than neighboring nonaboriginal communities (17). We accounted for this in part by adjusting for the level of comorbidity in our cohort. However, aboriginal groups and others

Table 1—Multivariate predictors of acute diabetic complications

	Estimated total number of episodes (GEE model)	Likelihood of $\geq 1$ episode (logistic regression model)		
		Adjusted odds ratio	95% CI	P value
Per year	-0.05465*	0.94	0.94-0.95	<0.0001
Geographic predictors				
Rural	0.51679*	1.54	1.51-1.57	<0.0001
Aboriginal community	0.38295†	1.84	1.65-2.05	<0.0001
Remote community	0.88850*	2.84	2.41-3.35	<0.0001
Toronto region	-0.55230*	0.55	0.54-0.57	<0.0001
Community-level factors				
Low education level	0.00031†	1.02	0.97-1.07	NS
Neighborhood income				
Quintile 1 (lowest)	0.22859*	1.26	1.23-1.29	<0.0001
Quintile 2	0.17393‡	1.19	1.16-1.22	<0.0001
Quintile 3	0.07216†	1.09	1.06-1.12	<0.0001
Quintile 4	0.08033†	1.09	1.06-1.12	<0.0001
Quintile 5 (highest)	—	1.00	—	—

All analyses were adjusted for age, sex, comorbidity, and annual number of visits to primary care providers, general internists, and endocrinologists. Logistic regression analysis included the entire cohort ( $n = 577,659$ ). An episode is defined as hospitalization for hyperglycemia or hypoglycemia or an emergency department visit for diabetes. \* $P < 0.001$ ; † $P$  was not significant;  $P \geq 0.05$  on two or more randomly selected samples (15% of cohort) out of 10; ‡ $P < 0.01$ .

may be more prone to developing acute illnesses that can adversely affect glycemic control, thus leading to higher rates of admission for hyper- or hypoglycemia. Other key factors, including health literacy, attitudes and beliefs, and the presence or absence of adequate social support, could cause cultural differences in the propensity to seek care and general competency in self-managing diabetes, and therefore could contribute to the observed variation in diabetes complication rates across communities (23–25).

Although administrative data offer a population-wide picture of acute diabetes complications, there are some limitations to using these sources. First, an increased frequency of screening for diabetes could have led to proportionately greater numbers of asymptomatic subjects in our database, thus resulting in higher population denominators and a greater apparent drop in complication rates than what actually occurred. However, acute complication rates fell progressively throughout the period of study, even before 1998 when clinical guidelines promoting lower thresholds for diagnosing diabetes were published (26). Moreover, previous analyses based on the same time period and the same data sources suggested that the rate of new cases of diabetes was relatively stable (27). Secondly, the amount of clin-

ical information contained in administrative records is limited. For example, episodes of severe hypoglycemia treated by emergency medical personnel in the field are not captured by these sources; therefore emergency department visit rates may underestimate the prevalence of this complication (28). However, a shift from in-hospital to out-of-hospital care in the management of hyper- and hypoglycemia probably reflects a lesser degree of patient acuity and translates to a lesser burden on the health care system. Lastly, physicians may vary in their coding of service claims. Therefore, some emergency department visits, classified as an outcome event, might in fact have been non-urgent or even unrelated to diabetes. However, increasing shortages of primary care physicians during this period would have tended to drive emergency department visit rates higher (16); thus, the observed fall in rates suggests a true reduction in acute complications.

Because of its complexity, diabetes management requires intense resources and regular access to health care services to prevent long-term complications. Although our findings suggest an overall improvement in diabetes care in Ontario, certain subgroups of the population continue to experience higher rates of complications that are potentially preventable

through good ambulatory care. Our findings have direct implications for both clinical practice and policy. Providers need to be aware of available resources to reduce geographic inequities in access to services and other barriers to receiving care. However, given the dramatic rise in diabetes prevalence rates, further strategies are urgently needed. Factors influencing the accessibility of services vary substantially across health systems; thus, government and local health authorities should work together to better understand which elements modify access to care and outcomes within their own population.

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