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Original Research

Factors Associated With Attainment of Glycemic Targets Among Adults With Type 1 and Type 2 Diabetes in Canada: A Cross-sectional Study Using Primary- and Specialty-care Electronic Medical Record Data

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Key Messages

- We evaluated attainment of glycemic targets and associated characteristics among individuals with type 1 and type 2 diabetes.
- Most individuals do not meet the A1c target of ≤7.0% and sex, income, geographic location, and therapeutic inertia contributed to disparities in outcomes.
- Further work is required to understand and optimize glycemic outcomes for individuals with diabetes, and to address the factors contributing to disparities.

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ABSTRACT

Objective: Using a new database combining primary- and specialty-care electronic medical record (EMR) data in Canada, we determined attainment of glycemic targets and associated predictors among adults with diabetes.

Methods: We conducted a cross-sectional observational study combining primary- and specialty-care EMR data in Canada. Adults with diabetes whose primary-care provider contributed to the National Diabetes Repository or who were assessed at a diabetes specialty clinic (LMC Diabetes and Endocrinology) between July 3, 2015 and June 30, 2019 were included. Diabetes type was categorized as type 2 diabetes (T2D) not prescribed insulin, T2D prescribed insulin, and type 1 diabetes (T1D). Covariates were age, sex, income quintile, province, rural/urban location, estimated glomerular filtration rate, medications, and insulin pump use. Associations between predictors and the outcome (glycated hemoglobin [A1C] of ≤7.0%) were assessed by multivariable logistic regressions.

Results: Among 122,106 adults, consisting of 91,366 with T2D not prescribed insulin, 25,131 with T2D prescribed insulin, and 5,609 with T1D, attainment of an A1C of ≤7.0% was 60%, 25%, and 23%, respectively. Proportions with an A1C of ≤7.5% and ≤8.0% were 75% and 84% for those with T2D not prescribed insulin, 41% and 57% for those with T2D prescribed insulin, and 37% and 53% for those with T1D. Highest vs lowest income quintile was associated with greater odds of meeting the A1C target (adjusted odds ratio [95% confidence interval] for each diabetes category: 1.15 [1.10 to 1.21], 1.21 [1.10 to 1.33], and 1.29 [1.04 to 1.60], respectively). Individuals in Alberta and Manitoba had less antihyperglycemic medication use and attainment of A1C target than other provinces.

Conclusions: Attainment of glycemic targets among adults with diabetes was poor and differed by income and geographic location, which must be addressed in national diabetes strategies.

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RÉSUMÉ

Objectifs : En utilisant une nouvelle base de données combinant les données des dossiers médicaux électroniques (DME) des soins primaires et spécialisés au Canada, nous avons déterminé si les cibles de glycémie étaient atteintes et quels étaient les facteurs prédictifs associés chez les adultes diabétiques.
Méthodes : Nous avons mené une étude observationnelle transversale combinant les données de DME des soins primaires et spécialisés au Canada. Les adultes atteints de diabète dont le fournisseur de soins primaires a contribué au Répertoire National du Diabète ou qui ont été évalués dans une clinique spécialisée en diabète (LMC Diabète et Endocrinologie) entre le 3 juillet 2015 et le 30 juin 2019 ont été inclus dans l'étude. Le type de diabète a été catégorisé comme diabète de type 2 (DT2) sans prescription d'insuline, DT2 traité à l'insuline et diabète de type 1 (DT1). Les covariables étaient l'âge, le sexe, le quintile de revenu, la province, la localisation rurale/urbaine, le débit de filtration glomérulaire estimé, la médication et l'utilisation de pompe à insuline. Les associations entre les facteurs prédictifs et le bilan sanguin (HbA1c $\leq$7.0%) ont été évaluées par des régressions logistiques multivariées.
Résultats : Parmi les 122,106 adultes, dont 91,366 atteints DT2 sans prescription d'insuline, 25,131 traités à l'insuline et 5,609 atteints de DT1, un bilan sanguin de l'HbA1c $\leq$7.0% était observé pour 60%, 25% et 23% des patients, respectivement. Les proportions présentant une HbA1c $\leq$7.5% et $\leq$8.0% étaient de 75% et 84% pour le diabète de type 2 sans prescription d'insuline, 41% et 57% pour le diabète de type 2 traité à l'insuline et 37% et 53% pour le diabète de type 1. Le quintile de revenu le plus élevé par rapport au quintile le plus faible était associé à de meilleures chances d'atteindre la cible d'HbA1c [rapport de cotes ajusté et IC 95% 1.15 (1.10-1.21), 1.21 (1.10-1.33) et 1.29 (1.04-1.60) pour chaque catégorie de diabète]. Les individus de l'Alberta et du Manitoba présentaient un usage moindre de médicaments anti-hyperglycémiants et une plus faible atteinte de la cible d'HbA1c que pour ceux des autres provinces.
Conclusions : L'atteinte des cibles glycémiques chez les adultes atteints de diabète était modeste et différait en fonction du revenu et de la localisation géographique, ce qui doit être pris en compte dans les stratégies nationales de lutte contre le diabète.

Introduction

As the burden of diabetes rises globally, countries are increasingly focussing on national strategies for diabetes outcome evaluation and health-care delivery [1–3]. A critical outcome measure for diabetes is glycated hemoglobin (A1C), as chronic hyperglycemia is the major determinant of diabetes complications [4,5]. A target A1C of $\leq$7.0% (53 mmol/mol) is recommended for the majority of adults with type 1 and type 2 diabetes to reduce the risk of long-term diabetes complications [6–8]. Evaluating attainment of recommended A1C targets at a population level is important for assessing the effectiveness of diabetes care and identifying factors that may contribute to systematic differences in glycemic outcomes.

Studies have shown low attainment of glycemic targets in both type 1 and type 2 diabetes internationally and in Canada. In the T1D Exchange Registry in the United States, only 20% of participants in specialty care with type 1 diabetes have an A1C of $\leq$7.0% (53 mmol/mol), and this appears to be worsening over time [9,10]. In a meta-analysis including nearly 400,000 individuals with type 2 diabetes from 20 countries, only 43% had an A1C of $\leq$7.0% (53 mmol/mol) [11]. In Canada, several studies using similar primary-care electronic medical record (EMR) databases reported 50% to 60% of adults with diabetes attained the A1C target of $\leq$7.0% [12–14]. However, these studies evaluated associations between a limited number of predictors and A1C, with most evaluating only the influence of age and sex. Furthermore, primary-care databases are likely to overrepresent individuals with uncomplicated type 2 diabetes and underrepresent type 1 diabetes, which is likely to result in biased estimates of glycemic target attainment.

To overcome these limitations, we combined primary- and specialty-care EMR data from 5 provinces across Canada. Our objectives were to determine the proportion of individuals with type 1 and type 2 diabetes meeting glycemic targets, determine whether attainment of glycemic targets differs between those with type 1 and type 2 diabetes, and identify characteristics associated with differential attainment of the A1C target.

Methods

Study design and setting

A cross-sectional, observational study was conducted using a new combined primary- and specialty-care EMR database [15]. Data entered into the EMR between July 3, 2015 and June 30, 2019 were used. Variable definitions for medication use and dates analyzed were harmonized between the 2 databases. The index date was the date of the most recent visit before June 30, 2019. Variables were defined using the most recent data entered in the EMR, using a maximum lookback window of 2 years from the most recent. The study was designed and reported according to the STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) guidelines and the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement [16,17].

Data sources

Diabetes Action Canada's National Diabetes Repository (NDR) contains de-identified EMR data from participating primary-care providers in 5 provinces (Ontario, Alberta, Manitoba, Québec, and Newfoundland and Labrador) for approximately 100,000 patients with diabetes [18]. Patients with diabetes are identified by a validated case definition with 96% sensitivity and 97% specificity [19]. The LMC Diabetes Registry contained de-identified EMR data from a shared EMR for 13 diabetes specialty clinics in Canada (10 in Ontario, 2 in Québec, and 1 in Alberta) for approximately 40,000 patients with diabetes [15,20]. Details regarding each data source have been published [12,13,15,18,20,21]. Both databases contain patients' demographics, physical examination measures, medications, and laboratory parameters.

Participants

Patients were included if they were $\geq$18 years old with a documented EMR encounter between July 3, 2017 and June 30,

Table 1
Descriptive characteristics of patients in the National Diabetes Repository and LMC Diabetes Registry according to diabetes category *

	T2D not prescribed insulin (n=91,366)	T2D prescribed insulin (n=25,131)	T1D (n=5,609)
Patients' demographics			
Age, years	65.2 (13.7)	66.9 (12.3)	45.3 (14.9)
Female sex	42,797 (46.8%)	11,151 (44.4%)	2,578 (46.0%)
Income quintile			
1	19,036 (23.6%)	5,495 (23.5%)	869 (16.4%)
2	17,138 (21.2%)	5,115 (21.9%)	1,002 (18.9%)
3	15,469 (19.2%)	4,870 (20.8%)	1,057 (20.0%)
4	14,670 (18.2%)	4,160 (17.8%)	1,096 (20.7%)
5	14,346 (17.8%)	3,767 (16.1%)	1,267 (23.9%)
Province			
Alberta	19,435 (21.3%)	3,492 (13.9%)	959 (17.1%)
Manitoba	8,954 (9.8%)	984 (3.9%)	175 (3.1%)
Newfoundland and Labrador	258 (0.3%)	72 (0.3%)	10 (0.2%)
Ontario	60,289 (66.0%)	19,281 (76.7%)	3,700 (66.0%)
Québec	2,430 (2.7%)	1,302 (5.2%)	765 (13.6%)
Urban residence	75,001 (83.5%)	21,578 (87.3%)	4,899 (88.7%)
Laboratory values			
A1C value (%) (mmol/mol)	7.1 (1.4) [54 (15)]	8.1 (1.6) [65 (17)]	8.2 (1.7) [66 (19)]
A1C category			
≤7.0% (53 mmol/mol)	55,176 (60.4%)	6,164 (24.5%)	1,287 (22.9%)
7.1%–8.0% (54–64 mmol/mol)	21,343 (23.4%)	8,056 (32.1%)	1,698 (30.3%)
8.1%–9.0% (65–75 mmol/mol)	73,90 (8.1%)	4,957 (19.7%)	1,158 (20.6%)
>9.0% (75 mmol/mol)	7,457 (8.2%)	5,954 (23.7%)	1,466 (26.1%)
eGFR (mL/min per 1.73 m^2)	78.2 (22.4)	71.4 (27.0)	95.4 (24.1)
Total cholesterol (mmol/L)	4.1 (1.1)	3.8 (1.1)	4.4 (1.1)
LDL cholesterol (mmol/L)	2.1 (0.9)	1.8 (1.0)	2.3 (0.8)
HDL cholesterol (mmol/L)	1.4 (0.6)	1.3 (0.5)	1.6 (0.5)
Triglycerides (mmol/L)	1.6 [1.2–1.3]	1.6 [1.1–2.3]	0.9 [0.7–1.4]
Medications			
Metformin	47,282 (51.8%)	16,843 (67.0%)	369 (6.6%)
DPP-4 inhibitor	20,429 (22.4%)	9,653 (38.4%)	79 (1.4%)
Sulfonylurea	16,048 (17.6%)	6,269 (24.9%)	22 (0.4%)
SGLT-2 inhibitor	14,092 (15.4%)	8,768 (34.9%)	225 (4.0%)
GLP-1 receptor agonist	4,095 (4.5%)	3,709 (14.8%)	90 (1.6%)
Statin	46,632 (51.0%)	19,289 (76.8%)	2,266 (40.4%)
ACE inhibitor or ARB	44,828 (49.1%)	17,328 (69.0%)	1,751 (31.2%)
Number of non-insulin antihyperglycemic agents	1 [0–2]	2 [1–3]	0 [0–0]
No antihyperglycemic agents	37,789 (41.4%)		
Insulin pump	–	–	2,354 (42.0%)
Basal insulin only	–	14,286 (56.9%)	–

A1C, glycated hemoglobin; *ACE*, angiotensin-converting enzyme; *ARB*, angiotensin receptor blocker; *eGFR*, estimated glomerular filtration rate; *DPP-4*, dipeptidyl peptidase-4; *GLP-1*, glucagon-like peptide-1; *HDL*, high-density lipoprotein; *LDL*, low-density lipoprotein; *SGLT-2*, sodium-glucose cotransporter-2; *T1D*, type 1 diabetes; *T2D*, type 2 diabetes.
Notes: Values reported as mean (standard deviation), median [25th–75th percentile], or number (%). Missing data: 12,749 (10.4%) for income quintile, 1,998 (1.6%) for residence, 3,819 (3.1%) for eGFR, 17,561 (14.4%) for total cholesterol, 18,433 (15.1%) for LDL cholesterol, 15,036 (12.3%) for HDL cholesterol, 15,795 (12.9%) for triglycerides, and 31 (0.03%) for insulin pump.
* p Values for comparisons between all 3 groups were <0.0001 for all comparisons using the chi-square test for categorical variables and Kruskal–Wallis test for continuous variables.

2019. For all analyses, diabetes was categorized as type 2 diabetes not prescribed insulin (no insulin prescriptions in the previous 2 years), type 2 diabetes prescribed insulin (prescriptions for basal or bolus insulin in the previous 2 years), or type 1 diabetes. In the NDR, type 1 diabetes was identified by a previously validated algorithm defined by prescription of insulin without any other antihyperglycemic medications and age <55 years (sensitivity 72.8%, specificity 99.5%, positive predictive value 86%, negative predictive value 99%) [21]. In the LMC Diabetes Registry, diabetes type was classified based on the endocrinologist's diagnosis.

Exposures, covariates, and outcomes

The primary outcome was A1C value categorized as meeting target (≤7.0% [53 mmol/mol]) or not meeting target (>7.0% [53 mmol/mol]). A single A1C value on the most recent visit date or closest to the most recent visit date within the previous 2 years was used. All A1C values were laboratory values obtained in the context of routine clinical care. Covariates included age, sex, income quintile, province, location of residence classified as rural or urban, most recent estimated glomerular filtration rate (eGFR), and medications and insulin pump use. Income quintiles were assigned based on the patient's postal code using the Postal Code Conversion File+, which permits comparisons between provinces by accounting for differences in income distribution between provinces. Patients were considered users of a medication class if there were at least 2 prescriptions for corresponding medications in the previous 2 years. Insulin pump use was only evaluated among those with type 1 diabetes, because its use among individuals with type 2 diabetes in Canada is rare. In the NDR, insulin pump use was identified based on the prescription of only bolus insulin without basal, mixed, or regular insulin, as used in a previous study [18]. One prescription per year for basal insulin was permitted to account for pump users receiving a "back-up" insulin prescription for emergency use. In the LMC Diabetes Registry, insulin pump use was documented in the EMR by the endocrinologist.

Statistical methods

Percentages and 95% confidence intervals (CIs) for individuals meeting the A1C targets of ≤7.0% (53 mmol/mol), ≤7.5% (58 mmol/mol), and ≤8.0% (64 mmol/mol) were determined. Differences in

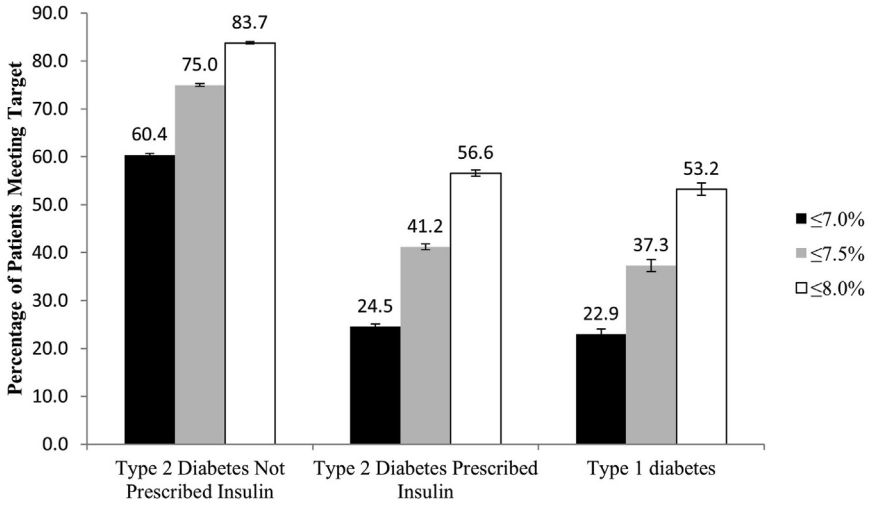

Figure 1. Percentages and 95% confidence intervals for attainment of glycated hemoglobin (A1C) targets of ≤7.0% (53 mmol/mol), ≤7.5% (58 mmol/mol), and ≤8.0% (64 mmol/mol), according to diabetes categorization as either type 2 diabetes not prescribed insulin, type 2 diabetes prescribed insulin, or type 1 diabetes. Comparison of those with type 2 diabetes not prescribed insulin vs those with type 2 diabetes prescribed insulin: p<0.0001 for all A1C target thresholds; comparison of those with type 2 diabetes not prescribed insulin vs type 1 diabetes: p<0.0001 for all A1C target thresholds; comparison of those with type 2 diabetes prescribed insulin vs type 1 diabetes: p=0.01 for those at ≤7.0% (53 mmol/mol), and <0.0001 for those at ≤7.5% (58 mmol/mol) and ≤8.0% (64 mmol/mol).

attainment of targets by diabetes category were determined using the chi-square test. Differences in predictors between individuals meeting or not meeting the A1C target of ≤7.0% (53 mmol/mol) within each diabetes category were evaluated using both standardized differences and p values. Standardized differences >10% are considered to reflect clinically meaningful differences and are preferred over p values for studies with larger sample sizes to examine effect sizes [22]. Multivariable logistic regressions were used to determine odds ratios (ORs) and 95% CIs for associations between predictors and the odds of meeting the A1C target of ≤7.0% (53 mmol/mol) within each diabetes category. Variables included in the multivariable models were selected *a priori* based on clinical relevance and included all covariates described earlier. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, North Carolina, United States).

Sensitivity analyses

Multivariable logistic regressions were repeated using multiple imputation for variables with missing data (income quintile, urban or rural location, eGFR, and insulin pump use). PROC MI was used for multiple imputation with 10 replications.

Ethics approval

This study was approved by the research ethics board at Mount Sinai Hospital (MSH REB No. 21-0015-C). Participant consent for inclusion in the NDR was not required. The LMC Diabetes Registry includes data for patients who had consented to inclusion in the Registry, which were provided by 92% of all LMC patients.

Results

Participants' characteristics

Our study included 122,106 individuals, including 83,272 from the NDR and 38,834 from the LMC Diabetes Registry; 91,366 had type 2 diabetes with no prescription for insulin in the previous 2 years, 25,131 had type 2 diabetes with insulin prescribed in the previous 2 years, and 5,609 had type 1 diabetes (Supplementary Figure 1). Individuals with type 1 diabetes were younger than those with type 2 diabetes (45.3±14.9 years for type 1 diabetes vs 65.2±13.7 years for type 2 diabetes not prescribed insulin and 66.9±12.3 years for type 2 diabetes prescribed insulin; p<0.0001; Table 1). Among individuals with type 1 diabetes, 2,354 (42.0%) were using insulin pumps. Mean A1C was 7.1±1.4% (54±15 mmol/mol) for type 2 diabetes patients not prescribed insulin, 8.1±1.6% (65±17 mmol/mol) for type 2 diabetes patients prescribed insulin, and 8.2±1.7% (66±19 mmol/mol) for those with type 1 diabetes (p<0.0001). Patients' characteristics were generally similar between the NDR and the LMC Diabetes Registry, with higher rates of all antihyperglycemic medication use in the LMC Diabetes Registry (Supplementary Table 1). The median time between the most recent A1C value and the most recent visit date was 35 (interquartile range 8 to 119) days.

Attainment of glycemic targets

The A1C target of ≤7.0% (53 mmol/mol) was met by 60% (95% CI 60% to 61%) of individuals with type 2 diabetes not prescribed insulin, 25% (95% CI 24% to 25%) of those with type 2 diabetes prescribed insulin, and 23% (95% CI 22% to 24%) of those with type 1 diabetes (Figure 1). Differences in attainment of the A1C targets of ≤7.0%, ≤7.5%, and ≤8.0% between diabetes categories are presented in Figure 1. The percentages of individuals meeting each A1C target were similar between the NDR and the LMC Diabetes Registry (Supplementary Figure 1).

Characteristics associated with attainment of A1C target of ≤7.0% (53 mmol/mol)

Sex: Fewer females with type 2 diabetes were prescribed insulin (20.1% of females with type 2 diabetes were prescribed insulin vs 22.4% for males; p<0.0001). After adjustment for covariates, female sex was associated with greater odds of meeting the A1C target among individuals with type 2 diabetes not prescribed insulin (adjusted OR 1.14 [1.11 to 1.18]), but lower odds among those with

type 2 diabetes prescribed insulin and those with type 1 diabetes (adjusted OR 0.93 [0.88 to 0.99] and 0.84 [0.74 to 0.96], respectively).

Income quintile: Across all diabetes categories, higher income quintile was associated with greater odds of meeting the A1C target of ≤7.0% (53 mmol/mol; Tables 2 and 3). Adjusted ORs for attaining the A1C target in the highest vs lowest income quintile were 1.15 (1.10 to 1.21), 1.21 (1.10 to 1.33), and 1.29 (1.04 to 1.60) for those with type 2 diabetes not prescribed insulin, those with type 2 diabetes prescribed insulin, and those with type 1 diabetes, respectively.

Province: Differences in outcomes were observed depending on province of care. After adjustment for covariates, living in Alberta or Manitoba was associated with lower odds of attaining the A1C target of ≤7.0% (53 mmol/mol) for all diabetes types relative to living in Ontario (Table 3). Living in Newfoundland and Labrador was associated with lower odds of attaining the A1C target for both categories of type 2 diabetes but not type 1 diabetes, although the small sample size for type 1 diabetes in Newfoundland and Labrador meant the CI was wide. Relative to Ontario, living in Québec was associated with higher odds of having an A1C of ≤7.0% (53 mmol/mol) for those with type 2 diabetes not prescribed insulin, but the odds were not different for those with type 2 diabetes prescribed insulin or type 1 diabetes. In post hoc exploratory analyses, use of specific antihyperglycemic medication classes for individuals with both categories of type 2 diabetes differed by province (Supplementary Table 2), with medication rates being highest in Ontario and Québec, particularly for sodium-glucose cotransporter-2 (SGLT-2) inhibitors and glucagon-like peptide-1 (GLP-1) receptor agonists.

Rural or urban location: For individuals with type 2 diabetes, attainment of the A1C target of ≤7.0% (53 mmol/mol) was statistically higher among those not prescribed insulin for urban vs rural location, but did not differ for those prescribed insulin (adjusted OR 1.08 [1.04 to 1.13] and 1.02 [0.93 to 1.28], respectively). For individuals with type 1 diabetes, living in an urban location was associated with higher odds of meeting the target (adjusted OR 1.49 [1.17 to 1.89]).

Antihyperglycemic medications in individuals with type 2 diabetes

There were 10,042 (27.8%) individuals with type 2 diabetes who were not prescribed insulin and had no antihyperglycemic medication use despite having an A1C of >7.0% (53 mmol/mol; Table 2). Non-use of antihyperglycemic medications occurred more commonly in primary care than specialty care (Supplementary Table 1). and these individuals were younger, had lower income, and were more likely to reside in Alberta or Manitoba and in rural locations (Supplementary Table 3).

Among those with type 2 diabetes, a higher number of antihyperglycemic medications prescribed was associated with lower odds of meeting the A1C target for both non−insulin users (adjusted OR 0.51 [0.45 to 0.58]) and insulin users (adjusted OR 0.78 [0.65 to 0.95]). Similarly, for those with type 2 diabetes prescribed insulin, use of basal insulin (without bolus insulin) was associated with higher odds of meeting the target (adjusted OR 1.57 [1.46 to 1.68]) compared with those using basal and bolus insulin.

Sensitivity analyses

Multivariable logistic regression analyses using multiple imputation for missing data were consistent with the primary analysis (Supplementary Table 4). Regressions were also performed separately for NDR and the LMC Diabetes Registry (Supplementary Table 5).

Discussion

Using a new database combining primary- and specialty-care EMR data for 122,106 adults with diabetes from 5 provinces in Canada, we demonstrated that attainment of the A1C target of ≤7.0% (53 mmol/mol) was markedly low, but it differed considerably by use or non-use of insulin. Although two thirds of individuals with type 2 diabetes who were not prescribed insulin met the A1C target, only one quarter of those prescribed insulin (whether type 1 or type 2 diabetes) met the recommended A1C target. Our finding of poor attainment of glycemic targets is generally consistent with international estimates for both type 1 and type 2 diabetes [9,11,15,20,23−27].

In our study, females were more likely than males to have an A1C of ≤7.0% (53 mmol/mol) if they were not prescribed insulin. However, females with type 2 diabetes were prescribed insulin less often and, once using insulin, they were less likely to attain the A1C target. Women with type 2 diabetes consistently have higher A1C than men [28−30]. Sex or gender differences in A1C are less consistent for type 1 diabetes, with some regions reporting no differences and others reporting women with higher A1C [26,31,32]. Possible reasons for our findings include insulin being less commonly recommended for women by providers, or less uptake of insulin by women. Alternatively, in clinical trials of basal insulin, women had smaller reductions in A1C despite higher insulin doses and more hypoglycemia than men, suggesting possible sex differences in insulin pharmacokinetics or hypoglycemia risk that affects glycemic outcomes [33].

Across all diabetes categories in our study, lower income quintile was associated with reduced odds of meeting the A1C target. Disparities in glycemic control by socioeconomic status have been well described for both type 1 and type 2 diabetes [34−36]. This is persistent even in Sweden, which has a universal health-care system and coverage for prescription medications [37]. Although income may affect access to antihyperglycemic medications, the association between income quintile and A1C was significant, even after adjustment for use of antihyperglycemic medications in the type 2 diabetes models. Thus, the association between income and glycemic control in our study may similarly reflect non-medication factors known to be associated with income, such as education, race or ethnicity, and health literacy, which could not be determined in our database [38−40].

Although Canada has a universal health-care system, there are substantial differences in health-care delivery by province. Individuals living in Alberta and Manitoba had higher A1C than those in Ontario and Québec. Importantly, public coverage for prescription medications differs between provinces. Alberta and Manitoba generally have higher out-of-pocket medication expenses compared with Ontario and Québec, which could potentially explain our findings [41]. Furthermore, even when medications are available through publicly funded programs, the criteria for access differ by province. For example, SGLT-2 inhibitors and GLP-1 receptor agonists in Alberta and Manitoba have restricted access through the public drug programs, being third-line therapy after metformin and sulfonylureas. In contrast, there are no prescribing limitations in Ontario for the SLGT-2 inhibitors and GLP-1 receptor agonists on the public formulary. However, differences by province were significant even after adjusting for medication use, implying there are other factors driving differences in attainment of glycemic targets between provinces that have not yet been identified.

Differences in attainment of glycemic targets between rural and urban locations were evident only for those with type 1 diabetes, even after adjustment for insulin pump use, which may be more

Table 2
Comparisons of predictors by attainment of A1C target of ≤7.0% (53 mmol/mol), according to diabetes categorization as T2D not prescribed insulin, T2D prescribed insulin, or T1D

	T2D not prescribed insulin (N=91,366)				T2D prescribed insulin (N=25,131)				T1D (N=5,609)			
	A1C >7.0% (53 mmol/mol) (N=36,190)	A1C ≤7.0% (53 mmol/mol) (N=55,176)	Std. diff. *	p Value †	A1C >7.0% (53 mmol/mol) (N=18,967)	A1C ≤7.0% (53 mmol/mol) (N=6,164)	Std. diff. *	p Value †	A1C >7.0% (53 mmol/mol) (N=4322)	A1C ≤7.0% (53 mmol/mol) (N=1,287)	Std. diff. *	p Value †
Age, years	64.4 (13.6)	65.8 (13.8)	0.10	<0.0001	66.6 (12.3)	68.1 (12.2)	0.13	<0.0001	45.1 (14.8)	45.9 (14.9)	0.06	0.07
Female sex	15,639 (43.2%)	27,158 (49.2%)	0.12	<0.0001	8,505 (44.8%)	2,646 (42.9%)	0.04	0.009	2,021 (46.8%)	557 (43.3%)	0.07	0.03
Income quintile			0.06	<0.0001			0.09	<0.0001			0.17	0.0003
1	7,645 (24.1%)	11,391 (23.3%)			4,218 (23.9%)	1,277 (22.1%)			682 (16.8%)	187 (15.3%)		
2	6,920 (21.8%)	10,218 (20.9%)			3,932 (22.3%)	1,183 (20.4%)			788 (19.4%)	214 (17.5%)		
3	6,097 (19.2%)	9,372 (19.2%)			3,672 (20.8%)	1,198 (20.7%)			846 (20.8%)	211 (17.2%)		
4	5,738 (18.1%)	8,932 (18.3%)			3,072 (17.4%)	1,088 (18.8%)			825 (20.3%)	271 (22.1%)		
5	5,385 (16.9%)	8,961 (18.3%)			2,727 (15.5%)	1,040 (18.0%)			925 (22.7%)	342 (27.9%)		
Province			0.07	<0.0001			0.23	<0.0001			0.22	0.0001
Alberta	7,491 (20.7%)	11,944 (21.6%)			2,806 (14.8%)	686 (11.1%)			788 (18.2%)	171 (13.3%)		
Manitoba	3,905 (10.8%)	5,049 (9.2%)			832 (4.4%)	152 (2.5%)			149 (3.4%)	26 (2.0%)		
Newfoundland and Labrador	117 (0.3%)	141 (0.3%)			58 (0.3%)	14 (0.2%)			6 (0.1%)	4 (0.3%)		
Ontario	23,661 (65.4%)	36,628 (66.4%)			14,313 (75.5%)	4,968 (80.6%)			2,804 (64.9%)	896 (69.6%)		
Québec	1,016 (2.8%)	1,414 (2.6%)			958 (5.1%)	344 (5.6%)			575 (13.3%)	190 (14.8%)		
Urban residence (reference: rural)	29,656 (83.4%)	45,345 (83.5%)	0.00	0.62	16,232 (87.1%)	5,346 (87.9%)	0.02	0.11	3,737 (87.9%)	1,162 (91.1%)	0.10	0.002
eGFR (mL/min per 1.73 m^2)	80.2 (23.2)	76.8 (21.8)	0.15	<0.0001	72.4 (26.7)	68.4 (27.7)	0.15	<0.0001	95.9 (24.5)	93.8 (22.8)	0.09	0.009
Total cholesterol (mmol/L)	4.1 (1.2)	4.1 (1.1)	0.01	0.33	3.8 (1.2)	3.6 (0.9)	0.27	<0.0001	4.4 (1.1)	4.3 (1.1)	0.13	0.0001
LDL cholesterol (mmol/L)	2.0 (0.9)	2.1 (0.9)	0.07	<0.0001	1.8 (1.1)	1.6 (0.3)	0.19	<0.0001	2.3 (0.8)	2.2 (0.8)	0.11	0.002
HDL cholesterol (mmol/L)	1.3 (0.5)	1.4 (0.6)	0.19	<0.0001	1.3 (0.5)	1.3 (0.5)	0.06	<0.0001	1.6 (0.5)	1.6 (0.6)	0.06	0.09
Triglycerides (mmol/L)	1.7 [1.2–2.5]	1.5 [1.1–2.1]	0.27	<0.0001	1.6 [1.1–2.4]	1.4 [1.0–2.1]	0.20	<0.0001	1 [0.7–1.5]	0.8 [0.6–1.3]	0.13	0.0001
Metformin	22,731 (62.8%)	24,551 (44.5%)	0.37	<0.0001	12,789 (67.4%)	4,054 (65.8%)	0.04	0.02	298 (6.9%)	71 (5.5%)	0.06	0.08
DPP-4 inhibitor	11,769 (32.5%)	8,660 (15.7%)	0.40	<0.0001	7,372 (38.9%)	2,281 (37.0%)	0.04	0.009	63 (1.5%)	16 (1.2%)	0.02	0.57
Sulfonylurea	10,633 (29.4%)	5,415 (9.8%)	0.51	<0.0001	4,992 (26.3%)	1,277 (20.7%)	0.13	<0.0001	17 (0.4%)	5 (0.4%)	0.00	0.98
SGLT-2 inhibitor	8,847 (24.4%)	5,245 (9.5%)	0.41	<0.0001	6,851 (36.1%)	1,917 (31.1%)	0.11	<0.0001	173 (4.0%)	52 (4.0%)	0.00	0.95
GLP-1 RA	2,142 (5.9%)	1,953 (3.5%)	0.11	<0.0001	2,780 (14.7%)	929 (15.1%)	0.01	0.43	71 (1.6%)	19 (1.5%)	0.01	0.68
Statin	19,475 (53.8%)	27,157 (49.2%)	0.09	<0.0001	14,567 (76.8%)	4,722 (76.6%)	0.00	0.75	1,793 (41.5%)	473 (36.8%)	0.10	0.002
ACE inhibitor or ARB	18,427 (50.9%)	26,401 (47.8%)	0.06	<0.0001	13,008 (68.6%)	4,320 (70.1%)	0.03	0.03	1,391 (32.2%)	360 (28.0%)	0.09	0.004
Number of non-insulin antihyperglycemic agents	1 [0–3]	0 [0–1]	0.61	<0.0001	2 [1–3]	2 [1–3]	0.12	<0.0001	–	–		
No antihyperglycemic agents	10,042 (27.8%)	27,747 (50.3%)	0.47	<0.0001	–	–			–	–		
Insulin pump	–	–			–	–			1,779 (41.2%)	575 (44.7%)	0.07	0.02
Basal insulin only	–	–			10,534 (55.5%)	3,752 (60.9%)	0.11	<0.0001	–	–		

ACE, angiotensin-converting enzyme; *ARB*, angiotensin receptor blocker; *DPP-4*, dipeptidyl peptidase 4; *eGFR*, estimated glomerular filtration rate; *GLP-1*, glucagon-like peptide-1 receptor agonist; *HDL*, high-density lipoprotein; *LDL*, low-density lipoprotein; *SGLT-2*, sodium-glucose cotransporter-2; *Std. diff.*, standardized difference; *T1D*, type 1 diabetes; *T2D*, type 2 diabetes.
Note: Values reported as mean (standard deviation), median [25th–75th percentile], or number (%).
* Standardized differences of >10% are considered to reflect clinically meaningful differences.
† p Values are from chi-square test for categorical variables and Kruskal–Wallis test for continuous variables.

Table 3
Multivariable logistic regressions (odds ratios and 95% confidence intervals) for associations between predictors and attainment of A1C target of ≤7.0% (53 mmol/mol), according to diabetes categorization as T2D not prescribed insulin, T2D prescribed insulin, or T1D

Predictor	T2D not prescribed insulin (N=91,366)	T2D prescribed insulin (N=25,131)	T1D (N=5,609)
Age (per 10 years)	1.05 (1.03–1.06)	1.05 (1.02–1.09)	1.01 (0.95–1.07)
Sex (reference: male)	1.14 (1.11–1.18)	0.93 (0.88–0.99)	0.84 (0.74–0.96)
Income quintile (reference: 1)			
2	1.04 (0.99–1.09)	1.00 (0.91–1.10)	0.96 (0.77–1.21)
3	1.09 (1.04–1.14)	1.08 (0.98–1.18)	0.91 (0.72–1.14)
4	1.09 (1.04–1.15)	1.18 (1.07–1.30)	1.19 (0.96–1.49)
5	1.15 (1.10–1.21)	1.21 (1.10–1.33)	1.29 (1.04–1.60)
Province (reference: Ontario)			
Alberta	0.71 (0.69–0.74)	0.62 (0.57–0.69)	0.66 (0.54–0.81)
Manitoba	0.63 (0.58–0.68)	0.48 (0.38–0.61)	0.52 (0.25–1.10)
Newfoundland and Labrador	0.60 (0.45–0.79)	0.57 (0.30–1.07)	2.96 (0.79–11.10)
Québec	1.40 (1.27–1.55)	1.13 (0.99–1.30)	1.01 (0.84–1.22)
Residence (reference: rural)	1.08 (1.04–1.13)	1.02 (0.93–1.28)	1.49 (1.17–1.89)
eGFR (per 10 mL/min per 1.73 m^2)	0.96 (0.95–0.96)	1.00 (0.9–0.98)	0.96 (0.93–1.00)
Number of non-insulin antihyperglycemic agents	0.51 (0.45–0.58)	0.78 (0.65–0.95)	–
No antihyperglycemic agents	1.57 (1.47–1.68)	–	–
Metformin	1.98 (1.72–2.28)	1.38 (1.12–1.69)	–
DPP-4 inhibitor	1.26 (1.10–1.45)	1.10 (0.90–1.35)	–
SGLT-2 inhibitor	1.12 (0.98–1.29)	1.02 (0.83–1.25)	–
Sulfonylurea	0.80 (0.70–0.91)	0.79 (0.65–0.97)	–
GLP-1 RA	1.78 (1.53–2.07)	1.32 (1.07–1.63)	–
Basal insulin only	–	1.57 (1.47–1.68)	–
Insulin pump	–	–	1.15 (1.00–1.31)

DPP-4, dipeptidyl peptidase-4; *eGFR*, estimated glomerular filtration rate; *GLP-1 RA*, glucagon-like peptide-1 receptor agonist; *SGLT-2*, sodium-glucose cotransporter-2; *T1D*, type 1 diabetes; *T2D*, type 2 diabetes.
Note: Complete case analysis was used: 77,665 for T2D not prescribed insulin, 23,076 for T2D not prescribed insulin, and 5,075 for T1D.

common in urban settings. We hypothesize that access to multidisciplinary diabetes teams may have a greater impact on favourable glycemic outcomes for those with type 1 diabetes as compared with type 2 diabetes, and access to these teams is likely greater in urban settings. Although rural–urban differences in glycemic control have not been noted in all studies, similar findings were seen among individuals with type 1 diabetes in the United States [42,43].

Several findings in our study are suggestive of therapeutic inertia specific to type 2 diabetes. Among individuals prescribed no antihyperglycemic medications, 28% had an A1C of >7.0% (53 mmol/mol). This finding was more common in primary care than specialty care, which is consistent with reports of more therapeutic inertia in primary care [44]. This could reflect earlier adoption of newer therapies such as SGLT-2 inhibitors and GLP-1 receptor agonists by endocrinologists as compared with primary-care physicians. Among individuals prescribed a greater number of non-insulin antihyperglycemic therapies, there was an unexpected lower likelihood of attaining the A1C target of ≤7.0% (53 mmol/mol), which may reflect a delayed intensification of therapy when A1C is already substantially elevated [45–47]. However, it is also possible these findings reflect reverse causality because medication assessment was determined at the most recent appointment, occurring a median of 35 days after the latest A1C result. An elevated A1C would likely have prompted the addition of antihyperglycemic medications. Alternatively, individuals who may not have ideal responses to medications because of other challenges such as adherence may be more likely to have further medications added [48]. The substantially lower attainment of the A1C target of ≤7.0% among individuals with type 2 diabetes prescribed insulin compared with those not prescribed insulin (25% vs 60%) may suggest delayed initiation of insulin. For example, in one international observational study, the mean A1C at the time of insulin initiation was 8.9±1.6% [49].

In this study we have assessed glycemic outcomes in Canada using the largest sample to date while combining primary- and specialty-care data for the first time, which is important given the spectrum of management for diabetes. Our results are consistent with 2 earlier studies using similar primary-care data [12,13] and add to those results by including specialty-care data and evaluating differences between type 1 and type 2 diabetes, as well as by insulin use among those with type 2 diabetes. Future efforts should be aimed at expanding the database to include additional clinical variables and a broader geographic scope. There are some weaknesses to our study. First, our estimates are not at the population level, owing to the nonrandom inclusion of individuals in the databases. Our sample likely underrepresented those living in rural areas and did not reflect equal representation of all provinces. Thus, our results may not be generalizable to the entire diabetes population in Canada. Second, only the single most recent A1C value was used to determine attainment of glycemic targets. A1C may change over time and we were not able to account for the effects of therapeutic changes on A1C. Third, we were not able to consider individualized A1C targets. However, we assessed the proportion of individuals attaining the higher A1C target thresholds of ≤7.5% (58 mmol/mol) and ≤8.0% (64 mmol/mol), which would incorporate the majority of individualized A1C targets recommended by the Clinical Practice Guidelines [6]. Fourth, some variables were not available in the EMR databases, such as individual measures of socioeconomic status, diabetes duration, lifestyle factors, family history, and data regarding self-monitoring of glucose (e.g. use of continuous glucose monitors). Particularly for individuals with type 1 diabetes, continuous glucose monitors and use of automated insulin delivery systems are major predictors of glycemic control, but were not included in our analyses. Prescription fulfillment data, or other measures of adherence, were also not available. Fifth, there were some differences in variable definitions such as identification of type 1 diabetes and insulin pump use between the NDR and LMC Diabetes Registry, but glycemic outcomes were nearly identical despite these differences. Finally, our study was cross-sectional and, as such, correlations cannot be inferred to represent causation.

In conclusion, our analysis of a new combined primary- and specialty-care EMR database has demonstrated low attainment of glycemic targets recommended by clinical guidelines, particularly

for individuals with type 2 diabetes who are using insulin and individuals with type 1 diabetes. Sex, income, geographic location, and therapeutic inertia are potential contributors to suboptimal glycemic outcomes. These findings underscore the importance of developing national diabetes databases, which are required for health system planning and evaluation.

Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Diabetes* at www.canadianjournalofdiabetes.com.

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Author Disclosures

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Author Contributions

A.W., R.B., L.C., R.A., and B.A.P. were involved in the conception, design, and conduct of the study and the analysis and interpretation of the results. A.W. wrote the first draft of the manuscript, and all authors edited, reviewed, and approved the final version of the manuscript. A.W. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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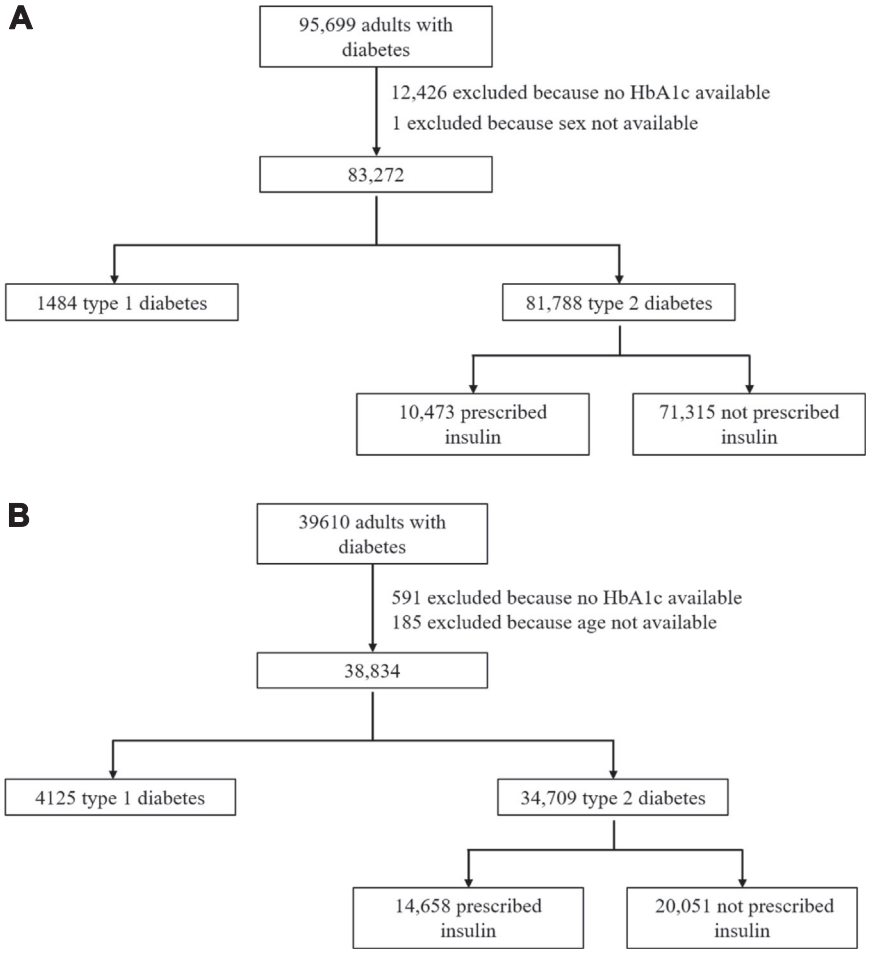
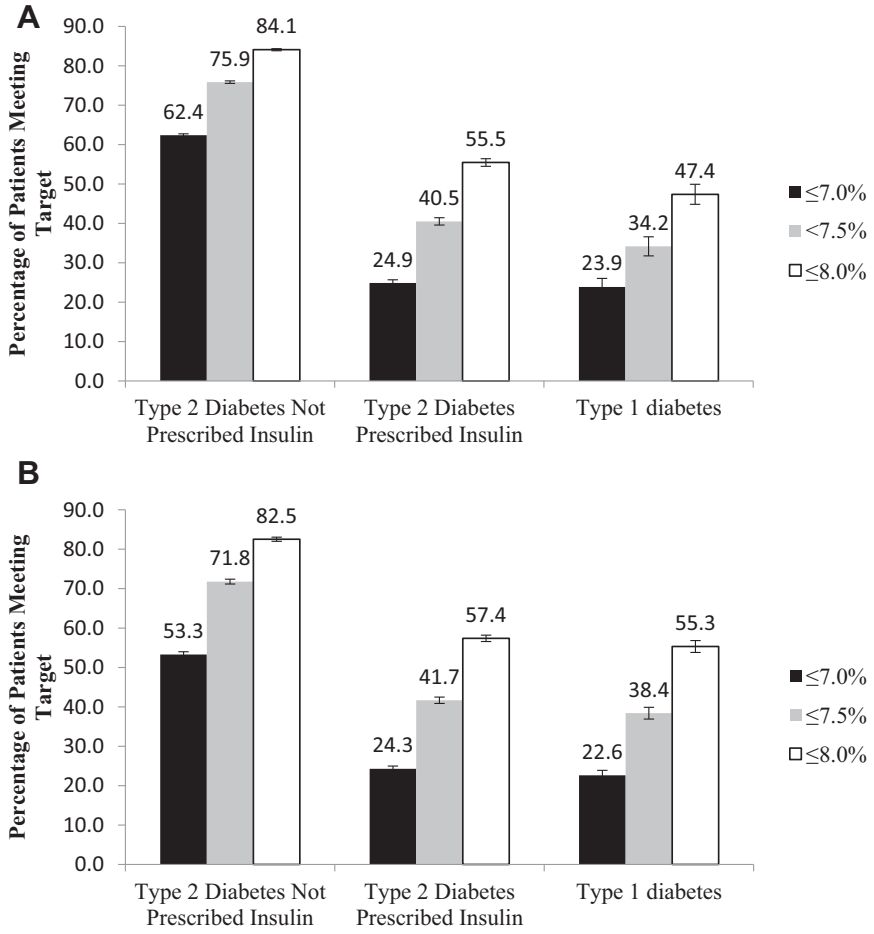


Supplementary Figure 1. Patient inclusion diagram for: (A) National Diabetes Repository and (B) LMC Diabetes Registry. *HbA1c*, glycated hemoglobin.



Supplementary Figure 2. Percentages and 95% confidence intervals for attainment of glycated hemoglobin targets of ≤7.0%, ≤7.5%, and ≤8.0%, according to diabetes categorization as either type 2 diabetes not prescribed insulin, type 2 diabetes prescribed insulin, or type 1 diabetes, for National Diabetes Repository (A) and LMC Diabetes Registry (B) patients separately.

Supplementary Table 1
Characteristics of patients according to diabetes category, separated by database

	National Diabetes Repository (N=83,272)			LMC Diabetes Registry (N=38,834)		
	T2D not prescribed insulin (n=71,315)	T2D prescribed insulin (n=10,473)	T1D (n=1,484)	T2D not prescribed insulin (n=20,051)	T2D prescribed insulin (n=14,658)	T1D (n=4125)
Patients' demographics						
Age, years	65.5 (14.0)	66.4 (12.1)	39.4 (10.4)	64.3 (12.9)	67.3 (12.4)	47.4 (15.6)
Female sex	34,130 (47.9%)	4,772 (45.6%)	682 (46.0%)	8,667 (43.2%)	6,379 (43.5%)	1,896 (46.0%)
Income quintile						
1	15,442 (25.1%)	2,493 (27.0%)	292 (23.0%)	3,594 (18.2%)	3,002 (20.8%)	577 (14.2%)
2	13,018 (21.2%)	1,964 (21.3%)	261 (20.5%)	4,120 (20.9%)	3,151 (21.8%)	741 (18.2%)
3	11,347 (18.4%)	1,685 (18.2%)	263 (20.7%)	4,122 (20.9%)	3,185 (22.1%)	794 (19.5%)
4	10,982 (17.8%)	1,622 (17.6%)	239 (18.8%)	3,688 (18.7%)	2,538 (17.6%)	857 (21.1%)
5	10,408 (16.9%)	1,418 (15.3%)	211 (16.6%)	3,938 (20.0%)	2349 (16.3%)	1,056 (26.0%)
Province						
Alberta	18,510 (26.0%)	2,658 (25.4%)	443 (29.9%)	925 (4.6%)	834 (5.7%)	516 (12.5%)
Manitoba	8,954 (12.6%)	984 (9.4%)	175 (11.8%)			
Newfoundland	258 (0.4%)	72 (0.7%)	10 (0.7%)			
Ontario	42,747 (59.9%)	6,628 (63.3%)	839 (56.5%)	17,542 (87.5%)	12,653 (86.3%)	2,861 (69.4%)
Québec	846 (1.2%)	131 (1.3%)	17 (1.1%)	1,584 (7.9%)	1,171 (8.0%)	748 (18.1%)
Urban residence	56,025 (79.9%)	7,834 (76.1%)	1,148 (78.8%)	18,976 (96.2%)	13,744 (95.3%)	3,751 (92.2%)
Laboratory values						
A1C value (%)	7.0 (1.4)	8.1 (1.7)	8.5 (2.0)	7.2 (1.3)	8.1 (16.)	8.1 (1.5)
A1C category						
≤7.0%	44,492 (62.4%)	2,604 (24.9%)	354 (23.9%)	10,684 (53.3%)	3,560 (24.3%)	933 (22.6%)
7.1%–8.0%	15,481 (21.7%)	3,204 (30.6%)	349 (23.5%)	5,862 (29.2%)	4,852 (33.1%)	1,349 (32.7%)
8.1%–9.0%	5,578 (7.8%)	2,068 (19.7%)	261 (17.6%)	1,812 (9.0%)	2,889 (19.7%)	897 (21.7%)
>9.0%	5,764 (8.1%)	2,597 (24.8%)	520 (35.0%)	1,693 (8.4%)	3,357 (22.9%)	946 (22.9%)
eGFR (mL/min per 1.73 m^2)	77.3 (22.56)	70.2 (27.06)	98.4 (26.04)	81.3 (21.58)	72.2 (26.98)	94.4 (23.34)
Total cholesterol	4.2 (1.2)	3.9 (1.1)	4.6 (1.3)	3.9 (1.1)	3.7 (1.1)	4.3 (1.00)
LDL cholesterol	2.1 (1.0)	1.8 (0.9)	2.4 (1.0)	1.9 (0.8)	1.7 (1.1)	2.3 (0.8)
HDL cholesterol	1.4 (0.6)	1.4 (0.6)	1.6 (0.6)	1.2 (0.3)	1.2 (0.4)	1.6 (0.8)
Triglycerides	1.6 [1.1–2.3]	1.7 [1.2–2.5]	1.2 [0.8–1.9]	1.5 [1.0–2.1]	1.5 [1.0, 2.2]	0.9 [0.7–1.3]
Medications						
Metformin	30,377 (42.6%)	5,813 (55.5%)	0 (0.0%)	16,905 (84.3%)	11,030 (75.2%)	369 (8.9%)
DPP-4 inhibitor	10,505 (14.7%)	3,044 (29.1%)	0 (0.0%)	9,924 (49.5%)	6,609 (45.1%)	79 (1.9%)
Sulfonylurea	9,383 (13.2%)	2,217 (21.2%)	0 (0.0%)	6,665 (33.2%)	4,052 (27.6%)	22 (0.5%)
SGLT-2 inhibitor	5,181 (7.3%)	1,869 (17.8%)	0 (0.0%)	8,911 (44.4%)	6,899 (47.1%)	225 (5.5%)
GLP-1 receptor agonist	1,150 (1.6%)	515 (4.9%)	0 (0.0%)	2,945 (14.7%)	3,194 (21.8%)	90 (2.2%)
Statin	30,439 (42.7%)	6,509 (62.2%)	326 (22.0%)	16,193 (80.8%)	12,780 (87.2%)	1,940 (47.0%)
ACE inhibitor or ARB	32,358 (45.4%)	6,677 (63.8%)	300 (20.2%)	12,470 (62.2%)	10,651 (72.7%)	1,451 (35.2%)
Number of non-insulin antihyperglycemic agents	0 [0–1]	1 [0–2]	0 [0]	2 [1–3]	2 [1–3]	0 [0]
No antihyperglycemic agents	36,018 (50.5%)	—	—	1,771 (8.8%)	—	—
Insulin pump	—	—	687 (46.3%)	—	—	1,667 (40.4%)
Basal insulin only	—	7,398 (70.6%)	—	—	6,914 (47.0%)	—

A1C, glycated hemoglobin; *ACE*, angiotensin-converting enzyme; *ARB*, angiotensin receptor blocker; *DPP-4*, dipeptidyl peptidase-4; *eGFR*, estimated glomerular filtration rate, *HDL*, high-density lipoprotein; *LDL*, low-density lipoprotein; *GLP-1*, glucagon-like peptide-1; *SGLT-2*, sodium-glucose cotransporter-2.
Notes: Data expressed as mean (standard deviation), median [IQR], or number (%). Missing data for National Diabetes Repository: 11,627 missing income quintile and 1,393 missing urban residence; missing data for LMC Diabetes Registry: 31 individuals missing insulin pump, 517 missing income quintile, and 605 missing urban residence.

Supplementary Table 2
Antihyperglycemic medication class use by province

	Alberta (n=22,927)	Manitoba (n=9,938)	Newfoundland (n=330)	Ontario (n=79,570)	Québec (n=3,732)	p Value *
Metformin	8,813 (38.4%)	3,372 (33.9%)	172 (52.1%)	48,826 (61.4%)	2,942 (78.8%)	<0.0001
DPP-4 inhibitor	2,293 (1.0%)	540 (5.4%)	9 (2.7%)	25,715 (32.3%)	1,525 (40.9%)	<0.0001
Sulfonylurea	2,295 (10.0%)	1,794 (18.1%)	98 (29.7%)	16,776 (21.1%)	1,354 (36.3%)	<0.0001
SGLT-2 inhibitor	2,690 (11.7%)	300 (3.0%)	8 (2.4%)	18,482 (23.2%)	1,380 (37.0%)	<0.0001
GLP-1 RA	1,198 (5.2%)	12 (0.1%)	<6 (<1.8%)	5,941 (7.5%)	3,080 (17.5%)	<0.0001

DPP-4, dipeptidyl peptidase-4; *GLP-1*, glucagon-like peptide-1 receptor agonist; *SGLT-2*, sodium-glucose cotransporter-2.
* Using the chi-square test.

Supplementary Table 3
Characteristics of patients with T2D not prescribed insulin according to attainment of A1C ≤7.0% and use or non-use of antihyperglycemic agents

	A1C ≤7.0% and no antihyperglycemic medications (n=27,747)	A1C >7.0% and no antihyperglycemic medications (n=10,042)	A1C ≤7.0% and antihyperglycemic medications (n=27,429)	A1C >7.0% and antihyperglycemic medications (n=26,148)	Total (N=91,366)
Patients' demographics					
Age, years	65.9 (14.56)	63.6 (15.29)	65.6 (12.91)	64.6 (12.90)	65.2 (13.73)
Female sex	14,579 (52.5%)	4,485 (44.7%)	12,579 (45.9%)	11,154 (42.7%)	42,797 (46.8%)
Income quintile					
1	5,717 (24.5%)	2,090 (26.1%)	5,674 (22.2%)	5,555 (23.4%)	19,036 (23.6%)
2	4,834 (20.7%)	1,763 (22.0%)	5,384 (21.1%)	5,157 (21.7%)	17,138 (21.2%)
3	4,493 (19.3%)	1,460 (18.2%)	4,879 (19.1%)	4,637 (19.5%)	15,469 (19.2%)
4	4,203 (18.0%)	1,377 (17.2%)	4,729 (18.5%)	4,361 (18.3%)	14,670 (18.2%)
5	4,084 (17.5%)	1,324 (16.5%)	4,877 (19.1%)	4,061 (17.1%)	14,346 (17.8%)
Province					
Alberta	7,815 (28.2%)	3,323 (33.1%)	4,129 (15.1%)	4,168 (15.9%)	19,435 (21.3%)
Manitoba	3,618 (13.0%)	1,776 (17.7%)	1,431 (5.2%)	2,129 (8.1%)	8,954 (9.8%)
Newfoundland	71 (0.3%)	26 (0.3%)	70 (0.3%)	91 (0.3%)	258 (0.3%)
Ontario	15,957 (57.5%)	4,857 (48.4%)	20,671 (75.4%)	18,804 (71.9%)	60,289 (66.0%)
Québec	286 (1.0%)	60 (0.6%)	1,128 (4.1%)	956 (3.7%)	2,430 (2.7%)
Urban residence	21,916 (80.3%)	7,632 (77.6%)	23,429 (86.7%)	22,024 (85.6%)	75,001 (83.5%)
Laboratory values					
A1C value (%)	6.1 (0.53)	8.3 (1.40)	6.4 (0.50)	8.2 (1.28)	7.1 (1.35)
eGFR (mL/min per 1.73 m^2)	75.9 (22.12)	78.6 (25.39)	77.8 (21.40)	80.8 (22.26)	78.2 (22.40)
Total cholesterol	4.4 (1.13)	4.4 (1.22)	3.9 (1.02)	4.1 (1.16)	4.1 (1.14)
LDL cholesterol	2.3 (0.97)	2.2 (0.99)	1.9 (0.84)	2.0 (0.91)	2.1 (0.93)
HDL cholesterol	1.5 (0.59)	1.4 (0.58)	1.4 (0.52)	1.3 (0.52)	1.4 (0.55)
Triglycerides	1.5 [1.1−2.2]	1.8 [1.2−2.6]	1.5 [1.1−2.1]	1.7 [1.2−2.5]	1.6 [1.1−2.3]
Medications					
Metformin	0 (0.0%)	0 (0.0%)	24,551 (89.5%)	22,731 (86.9%)	47,282 (51.8%)
DPP-4 inhibitor	0 (0.0%)	0 (0.0%)	24,551 (89.5%)	22,731 (86.9%)	47,282 (51.8%)
Sulfonylurea	0 (0.0%)	0 (0.0%)	5,415 (19.7%)	10,633 (40.7%)	16,048 (17.6%)
SGLT-2 inhibitor	0 (0.0%)	0 (0.0%)	5,245 (19.1%)	8,847 (33.8%)	14,092 (15.4%)
GLP-1 RA	0 (0.0%)	0 (0.0%)	1,953 (7.1%)	2,142 (8.2%)	4,095 (4.5%)
Statin	8,313 (30.0%)	2,114 (21.1%)	18,844 (68.7%)	17,361 (66.4%)	46,632 (51.0%)
ACE inhibitor or ARB	9,216 (33.2%)	2,538 (25.3%)	17,185 (62.7%)	15,889 (60.8%)	44,828 (49.1%)

A1C, glycated hemoglobin; *DPP-4*, dipeptidyl peptidase-4; *eGFR*, estimated glomerular filtration rate; *GLP-1 RA*, glucagon-like peptide-1 receptor agonist; *SGLT-2*, sodium-glucose cotransporter-2; *T1D*, type 1 diabetes; *T2D*, type 2 diabetes.
Note: p<0.0001 for all comparisons using the chi-square test for categorical variables and Kruskal–Wallis test for continuous variables.

Supplementary Table 4
Sensitivity analysis using multiple imputation for multivariate logistic regressions (odds ratios and 95% confidence intervals) for associations between predictors and attainment of A1C target of ≤7.0%, according to diabetes categorization as T2D not prescribed insulin, T2D prescribed insulin, or T1D

Predictor	T2D not prescribed insulin (n=91,366)	T2D prescribed insulin (n=25,131)	T1D (n=5,609)
Age (per 1 year)	1.00 (1.00–1.01)	1.00 (1.00–1.01)	1.00 (0.99–1.01)
Sex (reference: male)	1.14 (1.11–1.18)	0.93 (0.88–0.99)	0.85 (0.74–0.96)
Income quintile (reference: 1)			
2	1.04 (0.99–1.08)	1.00 (0.91–1.09)	0.99 (0.79–1.23)
3	1.09 (1.04–1.14)	1.09 (0.99–1.19)	0.90 (0.72–1.12)
4	1.10 (1.05–1.15)	1.17 (1.07–1.29)	1.19 (0.96–1.47)
5	1.16 (1.10–1.21)	1.21 (1.10–1.33)	1.28 (1.04–1.58)
Province (reference: Ontario)			
Alberta	0.72 (0.69–0.75)	0.63 (0.57–0.69)	0.69 (0.58–0.84)
Manitoba	0.62 (0.58–0.67)	0.51 (0.41–0.64)	0.45 (0.21–0.94)
Newfoundland	0.64 (0.49–0.83)	0.59 (0.32–1.09)	2.37 (0.67–8.46)
Québec	1.42 (1.29–1.55)	1.14 (1.00–1.30)	1.04 (0.87–1.26)
Residence (reference: rural)	1.08 (1.04–1.13)	1.02 (0.92–1.12)	1.42 (1.13–1.80)
eGFR (per 1 mL/min per 1.73 m^2)	1.00 (0.99–1.00)	1.00 (0.99–1.00)	1.00 (0.99–1.00)
Number of non-insulin antihyperglycemic agents	0.50 (0.44–0.57)	0.77 (0.64–0.93)	–
No antihyperglycemic medications	1.57 (1.47–1.68)	–	–
Metformin	2.00 (1.75–2.30)	1.40 (1.14–1.72)	–
DPP-4 inhibitor	1.28 (1.12–1.46)	1.12 (0.91–1.37)	–
SGLT-2 inhibitor	1.13 (0.99–1.29)	1.04 (0.85–1.27)	–
Sulfonylurea	0.81 (0.71–0.93)	0.81 (0.66–0.99)	–
GLP-1 receptor agonist	1.81 (1.56–2.10)	1.34 (1.09–1.65)	–
Insulin pump	–	–	1.15 (1.01–1.32)
Basal insulin only	–	1.57 (1.47–1.68)	–

A1C, glycated hemoglobin; *DPP-4*, dipeptidyl peptidase-4; *eGFR*, estimated glomerular filtration rate; *GLP-1*, glucagon-like peptide-1; *SGLT-2*, sodium-glucose cotransporter-2; *T1D*, type 1 diabetes; *T2D*, type 2 diabetes.

Supplementary Table 5
Multivariate logistic regressions (odds ratios and 95% confidence intervals) for associations between predictors and attainment of A1C target of ≤7.0%, according to diabetes categorization as T2D not prescribed insulin, T2D prescribed insulin, or T1D, performed separately for the National Diabetes Repository and LMC Diabetes Registry

Predictor	National Diabetes Repository			LMC Diabetes Registry		
	T2D not prescribed insulin (n=71,315)	T2D prescribed insulin (n=10,473)	T1D (n=1,484)	T2D not prescribed insulin (n=20,051)	T2D prescribed insulin (n=14,658)	T1D (n=4,125)
Age (per 10 years)	1.06 (1.04–1.08)	1.04 (0.99–1.09)	1.05 (1.03–1.07)	1.00 (0.97–1.04)	1.07 (1.02–1.11)	0.94 (0.91–0.97)
Sex (reference: male)	1.18 (1.14–1.23)	0.96 (0.87–1.06)	1.28 (1.23–1.32)	1.01 (0.95–1.08)	0.92 (0.85–0.99)	1.19 (1.12–1.26)
Income quintile (reference: 1)						
2	1.01 (0.96–1.07)	0.97 (0.84–1.12)	1.01 (0.96–1.06)	1.08 (0.98–1.19)	1.02 (0.91–1.15)	1.06 (0.97–1.16)
3	1.07 (1.01–1.12)	1.04 (0.90–1.21)	1.08 (1.03–1.14)	1.08 (0.98–1.20)	1.11 (0.98–1.25)	1.08 (0.99–1.18)
4	1.09 (1.03–1.15)	1.16 (1.00–1.35)	1.09 (1.03–1.14)	1.06 (0.96–1.17)	1.19 (1.05–1.35)	1.11 (1.01–1.22)
5	1.09 (1.03–1.15)	1.22 (1.05–1.43)	1.10 (1.04–1.16)	1.28 (1.16–1.41)	1.19 (1.05–1.36)	1.35 (1.23–1.48)
Province (reference: Ontario)						
Alberta	0.75 (0.72–0.78)	0.65 (0.58–0.74)	0.93 (0.90–0.97)	0.80 (0.69–0.93)	0.62 (0.51–0.75)	0.69 (0.60–0.79)
Manitoba	0.67 (0.62–0.72)	0.47 (0.37–0.61)	0.68 (0.63–0.73)	–	–	–
Newfoundland and Labrador	0.63 (0.48–0.84)	0.57 (0.30–1.08)	0.61 (0.47–0.80)	–	–	–
Québec	1.70 (1.36–2.14)	1.35 (0.81–2.24)	1.44 (1.16–1.79)	1.17 (1.04–1.31)	1.13 (0.98–1.31)	0.89 (0.80–1.00)
Residence (reference: rural)	1.03 (0.99–1.08)	1.05 (0.93–1.19)	1.02 (0.97–1.06)	1.10 (0.94–1.29)	0.96 (0.80–1.15)	1.15 (0.99–1.34)
eGFR (per 10 mL/min per 1.73 m^2)	0.96 (0.95–0.97)	0.96 (0.94–0.99)	0.96 (0.95–0.97)	0.94 (0.92–0.96)	0.96 (0.94–0.97)	0.93 (0.91–0.94)
Number of non-insulin antihyperglycemic medications	0.48 (0.40–0.57)	0.73 (0.53–0.99)	–	0.55 (0.45–0.67)	0.82 (0.64–1.04)	–
No antihyperglycemic medications	1.66 (1.53–1.80)	–	–	2.46 (2.02–2.98)	–	–
Metformin	2.15 (1.79–2.58)	1.54 (1.10–2.14)	–	1.76 (1.41–2.21)	1.26 (0.97–1.63)	–
DPP-4 inhibitor	1.32 (1.10–1.59)	1.25 (0.89–1.75)	–	1.01 (0.82–1.24)	0.99 (0.76–1.28)	–
SGLT-2 inhibitor	1.05 (0.87–1.27)	0.98 (0.69–1.38)	–	1.01 (0.83–1.24)	1.02 (0.79–1.32)	–
Sulfonylurea	0.89 (0.74–1.06)	1.08 (0.77–1.51)	–	0.70 (0.57–0.86)	0.65 (0.50–0.84)	–
GLP-1 receptor agonist	3.19 (2.56–3.98)	1.68 (1.15–2.45)	–	1.09 (0.88–1.35)	1.18 (0.91–1.53)	–
Basal insulin only	–	1.39 (1.24–1.55)	–	–	1.78 (1.63–1.95)	–
Insulin pump	–	–	0.67 (0.09–4.74)	–	–	0.61 (0.10–3.70)

A1C, glycated hemoglobin; *DPP-4*, dipeptidyl peptidase-4; *eGFR*, estimated glomerular filtration rate; *GLP-1*, glucagon-like peptide-1; *SGLT-2*, sodium-glucose cotransporter-2; *T1D*, type 1 diabetes; *T2D*, type 2 diabetes.