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Original Research

The Health and Health Care of Adults With Type 1 And 2 Diabetes Across the Spectrum of Estimated Glomerular Filtration Rates

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Key Messages

- Patients with low kidney function and diabetes have many medical comorbidities and face a high burden of health care.
- In this setting, they are overmonitored, are underscreened, are more often hospitalized and experience more diabetes-related complications.
- "Siloed" and fragmented health care might lead to observed gaps across the spectrum of kidney disease. Coordinated patient care and patient and provider support might be explored.

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ABSTRACT

Objectives: Little is known about the health and health-care patterns of patients with diabetes according to their estimated glomerular filtration rates, especially within a publicly funded health-care system.

Methods: Using linked health-care databases in Ontario, Canada, we performed a population-based study of adults 50 years of age and older (mean age, 68 years) with prevalent diabetes on January 1, 2014. We categorized patients according to their levels of kidney function (estimated glomerular filtration rate ≥90, 60 to 89, 30 to 59, 15 to 29 or <15 mL/min/1.73 m^2, or the receipt of ongoing maintenance dialysis). We then followed patients for 2 years to determine: 1) their level of contact with health-care providers (i.e. visits to family doctors, specialists); 2) their use and repeated use of acute medical services (i.e. hospitalizations and emergency department encounters; 3) diabetes-related monitoring and screening (i.e. glycated hemoglobin and cholesterol tests, vision screening); 4) glycemic and lipid control; and 5) diabetes-related outcomes.

Results: There were 569,384 patients in our study. Most had estimated glomerular filtration rates between 60 and 89 mL/min/1.73 m^2. At baseline, patients with lower kidney function had longer durations of diabetes and more comorbidities. Over 2 years of follow up, they had higher burdens of medical care, excessive diabetes monitoring and were underscreened for diabetes-related complications. Although metabolic control was reasonable across groups, patients with low kidney function had more hospital encounters and more diabetes-related complications.

Conclusions: Patients with diabetes and low kidney function are a vulnerable population that faces health system challenges and care gaps. Suggestions for policy and practice are discussed.

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RÉSUMÉ

Objectifs : On en connaît peu sur les profils de santé et de soins de santé des patients diabétiques pour ce qui est de l'estimation des débits de filtration glomérulaire, notamment dans le système public de soins de santé.
Méthodes : À partir des banques de données liées des soins de santé de l'Ontario, au Canada, nous avons réalisé une étude de population auprès d'adultes de 50 ans et plus (âge moyen, 68 ans) atteints de diabète le 1er janvier 2014. Nous avons réparti les patients selon leur niveau de fonctionnement rénal (estimation du débit de filtration glomérulaire≥90, de 60 à 89, de 30 à 59, de 15 à 29 ou<15 ml/min/1,73 m^2, ou l'administration continue d'une dialyse d'entretien). Nous avons ensuite suivi les patients durant 2 ans pour déterminer : 1) leur fréquence de contact avec les prestataires de soins de santé (c.–à–d. les rendez-vous chez les médecins de famille et les spécialistes); 2) leur utilisation et leur utilisation récurrente des services de soins médicaux aigus (c.–à–d. les hospitalisations et les rendez-vous au service des urgences; 3) la surveillance et le dépistage du diabète (c.–à–d. les analyses de l'hémoglobine glyquée et du cholestérol, le dépistage des troubles de la vue); 4) la régulation du métabolisme des glucides et des lipides; 5) les résultats liés au diabète.
Résultats : Notre étude regroupait 569 384 patients. L'estimation des débits de filtration glomérulaire se situait entre 60 et 89 ml/min/1,73 m^2 chez la plupart des patients. Au début, les patients qui montraient une diminution du fonctionnement des reins avaient un diabète depuis plus longtemps et plus de maladies associées. Pendant les 2 années de suivi, ils portaient un fardeau de soins médicaux plus lourd et démontraient une surveillance excessive de leur diabète, en plus de subir un sous-dépistage des complications liées au diabète. Bien que tous les groupes aient montré une régulation satisfaisante du métabolisme, les patients qui accusaient une diminution du fonctionnement rénal avaient plus de consultations à l'hôpital et plus de complications liées au diabète.
Conclusions : Les patients diabétiques dont le fonctionnement rénal est diminué constituent une population vulnérable qui fait face aux enjeux du système de soins de santé et aux lacunes en matière de soins. Des suggestions de politiques et de pratiques font l'objet de discussions.

Introduction

Between 20% and 50% of patients with diabetes live with chronic kidney disease (CKD), including those with disease in advanced stages. With our aging population, a higher prevalence of obesity and fewer deaths from cardiovascular disease and cancer, the number of patients with diabetes and CKD is expected to increase over the coming decades (1,2).

Despite the increasing prevalence of these conditions, there are surprisingly few data concerning the health and health-care patterns of patients with diabetes and CKD. When studies have been conducted previously, most have been small, captured care patterns at only 1 time point, ascertained a limited number of care measures (e.g. process measures such as glycated hemoglobin [A1C] tests) (3), provided little context for emerging trends (e.g. few characteristics of patients at baseline), and were performed outside of Canada, which has a publicly funded health-care system. Furthermore, patients with CKD are a heterogeneous population (4), and few studies have evaluated how the health and health care of these patients differs across the spectrum of kidney disease.

A comprehensive care-pattern analysis can serve multiple purposes. An analysis might elucidate the impact of multiple illnesses on our health-care system (5); identify care gaps and inform clinical practice and policy change (6); assist in our understanding of the burden of care placed upon patients living within a system that is organized around single diseases; and help researchers ascertain the baseline risks and outcomes of patient groups for study planning.

Using a large cohort of patients with diabetes and stable kidney function in Ontario, Canada, in the current study we aimed to comprehensively evaluate their health and health care according to their estimated glomerular filtration rates (eGFRs). Alongside important baseline characteristics, we ascertained 1) their levels of contact with health-care providers (i.e. visits to family doctors, specialists); 2) their use and repeated use of acute medical services (i.e. hospitalizations and emergency department encounters); 3) their receipt of diabetes-related monitoring and screening (i.e. glycated hemoglobin [A1C] levels and cholesterol tests, vision screening); 4) glycemic and lipid control; and 5) diabetes-related outcomes over 2 years of follow up. We hypothesized that those with lower kidney function would require more health-care services and exhibit more diabetes-related care gaps.

Methods

Design and setting

Using linked health-care databases, we conducted a population-based study of adults 50 years of age and older who had diabetes and stable kidney function or were using maintenance dialysis in Ontario, Canada.

There are more than 14 million residents in Ontario (7). In our province, people have universal access to hospital, diagnostic and physician services. Those 65 years of age and older also have universal access to medications. Information about the use of these services is collected and maintained in the records of databases held at the Institute for Clinical Evaluative Sciences (ICES). Databases are linked using unique encoded identifiers.

This project was approved by the Research Ethics Board at Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada. We used the REporting of studies Conducted using Observational Routinely-collected Data (RECORD) Statement (Supplementary Table S1) to report our study's findings (8).

Data sources

We used the Ontario Diabetes Database (sensitivity 86%, specificity 97%) to determine the diabetes status of patients (9) and the Ontario Laboratories Information System database to ascertain laboratory data, including serum creatinine, low-density lipoprotein cholesterol (LDL-C) and A1C levels. The Ontario Laboratories Information System database holds laboratory data from both community and hospital laboratories across the province, and it represents more than 91% of annual provincial test volumes (10). We used the Gamma

Dynacare Laboratory Database to ascertain additional laboratory values, including fasting and random plasma glucose levels.

The Registered Persons Database of Ontario was used to ascertain the vital statistics of included patients. It contains demographic information concerning those who have received health cards in our province. The CONTACT database allowed us to capture information about patients with evidence of health-care utilization, including hospital visits and billing claims. The database helped us to determine whether patients had emigrated from Ontario during the follow-up period.

To provide additional baseline information, we used the Ontario Marginalization Index database, which is a geographically based index that quantifies the degree of marginalization across our province. It is composed of the 4 dimensions thought to underlie the construct of marginalization: residential instability, material deprivation, dependency and ethnic concentration (11). We also used the Immigration, Refugees, and Citizenship Canada's Permanent Resident Database to determine the immigration status of patients (Immigration, Refugees and Citizenship Canada). Further, we used the Client Agency Program Enrollment database (a registry of patients enrolled in primary care groups) to determine whether a patient was rostered to a family physician. The Home Care Database was used to ascertain whether patients accessed home care services.

The Canadian Institute for Health Information's Discharge Abstract Database and the National Ambulatory Care Reporting System databases were used to capture information coded during inpatient and emergency department encounters, respectively. Administrative codes contained within these databases (International Statistical Classification of Diseases and Related Health Problems, 10th revision, and Canadian Classification of Health Interventions) were used to evaluate patients' comorbidities. We also used derived ICES databases, including the Ontario Congestive Heart Failure, Chronic Obstructive Pulmonary and Hypertension Datasets, to capture additional comorbidities. The Ontario portion of the Canadian Organ Replacement Register database was used to determine the kidney-transplant statuses of patients.

Medication information for those 65 years of age or older was ascertained from the Ontario Drug Benefit database and the Drug Identification Number database. The Ontario Drug Benefit database contains accurate records of all prescriptions dispensed to patients and has an error rate of <1% (12). Additional information about physician visits, laboratory and imaging services and medical diagnoses were obtained from the Ontario Health Insurance Plan database.

Our coding definitions are provided in Supplementary Table S2. We ascertained all baseline characteristics in the 5 years prior to the index date (defined below), medications within 180 days of the index date and baseline health-care utilization in the 1 year prior to the index date. Apart from locations of residence, income quintiles and marginalization indexes (missing in <3% of patients), datasets were complete for every variable studied.

Patients

We included adults 50 years of age or older with prevalent diabetes and either stable kidney function or the receipt of maintenance dialysis as of January 1, 2014. We defined stable kidney function as an eGFR test (calculated using serum creatinine and the Chronic Kidney Disease Epidemiology Collaboration equation) in the prior year (i.e. January 1, 2013, to January 1, 2014), with a second eGFR test within 3 months to 2 years prior to the most recent value. eGFR values had to be within 10 mL/min/1.73 m^2, or 10%, of each other. To be included as a person receiving maintenance dialysis, patients required 2 chronic dialysis codes within the prior year, billed between 90 and 150 days of each other (Supplementary Table S2) (13).

We excluded patients 1) who had invalid identification numbers and missing age, sex or date of birth; 2) who had died prior to January 1, 2014; 3) who were not residents of Ontario; 4) who had invalid ages (i.e. negative age or age >105 years); 5) who died or emigrated from Ontario within 2 years of the index date; and 6) who lived in long-term care.

We then stratified patients by their most recent eGFR readings preceding January 1, 2014 (i.e. ≥90, 60 to 89, 30 to 59, 15 to 29, <15 mL/min/1.73 m^2 or using maintenance dialysis). Each group was mutually exclusive, and patients receiving dialysis were not included in any eGFR group. A flow diagram of patient inclusion and exclusion is provided (Supplementary Figure S1).

Health-care patterns

Using January 1, 2014, as our index date (i.e. start time for follow up), we followed patients for 2 years to determine their health and health-care patterns. We ascertained their 1) health-care provider patterns (i.e. visits to family doctors, specialists); 2) use and repeated use of acute medical services; 3) diabetes-related monitoring and screening; 4) glycemic and lipid control; and 5) diabetes-related outcomes. We used the recommendations published by Diabetes Canada and the Kidney Disease Outcome Quality Initiative to establish our care indicators and comment upon relevant gaps (Supplementary Table S3) (14,15).

Statistical analyses

We used descriptive statistics to summarize the baseline characteristics of patients along with their 2-year patterns of care. Continuous variables were presented as means ± standard deviation and medians (interquartile range). Binary variables were presented as proportions. All analyses were conducted using SAS v. 9.4 (SAS Institute, Cary, North Carolina, United States).

Results

Baseline characteristics

Included in our study were 569,384 patients with diabetes and stable kidney function or receiving maintenance dialysis. Most had eGFRs between 60 and 89 mL/min/1.73 m^2 (n=253,915; 44.6%).

The baseline characteristics of patients across the spectrum of kidney disease are presented in Table 1. Patients with lower kidney function and using maintenance dialysis had more medical comorbidities and diabetes-related complications and used more medications than those with normal kidney function. Those using maintenance dialysis were of lower socioeconomic status and had higher levels of social deprivation compared with other groups.

Health-care patterns

The health-care patterns of patients across the spectrum of kidney disease are illustrated in Table 2 and in Figure 1 and Figure 2.

eGFR 30 to 59 mL/min/1.73 m^2. Compared to those with eGFRs ≥60 mL/min/1.73 m^2 over the 2-year follow-up period, patients in this group saw more specialists. Most had adequate diabetes monitoring (i.e. 3 to 8 A1C tests over 2 years) but, like those with normal kidney function, a high proportion did not receive annual vision assessments.

The majority had A1C levels ≤7% and LDL-C levels ≤2 mmol/L. Compared to those with eGFRs ≥60 mL/min/1.73 m^2, however, they had more hospitalizations and emergency department visits, and a higher proportion had diabetes-related complications. Over the

Table 1
Baseline characteristics of patients aged ≥50 years with diabetes by estimated glomerular filtration rates

	Estimated glomerular filtration rate, mL/min/1.73 m^2					Dialysis (n=3,575)
	≥90 (n=200,832)	60– <90 (n=253,915)	30– <60 (n=98,051)	15– <30 (n=11,504)	<15 (n=1,507)	
Age, years						
Mean ± SD	60.2±6.6	70.1±9.0	75.9±8.8	77.0±9.6	71.7±10.4	68.1±10.0
Median (IQR)	60.1 (55.0–65.0)	70.0 (64.0–77.0)	77.0 (70.0–82.0)	78.0 (71.0–84.0)	72.0 (64.0–80.0)	68.0 (60.0–76.0)
50–65	156,409 (77.9%)	77,242 (30.4%)	12,469 (12.7%)	1,502 (13.1%)	452 (30.0%)	1,520 (42.5%)
66–74	39,979 (19.9%)	93,384 (36.8%)	27,628 (28.2%)	2,651 (23.0%)	436 (28.9%)	1,031 (28.8%)
75+	4,444 (2.2%)	83,289 (32.8%)	57,954 (59.1%)	7,351 (63.9%)	619 (41.1%)	1,024 (28.6%)
Female	94,048 (46.8%)	115,501 (45.5%)	51,418 (52.4%)	6,238 (54.2%)	727 (48.2%)	1,371 (38.3%)
Rural location						
Yes	21,375 (10.6%)	26,892 (10.6%)	10,935 (11.2%)	1,284 (11.2%)	150 (10.0%)	378 (10.6%)
Missing	0 (0.0%)	≤5	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Rostered to family doctor	176,945 (88.1%)	226,791 (89.3%)	87,579 (89.3%)	10,098 (87.8%)	1,297 (86.1%)	2,908 (81.3%)
Immigrant	45,056 (22.4%)	36,571 (14.4%)	11,030 (11.2%)	1,236 (10.7%)	249 (16.5%)	623 (17.4%)
Income quintile						
5 (highest income)	32,778 (16.3%)	46,180 (18.2%)	16,296 (16.6%)	1,734 (15.1%)	206 (13.7%)	437 (12.2%)
4	40,799 (20.3%)	52,665 (20.7%)	19,091 (19.5%)	2,174 (18.9%)	291 (19.3%)	594 (16.6%)
3	41,742 (20.8%)	51,931 (20.5%)	19,565 (20.0%)	2,262 (19.7%)	278 (18.4%)	709 (19.8%)
2	43,160 (21.5%)	53,425 (21.0%)	21,620 (22.0%)	2,576 (22.4%)	324 (21.5%)	770 (21.5%)
1 (lowest income)	41,491 (20.7%)	48,848 (19.2%)	21,137 (21.6%)	2,699 (23.5%)	401 (26.6%)	1,036 (29.0%)
Missing	862 (0.4%)	866 (0.3%)	342 (0.3%)	59 (0.5%)	7 (0.5%)	29 (0.8%)
Marginalization index						
Deprivation score						
1 (least deprived)	38,875 (19.4%)	50,615 (19.9%)	17,656 (18.0%)	1,867 (16.2%)	227 (15.1%)	518 (14.5%)
2	39,214 (19.5%)	50,956 (20.1%)	18,643 (19.0%)	2,105 (18.3%)	268 (17.8%)	563 (15.7%)
3	39,784 (19.8%)	50,750 (20.0%)	19,516 (19.9%)	2,226 (19.3%)	312 (20.7%)	653 (18.3%)
4	39,409 (19.6%)	50,370 (19.8%)	20,174 (20.6%)	2,420 (21.0%)	287 (19.0%)	747 (20.9%)
5 (most deprived)	41,171 (20.5%)	48,586 (19.1%)	20,979 (21.4%)	2,731 (23.7%)	392 (26.0%)	999 (27.9%)
Missing	2,379 (1.2%)	2,638 (1.0%)	1,083 (1.1%)	155 (1.3%)	21 (1.4%)	95 (2.7%)
Ethnic concentration						
1 (fewer minorities)	31,107 (15.5%)	45,427 (17.9%)	19,299 (19.7%)	2,229 (19.4%)	211 (14.0%)	515 (14.4%)
2	29,557 (14.7%)	41,568 (16.4%)	17,097 (17.4%)	1,999 (17.4%)	206 (13.7%)	469 (13.1%)
3	31,430 (15.6%)	43,428 (17.1%)	17,173 (17.5%)	2,009 (17.5%)	222 (14.7%)	534 (14.9%)
4	38,306 (19.1%)	48,834 (19.2%)	18,242 (18.6%)	2,145 (18.6%)	284 (18.8%)	712 (19.9%)
5 (more minorities)	68,053 (33.9%)	72,020 (28.4%)	25,157 (25.7%)	2,967 (25.8%)	563 (37.4%)	1,250 (35.0%)
Missing	2,379 (1.2%)	2,638 (1.0%)	1,083 (1.1%)	155 (1.3%)	21 (1.4%)	95 (2.7%)
Dependency						
1 (lowest)	45,485 (22.6%)	45,804 (18.0%)	15,107 (15.4%)	1,707 (14.8%)	291 (19.3%)	762 (21.3%)
2	43,066 (21.4%)	48,722 (19.2%)	16,743 (17.1%)	1,870 (16.3%)	300 (19.9%)	693 (19.4%)
3	37,696 (18.8%)	45,869 (18.1%)	16,738 (17.1%)	1,926 (16.7%)	279 (18.5%)	612 (17.1%)
4	34,161 (17.0%)	46,367 (18.3%)	18,772 (19.1%)	2,276 (19.8%)	240 (15.9%)	592 (16.6%)
5 (highest)	38,045 (18.9%)	64,515 (25.4%)	29,608 (30.2%)	3,570 (31.0%)	376 (25.0%)	821 (23.0%)
Missing	2,379 (1.2%)	2,638 (1.0%)	1,083 (1.1%)	155 (1.3%)	21 (1.4%)	95 (2.7%)
Instability						
1 (lowest)	43,431 (21.6%)	48,015 (18.9%)	15,007 (15.3%)	1,645 (14.3%)	259 (17.2%)	582 (16.3%)
2	39,670 (19.8%)	48,992 (19.3%)	17,090 (17.4%)	1,859 (16.2%)	253 (16.8%)	584 (16.3%)
3	36,578 (18.2%)	47,985 (18.9%)	18,591 (19.0%)	2,107 (18.3%)	266 (17.7%)	548 (15.3%)
4	36,983 (18.4%)	47,421 (18.7%)	19,617 (20.0%)	2,379 (20.7%)	294 (19.5%)	695 (19.4%)
5 (highest)	41,791 (20.8%)	58,864 (23.2%)	26,663 (27.2%)	3,359 (29.2%)	414 (27.5%)	1,071 (30.0%)
Missing	2,379 (1.2%)	2,638 (1.0%)	1,083 (1.1%)	155 (1.3%)	21 (1.4%)	95 (2.7%)
Summary score						
Mean ± SD	3.07±0.80	3.11±0.80	3.20±0.80	3.26±0.81	3.27±0.82	3.28±0.82
Median (IQR)	3.0 (2.5–3.8)	3.0 (2.5–3.8)	3.3 (2.5–3.8)	3.3 (2.4–4.0)	3.3 (2.5–4.0)	3.3 (2.8–4.0)
Diabetes duration						
>10 years	71,114 (35.4%)	101,172 (39.8%)	52,176 (53.2%)	7,921 (68.9%)	1,119 (74.3%)	2,600 (72.7%)
Comorbidities*						
Kidney transplant	32 (0.0%)	141 (0.1%)	181 (0.2%)	44 (0.4%)	≤5	124 (3.5%)
CAD	42,697 (21.3%)	75,956 (29.9%)	39,483 (40.3%)	5,513 (47.9%)	733 (48.6%)	2,367 (66.2%)
CVD	4,218 (2.1%)	9,006 (3.5%)	5,738 (5.9%)	848 (7.4%)	117 (7.8%)	352 (9.8%)
CHF	6,858 (3.4%)	19,404 (7.6%)	17,733 (18.1%)	3,834 (33.3%)	547 (36.3%)	1,717 (48.0%)
Foot ulcer	1,156 (0.6%)	1,434 (0.6%)	1,210 (1.2%)	344 (3.0%)	58 (3.8%)	340 (9.5%)
Amputation	478 (0.2%)	583 (0.2%)	447 (0.5%)	117 (1.0%)	12 (0.8%)	151 (4.2%)
Hospital encounter with hypoglycemia	1,907 (0.9%)	3,148 (1.2%)	3,293 (3.4%)	929 (8.1%)	188 (12.5%)	546 (15.3%)
Hospital encounter with hyperglycemia	680 (0.3%)	686 (0.3%)	434 (0.4%)	82 (0.7%)	15 (1.0%)	44 (1.2%)
Osteoporosis	11,763 (5.9%)	21,656 (8.5%)	8,812 (9.0%)	971 (8.4%)	108 (7.2%)	215 (6.0%)
Major cancer	14,370 (7.2%)	28,155 (11.1%)	13,158 (13.4%)	1,561 (13.6%)	198 (13.1%)	512 (14.3%)
Hypertension	129,419 (64.4%)	198,441 (78.2%)	89,256 (91.0%)	10,965 (95.3%)	1,435 (95.2%)	3,477 (97.3%)
Depression/anxiety	19,653 (9.8%)	21,026 (8.3%)	8,777 (9.0%)	1,044 (9.1%)	149 (9.9%)	455 (12.7%)
COPD	30,258 (15.1%)	47,080 (18.5%)	23,545 (24.0%)	3,316 (28.8%)	348 (23.1%)	942 (26.3%)
Charlson comorbidity index†						
Mean ± SD	1.52±1.47	1.64±1.54	2.24±1.77	3.23±1.95	3.54±1.89	4.39±1.89
Median (IQR)	1.0 (0.0–2.0)	1.0 (0.0–2.0)	2.0 (1.0–3.0)	3.0 (2.0–4.0)	3.0 (2.0–5.0)	4.0 (3.0–6.0)
0	12,889 (6.4%)	20,297 (8.0%)	7,033 (7.2%)	441 (3.8%)	48 (3.2%)	27 (0.8%)
1	16,025 (8.0%)	22,861 (9.0%)	9,744 (9.9%)	655 (5.7%)	46 (3.1%)	25 (0.7%)
2+	19,719 (9.8%)	35,671 (14.0%)	26,969 (27.5%)	5,649 (49.1%)	932 (61.8%)	3,089 (86.4%)
Not calculable (i.e. no hospitalization)	152,199 (75.8%)	175,086 (69.0%)	54,305 (55.4%)	4,759 (41.4%)	481 (31.9%)	434 (12.1%)

(*continued on next page*)

Table 1 (*continued*)

	Estimated glomerular filtration rate, mL/min/1.73 m^2					Dialysis (n=3,575)
	≥90 (n=200,832)	60– <90 (n=253,915)	30– <60 (n=98,051)	15– <30 (n=11,504)	<15 (n=1,507)	
Medications‡						
ACE/ARB	35,588 (17.7%)	131,044 (51.6%)	69,855 (71.2%)	7,584 (65.9%)	601 (39.9%)	1,109 (31.0%)
Statin	37,729 (18.8%)	136,215 (53.6%)	67,883 (69.2%)	8,264 (71.8%)	875 (58.1%)	1,637 (45.8%)
Ezetimibe	4,233 (2.1%)	15,365 (6.1%)	8,389 (8.6%)	1,108 (9.6%)	144 (9.6%)	220 (6.2%)
Other lipid	989 (0.5%)	4,431 (1.7%)	3,635 (3.7%)	406 (3.5%)	23 (1.5%)	17 (0.5%)
Beta blocker	12,116 (6.0%)	54,790 (21.6%)	37,052 (37.8%)	5,446 (47.3%)	647 (42.9%)	1,236 (34.6%)
Bisphosphonate	5,704 (2.8%)	22,308 (8.8%)	11,192 (11.4%)	1,015 (8.8%)	66 (4.4%)	48 (1.3%)
Denosumab	373 (0.2%)	1,642 (0.6%)	878 (0.9%)	119 (1.0%)	10 (0.7%)	10 (0.3%)
Insulin	6,778 (3.4%)	20,307 (8.0%)	16,200 (16.5%)	3,657 (31.8%)	481 (31.9%)	1,013 (28.3%)
Oral diabetes medication	34,164 (17.0%)	106,613 (42.0%)	51,470 (52.5%)	4,820 (41.9%)	346 (23.0%)	447 (12.5%)
Glucose test strips	22,725 (11.3%)	74,543 (29.4%)	39,653 (40.4%)	5652 (49.1%)	620 (41.1)	1182 (33.1)
Health-care visits§						
At least 1 home care visit	11,858 (5.9%)	24,391 (9.6%)	18,484 (18.9%)	3,578 (31.1%)	506 (33.6%)	1,767 (49.4%)
At least 1 home care nurse visit	1,154 (0.6%)	1,365 (0.5%)	582 (0.6%)	63 (0.5%)	7 (0.5%)	14 (0.4%)
Specialist visits¶						
0	59,842 (29.8%)	60,636 (23.9%)	16,582 (16.9%)	841 (7.3%)	35 (2.3%)	193 (5.4%)
1–2	56,434 (28.1%)	69,232 (27.3%)	23,266 (23.7%)	1,739 (15.1%)	73 (4.8%)	435 (12.2%)
3–5	46,267 (23.0%)	64,020 (25.2%)	26,147 (26.7%)	2,996 (26.0%)	240 (15.9%)	708 (19.8%)
6–11	29,095 (14.5%)	45,543 (17.9%)	23,202 (23.7%)	3,814 (33.2%)	583 (38.7%)	1,196 (33.5%)
12+	9,194 (4.6%)	14,484 (5.7%)	8,854 (9.0%)	2,114 (18.4%)	576 (38.2%)	1,043 (29.2%)
Primary care visits						
0	7,319 (3.6%)	8,280 (3.3%)	3,691 (3.8%)	572 (5.0%)	107 (7.1%)	725 (20.3%)
1–2	30,613 (15.2%)	36,922 (14.5%)	12,440 (12.7%)	1,526 (13.3%)	233 (15.5%)	896 (25.1%)
3–5	73,380 (36.5%)	93,745 (36.9%)	33,941 (34.6%)	3,613 (31.4%)	434 (28.8%)	915 (25.6%)
6+	89,520 (44.6%)	114,968 (45.3%)	47,979 (48.9%)	5,793 (50.4%)	733 (48.6%)	1,039 (29.1%)
Unique physician visits‖						
Mean ± SD	3.3±2.3	3.5±2.3	3.9±2.5	4.9±2.8	6.1±3.2	5.9±3.7
Median (IQR)	3.0 (2.0–4.0)	3.0 (2.0–5.0)	3.0 (2.0–5.0)	4.0 (3.0–6.0)	6.0 (4.0–8.0)	5.0 (3.0–8.0)
Hospitalizations in prior year						
0	185,312 (92.3%)	230,036 (90.6%)	83,667 (85.3%)	8,799 (76.5%)	1,012 (67.2%)	1,831 (51.2%)
1–2	14,659 (7.3%)	22,677 (8.9%)	13,246 (13.5%)	2,360 (20.5%)	422 (28.0%)	1,366 (38.2%)
3+	861 (0.4%)	1,202 (0.5%)	1,138 (1.2%)	345 (3.0%)	73 (4.8%)	378 (10.6%)
All-cause emergency department visits in prior year						
0	152,441 (75.9%)	193,126 (76.1%)	69,882 (71.3%)	7,367 (64.0%)	860 (57.1%)	1,646 (46.0%)
1–2	40,563 (20.2%)	51,377 (20.2%)	22,964 (23.4%)	3,232 (28.1%)	503 (33.4%)	1,333 (37.3%)
3+	7,828 (3.9%)	9,412 (3.7%)	5,205 (5.3%)	905 (7.9%)	144 (9.6%)	596 (16.7%)

Note: Cell sizes <6 were suppressed in accordance with Institute for Clinical Evaluative Sciences privacy policies.

ACE, angiotensin-converting enzyme inhibitor; *ARB,* angiotensin receptor blocker; *CAD,* coronary artery disease; *CHF,* congestive heart failure; *COPD,* chronic obstructive pulmonary disease; *CVD,* cerebrovascular disease; *IQR,* interquartile range; *SD,* standard deviation.

* Unless indicated, comorbidities were ascertained in the prior 5 years.

† Charlson Comorbidity index was calculated using 5 years of hospitalization data (50). Renal disease and diabetes may not always have been captured during a hospitalization.

‡ Unless indicated, medications were ascertained in the prior 180 days.

§ Unless indicated, health-care visits were ascertained in the prior 1 year.

¶ Specialist visits excluded visits to general practitioners, nurse practitioners, midwives and alternative health providers, anesthetists, pediatricians, lab directors, pathologists, microbiologists, biochemists, radiologists, dental professionals and nuclear medicine specialists.

‖ Unique physician visits excluded midwives and alternative health providers, anesthetists, pediatricians, lab directors, pathologists, microbiologists, biochemists, radiologists, dental professionals and nuclear medicine specialists.

follow-up period, a minority experienced progression of their kidney disease (Supplementary Table S4).

eGFR <30 mL/min/1.73 m^2. For patients with lower kidney function, specialist care continued to increase, and a higher proportion of patients were not rostered to family physicians. Compared with those with eGFRs ≥60 mL/min/1.73 m^2, a higher proportion showed no evidence of A1C or LDL-C tests (Figure 1). There was also a higher proportion in this group that had had more than the recommended number of A1C tests (i.e. >8 A1C tests were evident in 24.2% of patients) (Figure 2).

Most patients with eGFRs <30 mL/min/1.73 m^2 had A1C levels ≤7% and LDL-C levels ≤2 mmol/L. However, they faced a high number of hospitalizations, emergency department visits and diabetes-related complications over the follow-up period. The majority of patients with eGFRs <15 mL/min/1.73 m^2 progressed to dialysis.

Maintenance dialysis. Patients using dialysis saw fewer specialists than those with eGFRs <15 mL/min/1.73 m^2. They also used more home care services. In this group, there was a trend toward excessive diabetes monitoring (Figure 1) and underscreening for diabetes-related complications (Figure 2).

Compared with those not yet on dialysis, a smaller proportion had A1C levels ≤7% and LDL levels ≤2 mmol/L. They had the highest number of inpatient hospitalizations and emergency department visits, and a high proportion faced diabetes-related complications during the follow-up period.

Discussion

Main findings

In this large Ontario-wide study of patients with diabetes and stable kidney function, we noted several health-care patterns of interest.

First, with lower kidney function, the burden of health care becomes increasingly apparent. With their extensive comorbidities, patients saw more specialists to manage their health conditions. Those with eGFRs <15 mL/min/1.73 m^2 had an average of 19 specialist visits and saw 9 different physicians over the follow-up period, in addition to visits with their primary care providers.

In those using maintenance dialysis, both primary care and specialist visits waned. These patients' conditions may have become

Table 2
Two-year patterns of care of patients aged ≥50 years with diabetes by estimated glomerular filtration rates

	Estimated glomerular filtration rate (eGFR), mL/min/1.73 m^2					Dialysis (n=3,575)
	≥90 (n=200,832)	60– <90 (n=253,915)	30– <60 (n=98,051)	15– <30 (n=11,504)	<15 (n=1,507)	
Glycemic monitoring and control						
At least 1 A1C test	186,246 (92.7%)	234,366 (92.3%)	91,182 (93.0%)	10,717 (93.2%)	1,363 (90.4%)	2,521 (70.5%)
Number of A1C tests						
Mean ± SD	3.4±2.1	3.4±2.2	3.9±2.5	4.9±3.3	5.9±4.3	4.3±4.5
Median (IQR)	3.0 (2.0–5.0)	3.0 (2.0–5.0)	4.0 (2.0–5.0)	5.0 (2.0–7.0)	5.0 (2.0–8.0)	3.0 (0.0–7.0)
0–2	75,652 (37.7%)	97,226 (38.3%)	32,210 (32.9%)	2,987 (26.0%)	378 (25.1%)	1,667 (46.6%)
3–8	123,105 (61.3%)	153,122 (60.3%)	62,021 (63.3%)	7,101 (61.7%)	765 (50.8%)	1,257 (35.2%)
9–11	1,736 (0.9%)	3,025 (1.2%)	3,094 (3.2%)	1,001 (8.7%)	223 (14.8%)	408 (11.4%)
12+	339 (0.2%)	542 (0.2%)	726 (0.7%)	415 (3.6%)	141 (9.4%)	243 (6.8%)
>8 A1C tests	2,075 (1.0%)	3,567 (1.4%)	3,820 (3.9%)	1,416 (12.3%)	364 (24.2%)	651 (18.2%)
A1C (%)*						
Mean ± SD	7.2±1.3	6.8±1.0	6.9±1.1	7.0±1.2	6.8±1.2	6.9±1.3
Median (IQR)	6.9 (6.3–7.7)	6.6 (6.1–7.3)	6.7 (6.2–7.4)	6.8 (6.2–7.7)	6.5 (6.0–7.3)	6.7(5.9–7.7)
A1C (%)*						
≤7	100,644 (50.1%)	153,218 (60.3%)	56,522 (57.6%)	5,940 (51.6%)	901 (59.8%)	1,457 (40.8%)
7.1–8.5	61,648 (30.7%)	65,823 (25.9%)	27,522 (28.1%)	3,695 (32.1%)	353 (23.4%)	776 (21.7%)
>8.5	23,954 (11.9%)	15,325 (6.0%)	7,138 (7.3%)	1,082 (9.4%)	109 (7.2%)	288 (8.1%)
At least 1 fasting plasma glucose†	6,154 (3.1%)	6,406 (2.5%)	2,074 (2.1%)	250 (2.2%)	22 (1.5%)	32 (0.9%)
Fasting glucose (mmol/L)*,†						
Mean ± SD	7.3±2.3	7.0±2.1	7.1±2.2	6.9±2.4	7.0±2.7	7.6±3.8
Median (IQR)	6.8 (5.8–8.3)	6.6 (5.7–7.9)	6.6 (5.7–8.1)	6.4 (5.1–8.1)	6.3 (5.1–8.5)	6.9 (5.1–8.9)
At least 1 random plasma glucose†	4,354 (2.2%)	5,355 (2.1%)	2,208 (2.3%)	303 (2.6%)	33 (2.2%)	40 (1.1%)
Random glucose (mmol/L) *,†						
Mean ± SD	8.3±3.5	7.8±3.2	8.1±3.4	8.6±4.0	9.3±4.9	9.1±3.5
Median (IQR)	7.4 (5.9–9.8)	6.5 (5.6–9.1)	7.3 (5.7–9.7)	7.8 (5.9–10.3)	8.9 (5.8–11.8)	8.3 (6.4–10.9)
Lipid monitoring and control						
At least 1 LDL-C test	182,075 (90.7%)	229,397 (90.3%)	85,846 (87.6%)	9,584 (83.3%)	1,204 (79.9%)	2,245 (62.8%)
Number of LDL-C tests*						
Mean ± SD	2.4±1.7	2.4±1.7	2.4±1.9	2.5±2.1	2.6±2.5	1.7±2.2
Median (IQR)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–4.0)	2.0 (1.0–4.0)	1.0 (0.0–3.0)
LDL-C (mmol/L)*						
Mean ± SD	2.1±0.8	2.0±0.8	1.9±0.8	1.8±0.7	1.8±0.8	1.7±0.8
Median (IQR)	1.9 (1.5–2.6)	1.8 (1.4–2.4)	1.7 (1.3–2.2)	1.7 (1.3–2.1)	1.7 (1.3–2.2)	1.6 (1.2–2.1)
LDL-C (mmol/L)*						
≤2	96,986 (48.3%)	136,398 (53.7%)	57,730 (58.9%)	6,733 (58.5%)	812 (53.9%)	1,583 (44.3%)
>2	85,089 (42.4%)	92,999 (36.6%)	28,116 (28.7%)	2,851 (24.8%)	392 (26.0%)	662 (18.5%)
Diabetes screening						
At least 1 vision exam	148,978 (74.2%)	206,574 (81.4%)	80,889 (82.5%)	9,205 (80.0%)	1,157 (76.8%)	2,717 (76.0%)
Annual vision exam (1 exam per yr)	90,355 (45.0%)	142,087 (56.0%)	57,273 (58.4%)	6,385 (55.5%)	793 (52.6%)	1,737 (48.6%)
At least 1 cardiac exam	116,961 (58.2%)	164,316 (64.7%)	69,861 (71.2%)	8,841 (76.9%)	1,323 (87.8%)	3,334 (93.3%)
Ambulatory care visits						
Number of primary care visits						
Mean ± SD	12.0±10.5	12.1±9.7	12.8±10.1	12.9±10.9	11.0±11.0	8.3±10.5
Median (IQR)	10.0 (6.0–15.0)	10.0 (6.0–15.0)	11.0 (7.0–16.0)	10.0 (6.0–17.0)	9.0 (4.0–14.0)	6.0 (2.0–11.0)
Number of specialist visits‡						
Mean ± SD	6.6±8.3	7.8±8.7	9.9±9.7	14.7±11.8	19.4±12.9	17.4±15.1
Median (IQR)	4.0 (1.0–9.0)	5.0 (2.0–11.0)	7.0 (3.0–14.0)	12.0 (6.0–20.0)	17.0 (11.0–26.0)	14.0 (7.0–24.0)
Unique physician visits§						
Mean ± SD	4.8±3.4	5.1±3.4	5.8±3.8	7.3±4.4	9.3±5.0	8.8±5.2
Median (IQR)	4.0 (2.0–6.0)	4.0 (3.0–7.0)	5.0 (3.0–8.0)	6.0 (4.0–10.0)	9.0 (6.0–12.0)	8.0 (5.0–12.0)
Hospital encounters						
Number of inpatient hospitalizations						
Mean ± SD	0.2±0.7	0.3±0.8	0.5±1.1	0.9±1.5	1.4±1.7	1.9±2.2
Median (IQR)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.0 (0.0–1.0)	0.0 (0.0–1.0)	1.0 (0.0–2.0)	1.0 (0.0–3.0)
Number of emergency department visits						
Mean ± SD	0.9±2.2	0.9±2.0	1.2±2.3	1.6±2.6	1.9±2.6	2.8±4.6
Median (IQR)	0.0 (0.0–1.0)	0.0 (0.0–1.0)	0.0 (0.0–2.0)	1.0 (0.0–2.0)	1.0 (0.0–3.0)	2.0 (0.0–4.0)
Follow up after inpatient hospitalization¶						
Physician visit within 30 days of hospital discharge	17,950 (8.9%)	31,748 (12.5%)	20,425 (20.8%)	3,635 (31.6%)	645 (42.8%)	1,332 (37.3%)
Readmitted within 30 days of inpatient hospital discharge	2,842 (1.4%)	5,206 (2.1%)	3,635 (3.7%)	735 (6.4%)	173 (11.5%)	440 (12.3%)
ED visit within 30 days of hospital discharge	3,624 (1.8%)	5,592 (2.2%)	3,225 (3.3%)	561 (4.9%)	115 (7.6%)	326 (9.1%)

(*continued on next page*)

Table 2 (*continued*)

	Estimated glomerular filtration rate (eGFR), mL/min/1.73 m^2					Dialysis (n=3,575)
	≥90 (n=200,832)	60– <90 (n=253,915)	30– <60 (n=98,051)	15– <30 (n=11,504)	<15 (n=1,507)	
Diabetes-related complications						
AMI	1,751 (0.9%)	3,315 (1.3%)	2,392 (2.4%)	567 (4.9%)	108 (7.2%)	334 (9.3%)
CVD	2,302 (1.1%)	5,306 (2.1%)	3,484 (3.6%)	507 (4.4%)	85 (5.6%)	227 (6.3%)
Foot ulcer	972 (0.5%)	1,159 (0.5%)	993 (1.0%)	286 (2.5%)	55 (3.6%)	281 (7.9%)
Amputation	327 (0.2%)	400 (0.2%)	275 (0.3%)	95 (0.8%)	24 (1.6%)	153 (4.3%)
Hospital encounter for hypoglycemia	1,192 (0.6%)	2,006 (0.8%)	2,110 (2.2%)	607 (5.3%)	108 (7.2%)	243 (6.8%)
Hospital encounter for hyperglycemia	204 (0.1%)	273 (0.1%)	181 (0.2%)	34 (0.3%)	≤5	17 (0.5%)

Notes: Cell sizes <6 were suppressed in accordance with Institute for Clinical Evaluative Sciences privacy policies. Unless otherwise indicated, laboratory test information was ascertained from the Ontario Laboratory Information Service.

A1C, glycated hemoglobin; *AMI*, acute myocardial infarction; *CVD*, cerebrovascular disease; *ED*, emergency department visit; *IQR*, interquartile range; *LDL-C*, low-density lipoprotein cholesterol; *SD*, standard deviation.

* Calculated where at least 1 test was available. Values were ascertained over the 2-year follow-up period.

† Fasting and random plasma glucose data were ascertained from Gamma Dynacare medical laboratories over the 2-year follow-up period.

‡ Specialist visits excluded visits to general practitioners, nurse practitioners, midwives and alternative health providers, anaesthetists, pediatricians, lab directors, pathologists, microbiologists, biochemists, radiologists, dental professionals and nuclear medicine specialists.

§ Unique physician visits excluded midwives and alternative health providers, anesthetists, pediatricians, lab directors, pathologists, microbiologists, biochemists, radiologists, dental professionals and nuclear medicine specialists.

¶ If patients had more than 1 inpatient hospitalization during the follow-up period, this analysis was limited to their first encounter only.

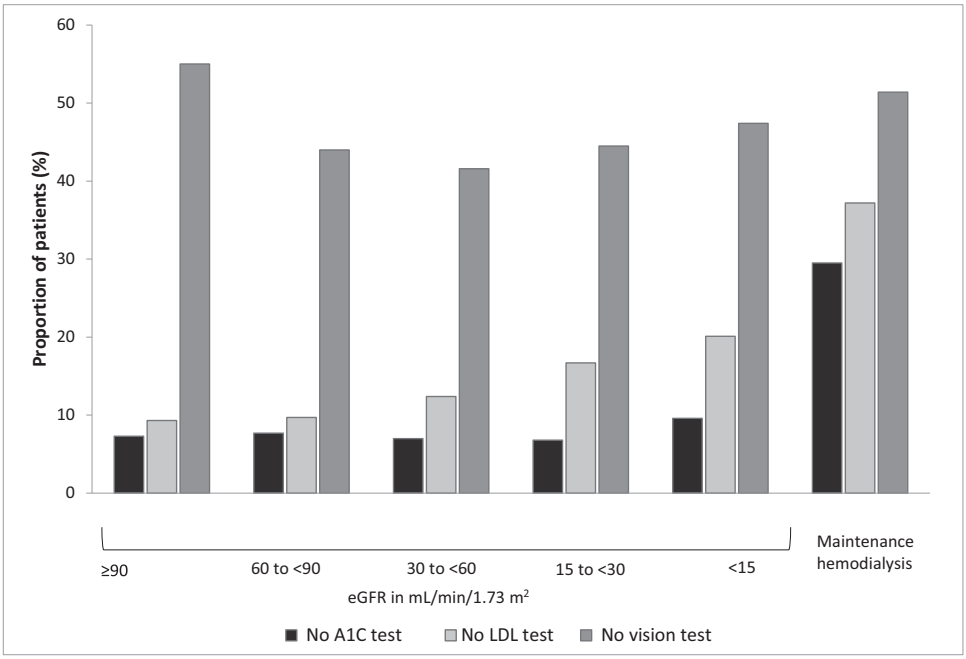

Figure 1. Proportion of patients with diabetes and with no evidence of glycated hemoglobin (A1C), low-density lipoprotein (LDL) cholesterol or annual vision screen tests during 2 years, across the spectrum of kidney disease.

too complex to be managed in primary care settings. Patients may have also been too busy with other appointments to see their primary care providers. Those using hemodialysis are seen up to 3 times per week in the dialysis unit, so their nephrologists may have also taken over both their primary and specialist care (16–18).

Second, with lower kidney function, patients appear to be prescribed more medications, including cardioprotective therapies (i.e. angiotensin-converting enzyme inhibitors, angiotensin receptor blockers and statins). Prescriptions for these drugs were most common in those with eGFRs of 30 to 59 mL/min/1.73 m^2, perhaps because of the increasing evidence of their efficacy in this population (1,19–23). The proportion of patients prescribed these drugs did, however, drop in those with eGFRs <15 mL/min/1.73 m^2 and in those using maintenance dialysis.

Third, across the spectrum of kidney disease, gaps in both diabetes monitoring and diabetes-related screening became more evident. As described previously (24), a small proportion of patients had annual eye examinations across the groups. There were also notable gaps in glycemic and lipid screening, especially in those with very low kidney function. Fewer of these patients also received prescriptions for glucose test strips for glycemic monitoring. An interesting trend to overmonitoring was also apparent in those with lower eGFRs. Where A1C levels reflect 3-month measures of glycemic control, and guidelines recommend testing every 3 to 6 months, a higher proportion of these patients had >8 tests over the follow-up period. Across our diabetes cohort, there were 30,140 of these "excess" A1C tests, which would have cost our health-care system $300,000 over 2 years (A1C tests cost about $10 in Ontario) (25).

Fourth, mean A1C levels for the majority of patients were ≤7%, and LDL-C levels were ≤2 mmol/L across groups. In those using dialysis, however, the proportion meeting these targets was smaller. However, clinical practice guidelines do recommend relaxing glycemic

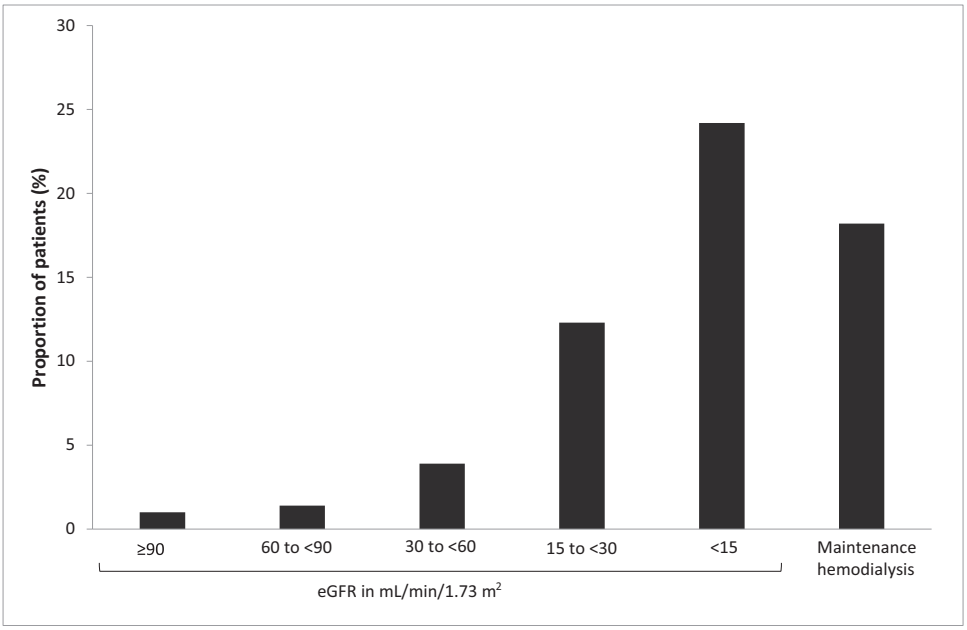

Figure 2. Proportion of patients with >8 A1C tests over 2 years, across the spectrum of kidney disease. *A1C*, glycated hemoglobin levels; *eGFR*, estimated glomerular filtration rate.

control in those with multiple comorbidities and long-standing diabetes and in those at increased risk for hypoglycemia (14,15).

Finally, whether due to their medical comorbidities at baseline or to gaps in their care, patients with low kidney function faced increasing numbers of hospitalizations and emergency department visits and higher proportions of diabetes-related complications over the follow-up period.

Why are care gaps apparent in those with low kidney function?

Although care gaps were evident across the spectrum of patients with kidney disease, they seemed especially apparent in those with eGFRs <30 mL/min/1.73 m^2 and those receiving maintenance dialysis. Gaps might be due to patient, provider or health system factors (26,27).

First, although health-care providers can provide advice and counselling to patients, patients themselves must decide which strategies to put into practice, which self-care exercises to consider (26) and which appointments to attend. In those with low kidney function, there may be personal, logistic and economic barriers to adhering to ideal practices (28). For example, patients might not have the time to attend screening tests and have laboratory work completed, or they may feel too unwell to attend appointments as scheduled. Competing medical comorbidities might also impair their diabetes self-management (27). Chronic disease and complex treatment regimens can also contribute to suboptimal medication adherence (29,30). As observed in the current study and described previously (31), patients with low kidney function are also of lower socioeconomic status and may have difficulty affording medications or travelling to scheduled medical appointments (27).

Second, health-care gaps might be related to care provider factors. Physicians might struggle with the complexity of treating patients with complex comorbidities or may fail to develop unified plans to care for them holistically (27). With patients' declining kidney function, providers might also focus care away from diabetes management and toward preparing for renal-replacement therapy (4). Furthermore, providers may feel a sense of "therapeutic nihilism," (32), knowing that these patients have already developed a multitude of diabetes-related complications and face limited survival times. There is also limited and controversial evidence about the utility of glycemic control and cardiovascular therapies in patients with advanced kidney disease (33,34). Furthermore, glycemic monitoring by A1C tests is controversial in kidney disease because this test can be impacted by reduced red cell survival, erythropoietin, modifications of hemoglobin and mechanical destruction of blood cells (20). We also anticipate that suboptimal communication among specialists, poor care coordination and "siloed" care might have contributed to the overmonitoring that we observed in those with lower kidney function.

Third, from a health systems standpoint, it is well recognized that our health-care system is built around treating patients with single diseases (35,36). Traditionally, a specialist is trained to provide care for a condition or a cluster of related conditions. For patients with multiple comorbidities, however, this means more visits to more specialists. Furthermore, with an increasing volume of patients, limited clinic space and increasing pressure to see patients quickly, our current system leaves many doctors too rushed to ensure that patients with complex conditions are fully managed (27,37).

Comparison with previous literature

To the best of our knowledge, our study is the largest, most comprehensive Canadian study to date on the health and health care of patients with diabetes across the eGFR spectrum. A previous study from Alberta, Canada, noted that in 31,337 patients with diabetes and CKD (eGFRs 15 to 59 mL/min/1.73 m^2), those who lived more remotely were most susceptible to health-care gaps than those who lived closer to a nephrologist (38). This study, however, was much smaller, assigned kidney function based upon 1 eGFR value, did not capture patterns in those with very low kidney function or using dialysis, and ascertained a more limited number of processes and outcome care measures.

In other regions, a study of 63,260 patients with diabetes and CKD (ascertained using administrative codes) noted that the majority of patients had low quality-of-care scores (scores based upon prescriptions, proteinuria and nutritional counselling) and were at increased risk for acute kidney injury and dialysis (39). In a questionnaire of 308 patients with diabetes and CKD in Australia, 31.9%

self-reported having A1C levels >8%; 39.3% had blood pressure ≥140/90 mmHg; 12.2% had not had an annual eye examination; 50.9% had not had foot checks every 3 months; and 17.7% of nondialysis patients were not taking a statin (26). In an Italian study of 707 patients with diabetes and eGFRs of 15 to 59 mL/min/1.73 m^2, only 4% to 6% of patients who presented for follow-up met their blood pressure, A1C and cholesterol targets (40). In an additional United Kingdom National Diabetes Audit study of patients with eGFRs <60 mL/min/1.73 m^2 or albuminuria and type 2 diabetes (n=868,616), 37.8% did not have systolic blood pressure <140 mmHg, and 67.8% did not have A1C levels below 7.5% (41). Gaps have also been described in patients with diabetes and end-stage kidney disease. The United States Renal Data System reported a decline in metabolic screening in patients with end-stage kidney disease over recent years (42). About 86.5% of patients with diabetes had had at least 1 A1C test, 71.8% had had a lipid test, and 46.9% had had a dilated eye examination in 2015. However, only 34.0% had completed all 3 tests (36.4% in 2010). In another small study of patients with diabetes using hemodialysis (n=188), 33% had A1C levels >7%, 51% had blood pressures >160/95 mmHg, and 23% had cholesterol levels >5.18 mmol/L (43). In a review of medical charts (n=55), 65.5% of patients using hemodialysis had not been seen in a diabetes clinic, and 58.2% had not been seen by a podiatrist in the previous year (44).

Strengths and weaknesses

There are several strengths to our study. We report the health-care patterns of more than a half million patients living with diabetes across the province of Ontario. We present comprehensive care measures across the spectrum of kidney disease, including structure, process and outcome data over a 2-year follow-up period. We used high-quality administrative and laboratory data rather than relying on patient self-reports. Whereas the majority of previous studies have categorized patients by 1 eGFR, in this study, we included only those with evidence of stable kidney function or users of maintenance dialysis to avoid misclassification. We also provided a needed narrative about why care gaps might be more apparent in patients with diabetes and low kidney function, with references to factors related to patients, providers and our health-care system.

There are limitations to our study. Administrative data are limited to records obtained for the purposes of reimbursement (i.e. physicians' claims and drug benefits) or for tracking health-care service delivery (i.e. hospitalizations or emergency department use) (6), so we were not able to capture the provision of self-management counselling, control of blood pressure or foot examinations. Furthermore, we categorized patients by eGFRs and did not consider levels of albuminuria, although we do not expect this to have changed the care patterns observed. Our results are also not fully generalizable to younger populations with private drug benefits or to individuals who live outside of Ontario.

Implications

Our study suggests that efforts might be focused on streamlining and on coordinating the care of patients with diabetes and low kidney function. Given the number of their health-care visits, the utility of collaborative care, shared care models or coordinated care programs might be explored (45–48). Efforts might also be made to help patients to understand and manage their own conditions (49). Strategies for physicians to better manage patients with complex comorbidities (37), including information technology, peer support, mentoring, protocols or enhanced primary care interventions might be considered (45,48). Methods to break down "siloes" and improve communication among specialists might also be helpful.

Conclusions

Patients with diabetes and low kidney function face medical, social and health-care challenges. Efforts to improve and support patient-centred care in this population are needed.

Supplementary Material

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

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Author Disclosures

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Author Contributions

KC contributed to the conception and design of the study and the interpretation of results and drafted the manuscript; AO contributed to the data acquisition and analysis and the interpretation of the results, and she reviewed the manuscript critically for its content; DN contributed to the conception and design of the study and the interpretation of results, and she reviewed the manuscript critically for its content; AG contributed to the conception and design of the study and the interpretation of the results and reviewed the manuscript critically for its content; SS contributed to the conception and design of the study and the interpretation of the results and reviewed the manuscript critically for its content. All authors gave final approval for the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Lloyd A, Komenda P. Optimizing care for Canadians with diabetic nephropathy in 2015. Can J Diabetes 2015;39:221–8.
2. Couser WG, Remuzzi G, Mendis S, Tonelli M. The contribution of chronic kidney disease to the global burden of major noncommunicable diseases. Kidney Int 2011;80:1258–70.
3. Brook RH, McGlynn EA, Cleary PD. Measuring quality of care. N Engl J Med 1996;335:966–70.
4. Fishbane S, Hazzan AD, Halinski C, Mathew AT. Challenges and opportunities in late-stage chronic kidney disease. Clin Kidney J 2015;8:54–60.
5. Muggah E, Graves E, Bennett C, Manuel DG. The impact of multiple chronic diseases on ambulatory care use: A population-based study in Ontario, Canada. BMC Health Serv Res 2012;12:452.
6. Bello A, Hemmelgarn B, Manns B, Tonelli M, Alberta Kidney Disease Network. Use of administrative databases for health-care planning in CKD. Nephrol Dial Transplant 2012;27(Suppl. 3):12–18.
7. Stats Canada Popul by Sex Age Group. By Prov Territ (Number, Both Sexes). 2014. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo31a-eng.htm. Accessed January 24, 2018.
8. Benchimol EI, Smeeth L, Guttmann A, et al. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLoS Med 2015;12:e1001885.
9. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario: Determination of prevalence and incidence using a validated administrative data algorithm. Diabetes Care 2002;25:512–16.
10. eHealth Ontario. Ontario Laboratory Information System. 2018. https://www.ehealthontario.on.ca/for-healthcare-professionals/ontario-laboratories-information-system-olis. Accessed May 23, 2018.
11. Matheson FI, Dunn JR, Smith KLW, Moineddin R, Glazier RH. Development of the Canadian Marginalization index: A new tool for the study of inequality. Can J Public Health 2012;103:3–5.
12. Levy AR, O'Brien BJ, Sellors C, Grootendorst P, Willison D. Coding accuracy of administrative drug claims in the Ontario Drug Benefit database. Can J Clin Pharmacol 2003;10:67–71.
13. Clement FM, James MT, Chin R, et al. Validation of a case definition to define chronic dialysis using outpatient administrative data. BMC Med Res Methodol 2011;11:25.
14. Harper W. Canadian Diabetes Association Guidelines: Pharmacological management of type 2 diabetes. Can Diabetes Assoc 2013. http://guidelines.diabetes.ca/Browse/Chapter13. Accessed January 24, 2018.
15. National Kidney Foundation. KDOQI Clinical Practice Guideline for Diabetes and CKD: 2012 update. Am J Kidney Dis 2012;60:850–86.
16. Hamad A, Lakshmi K, Khedr M, Ibrahim H, Cantelmo L, Ward L. Comparison of preventive care provided to dialysis patients by nephrologists and to patients followed in general medical clinics: Compliance with American College of Physicians guidelines. Hemodial Int 2002;6:31–4.
17. Nespor SL, Holley JL. Patients on hemodialysis rely on nephrologists and dialysis units for maintenance health care. ASAIO J 1992;38:M279–81.
18. Holley JL, Nespor SL. Nephrologist-directed primary health care in chronic dialysis patients. Am J Kidney Dis 1993;21:628–31.
19. Baigent C, Keech A, Kearney PM, et al. Efficacy and safety of cholesterol-lowering treatment: Prospective meta-analysis of data from 90,056 participants in 14 randomised trials of statins. Lancet 2005;366:1267–78. (See comment; erratum in Lancet 2005 366:1358).
20. Tuttle KR, Bakris GL, Bilous RW, et al. Diabetic kidney disease: A report from an ADA Consensus Conference. Diabetes Care 2014;37:2864–83.
21. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl 2013;3:1–150.
22. Palmer SC, Navaneethan SD, Craig JC, et al. HMG CoA reductase inhibitors (statins) for people with chronic kidney disease not requiring dialysis. Cochrane Database Syst Rev 2014;(5):CD007784.
23. McFarlane P, Gilbert R, MacCallum L, Senior P. Chronic kidney disease in diabetes. Diabetes Canada Clin Pract Guidelines 2015. http://guidelines.diabetes.ca/browse/chapter29. Accessed January 24, 2018.
24. Kiran T, Kopp A, Moineddin R, et al. Unintended consequences of delisting routine eye exams on retinopathy screening for people with diabetes in Ontario, Canada. CMAJ 2013;185:e167–73.
25. Chadee A, Blackhouse G, Goeree R. Point-of-care hemoglobin A1c testing: A budget impact analysis. Ont Heal Technol Assess Ser 2014;14:1–23.
26. Lo C, Teede H, Fulcher G, et al. Gaps and barriers in health-care provision for co-morbid diabetes and chronic kidney disease: A cross-sectional study. BMC Nephrol 2017;18:80.
27. Piette JD, Kerr EA. The impact of comorbid chronic conditions on diabetes care. Diabetes Care 2006;29:725–31.
28. Glasgow RE, Hiss RG, Anderson RM, et al. Report of the Health Care Delivery Work Group: Behavioral research related to the establishment of a chronic disease model for diabetes care. Diabetes Care 2001;24:124–30.
29. Williams A, Manias E. Exploring motivation and confidence in taking prescribed medicines in coexisting diseases: A qualitative study. J Clin Nurs 2014;23:471–81.
30. Jansà M, Hernández C, Vidal M, et al. Multidimensional analysis of treatment adherence in patients with multiple chronic conditions: A cross-sectional study in a tertiary hospital. Patient Educ Couns 2010;81:161–8.
31. Kim Y, Evangelista LS. Relationship between illness perceptions, treatment adherence, and clinical outcomes in patients on maintenance hemodialysis. Nephrol Nurs J 2010;37:271–80, quiz 281.
32. Lau DCW. Therapeutic inertia and nihilism. Can J Diabetes 2014;38:290–1.
33. Morioka T, Emoto M, Tabata T, et al. Glycemic control is a predictor of survival for diabetic patients on hemodialysis. Diabetes Care 2001;24:909–13.
34. Adler A, Casula A, Steenkamp R, et al. Association between glycemia and mortality in diabetic individuals on renal replacement therapy in the U.K. Diabetes Care 2014;37:1304–11.
35. Fortin M, Soubhi H, Hudon C, Bayliss EA, Van Den Akker M. Multimorbidity's many challenges. Br Med J 2007;334:1016–7.
36. Atun R. Transitioning health systems for multimorbidity. Lancet 2015;386:721–2.
37. Cheung A, Stukel TA, Alter DA, et al. Primary care physician volume and quality of diabetes care. Ann Intern Med 2016;137:511–20.
38. Bello AK, Hemmelgarn B, Lin M, et al. Impact of remote location on quality care delivery and relationships to adverse health outcomes in patients with diabetes and chronic kidney disease. Nephrol Dial Transplant 2012;27:3849–55.
39. Wu H-Y, Fukuma S, Shimizu S, et al. Effects of higher quality of care on initiation of long-term dialysis in patients with CKD and diabetes. Am J Kidney Dis 2017;70:666–74.
40. Minutolo R, Sasso FC, Chiodini P, et al. Management of cardiovascular risk factors in advanced type 2 diabetic nephropathy: A comparative analysis in nephrology, diabetology and primary care settings. J Hypertens 2006;24:1655–61.
41. Hill CJ, Cardwell CR, Patterson CC, et al. Chronic kidney disease and diabetes in the national health service: A cross-sectional survey of the U.K. national diabetes audit. Diabet Med 2014;31:448–54.
42. United States Renal Data System. Clinical indicators and preventive care. 2017 USRDS Annu Data Rep 2017. https://www.usrds.org/2017/view/v2_02.aspx. Accessed January 25, 2018.
43. Flauto RP, Leon JB, Sehgal AR. The provision and outcomes of diabetic care of hemodialysis patients. Am J Kidney Dis 2003;41:125–31.
44. Mark P, McNally M, Jones GC. Deficiencies in foot care of diabetic patients on renal replacement therapy. Pract Diabetes Int 2003;20:294–6.
45. Dean J. Organising care for people with diabetes and renal disease. J Ren Care 2012;38(Suppl. 1):23–9.
46. Bergeson SC, Dean JD. A systems approach to patient-centered care. JAMA 2006;296:2848–51.
47. Strand H, Parker D. Effects of multidisciplinary models of care for adult predialysis patients with chronic kidney disease: A systematic review. Int J Evid Based Healthc 2012;10:53–9.
48. Landman N, Aannestad LK, Smoldt RK, Cortese DA. Teamwork in health care. Nurs Adm Q 2014;38:198–205.
49. Pagels AA, Hylander B, Alvarsson M. A multi-dimensional support programme for patients with diabetic kidney disease. J Ren Care 2015;41:187–94.
50. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. J Chronic Dis 1987;40:373–83.

Supplementary Table S1
REporting of studies Conducted using Observational Routinely-collected Data (RECORD) checklist of recommendations for the reporting of studies conducted using routinely collected health data

	Item #	Recommendation	Reported
Title and abstract	1	1.1 The type of data used should be specified in the title or abstract. When possible, the name of the databases should be included.	Abstract
		1.2 If applicable, the geographic region and time frame within which the study took place should be reported in the title or abstract.	Abstract
		1.3 If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Abstract
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported.	Introduction
Objectives	3	State specific objectives, including any pre-specified hypotheses.	Introduction
Methods			
Study design	4	Present key elements of study design early in the paper.	Methods
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection.	Methods
Participants	6	6.1 The methods of study population selection should be listed in detail. If this is not possible, an explanation should be provided.	Methods
		6.2 Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided.	Methods
		6.3 If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the linkage process, including the number of individuals with linked data at each stage.	Supplementary Figure S1
Variables	7	A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Supplementary Table S2
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than 1 group.	Supplementary Table S2
Bias	9	Describe any efforts to address potential sources of bias.	Methods
Study size	10	Explain how the study size was arrived at.	Methods
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why.	Table 1 and 2
Statistical methods	12	12.1 Describe all statistical methods, including those used to control for confounding.	Methods
		12.2 Describe any methods used to examine subgroups and interactions.	Not applicable
		12.3 Explain how missing data were addressed.	Not applicable
		12.4 If applicable, explain how loss to follow-up was addressed.	Methods
		12.5 Describe any sensitivity analyses.	Not applicable
Data access and cleaning methods		12.6 Authors should describe the extent to which the investigators had access to the database population used to create the study population.	Methods
		12.7 Authors should provide information on the data cleaning methods used in the study.	Methods
Linkage		12.8 State whether the study included person-level, institutional-level, or other data linkage across 2 or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	Methods
Results			
Participants	13	13.1 Describe in detail the selection of the persons included in the study (i.e. study population selection), including filtering based on data quality, data availability, and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Results and Supplementary Figure S1
Descriptive data	14	14.1 Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders.	Results, Table 1
		14.2 Indicate number of participants with missing data for each variable of interest.	Results, Table 1
		14.3 Summarize follow-up time (e.g. average and total amount).	Results
Outcome data	15	Report numbers of outcome events or summary measures over time.	Results, Tables 1 and 2
Main results	16	16.1 Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g. 95% confidence interval). Make clear which confounders were adjusted for and why they were included.	Results, Tables 1 and 2
		16.2 Report category boundaries when continuous variables were categorized.	Table 1
		16.3 If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period.	Not applicable
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses.	Not applicable
Discussion			
Key results	18	Summarize key results with reference to study objectives.	Discussion
Limitations	19	Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data and changing eligibility over time, as they pertain to the study being reported.	Discussion
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies and other relevant evidence.	Discussion

(*continued on next page*)

Supplementary Table S1 (*continued*)

	Item #	Recommendation	Reported
Generalizability	21	Discuss the generalizability (external validity) of the study results.	Discussion
Other information			
Funding	22	22.1 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based.	Acknowledgments
Accessibility of protocol, raw data and programming code		22.2 Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	The dataset from this study is held securely in coded form at the Institute for Clinical Evaluative Sciences (ICES). While data sharing agreements prohibit ICES from making the dataset publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS. The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the programs may rely upon coding templates or macros that are unique to ICES.

Supplementary Table S2
Variable definitions

Variable	Source	Codes
Chronic dialysis	OHIP	OHIP Fee: R849, G323, G325, G326, G860, G862, G865, G863, G866, G330, G331, G332, G333, G861, G082, G083, G085, G090, G091, G092, G093, G094, G095, G096, G294, G295, G864, H540, H740
Creatinine	OLIS	LOINC code: 14682-9
Renal transplant	CORR	CORR Treatment: 171
	CIHI-DAD	CORR Organ: 10, 11, 12,18,19
	OHIP	CCP: 6759
		CCI: 1PC85
		OHIP Fee: S435, S434
CAD	CIHI-DAD	ICD 10: I20, I21, I22, I23, I24, I25, Z955, Z958, Z959, R931 ,T822
	NACRS	CCI: 1IJ26, 1IJ27, 1IJ50, 1IJ54, 1IJ57 ,1IJ76
	OHIP	OHIP Fee: R741, R742, R743, G298, E646, E651, E652, E654, E655, G262, Z434 , Z448
		OHIP Dx: 410 ,412 ,413
Stroke/TIA	CIHI-DAD	ICD 10: I62 ,I630 ,I631 ,I632, I633, I634, I635, I638, I639 ,I64, H341,I600,I601, I602 ,I603, I604, I605 ,I606, I607, I609,
	NACRS	I61, G450, G451, G452, G453, G458, G459, H340
Osteoporosis	CIHI-DAD	ICD 10: M80, M81, M82
	NACRS	OHIP Dx: 733
	OHIP	
Foot Ulcer	CIHI-DAD	ICD 10: E1070, E1071, E1170, E1171, E1370, E1371, E1470, E1471
	NACRS	
Amputation	CIHI-DAD	CCI: 1VA93, 1VC93, 1VG93, IVQ93, 1WA93, 1WE93, 1WI93, 1WJ93, 1WK93, 1WL93, 1WM93, 1WN93, 1SN93, 1SQ93, 1TA93, 1TK93, 1TM93, 1TV93, 1UB93, 1UE93, 1UF93, 1UG93, 1UH93, 1UI93, 1UJ93, 1UK93, 1UM93
Hypoglycemia	CIHI-DAD	ICD 10: E15, E160, E161, E162, E1063, E1163, E1363, E1463
	NACRS	
Hyperglycemia	CIHI-DAD	ICD 10: E1101, E131, E141, R739
	NACRS	
Major cancer	CIHIR-DAD	ICD 10: 971, 980, 982, 984, 985, 986, 987, 988, 989, 990, 991, 993, C15, C18, C19, C20, C22, C25, C34, C50, C56, C61,
	NACRS	C82, C83, C85, C91, C92, C93, C94, C95, D00, D05, D010, D011, D012, D022, D075
	OHIP	OHIP Dx: 203, 204, 205, 206, 207, 208, 150, 154, 155, 157, 162, 174, 175, 183, 185
Depression/anxiety	CIHI-DAD	F063, F064, F204, F313, F314, F315, F32, F33, F341, F400, F401, F402, F408, F409, F410, F411, F412, F413, F418, F419,
	NACRS	F420, F421, F422, F428, F429, F430, F431, F432
	OHIP	OHIP Dx: 311
A1C test	OHIP	OHIP Fee: L093
Glucose test	OHIP	OHIP Fee: L111
Cholesterol test	OHIP	OHIP Fee: L055
LDL value	OLIS	LOINC code: 39469-2, 22748-8
A1C value	OLIS	LOINC code: 4548-4, 71875-9, 59261-8, 17855-8, 17856-6, 41995-2
Fasting plasma glucose value	GDML	Test code: 111K
Random plasma glucose value	GDML	Test code: 111L
Vision screening	OHIP	OHIP Fee: A110, A111, A112, A114, A115, A233, A234, A235, A236, A237, A238, A239, A240, K065, K066, V401,V402,V404,V405,V406,V407,V408,V409,V450, V451
Cardiac investigations	CIHI-DAD	CCI: 2HZ08, 3IP70
	OHIP	OHIP Fee: G310, G313, G315, G174, G111, G112, G319, G582, G583, G584, J607, J608, J807, J808, J809, J866, J609, J666

CCI, Canadian Classification of Health Interventions; *CIHI-DAD,* Canadian Institute for Health Information's Discharge Abstract Database; *CORR,* Canadian Organ Replacement Registry; *GDML,* Gamma Dynacare Medical Laboratory: *NACRS,* National Ambulatory Care Reporting System Database; *OHIP,* Ontario Health Insurance Plan; *OHIP Dx,* OHIP Diagnostic Code; *OHIP Fee,* OHIP Fee code; *OLIS,* Ontario Laboratories Information System.

Supplementary Table S3
Guideline recommendations

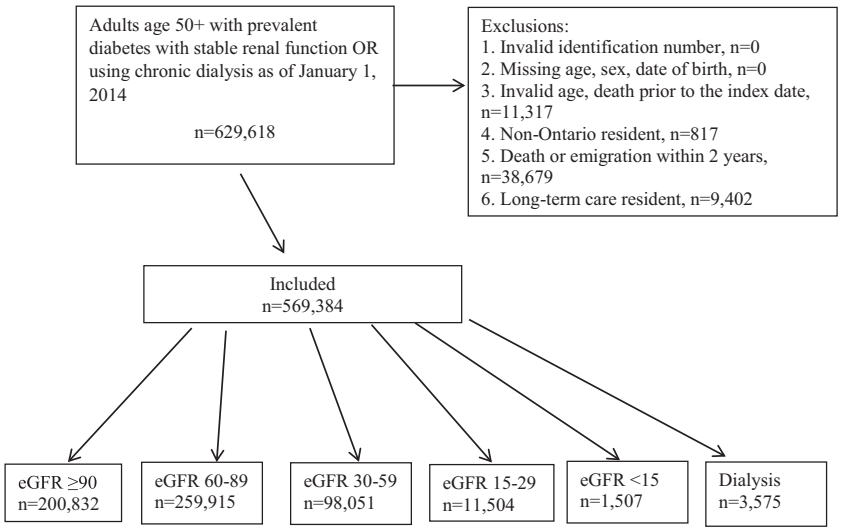
Screening	
A1C*	"For most individuals with diabetes, A1C should be measured every 3 months to ensure that glycemic goals are being met or maintained. Testing at least every 6 months should be performed in adults during periods of treatment and lifestyle stability when glycemic targets have been consistently achieved."
LDL-C*	"A lipid profile should be measured at the time of diagnosis of diabetes." "If lipid-lowering treatment is not initiated, repeat testing is recommended yearly. More frequent testing (every 3 to 6 months) should be performed after treatment for dyslipidemia is initiated."
Vision*	"Evaluation for retinopathy by an expert professional should be performed annually.. . ." "In those with no or minimal retinopathy, the recommended interval is 1 to 2 years."
Metabolic control	
A1C*	"For most patients with diabetes, target an A1C ≤7%." "Consider an A1c of 7.1 to 8.5% in those with: • Limited life expectancy • High level of functional dependency • Extensive coronary artery disease at high-risk of ischemic events • Multiple comorbidities • Recurrent, severe hypoglycemia • Hypoglycemia unawareness • Longstanding diabetes for whom it is difficult to achieve an A1C ≤7%, despite effective doses of multiple antihyperglycemic agents, including intensified basal-bolus insulin therapy."
LDL-C*	"For patients with indications for lipid-lowering therapy, treatment should be initiated with a statin to achieve an LDL-C≤2.0 mmol/L."
Cardioprotective medications	
Angiotensin converting enzyme inhibitors/Angiotensin receptor blockers*	"Adults with diabetes and CKD with either hypertension or albuminuria should receive an ACE inhibitor or an ARB to delay progression of CKD."
Statins†	"We recommend using LDL-C lowering medicines, such as statins or statin/ezetimibe combination, to reduce risk of major atherosclerotic events in patients with diabetes and CKD, including those who have received a kidney transplant."

* Diabetes Canada Clinical Practice Guidelines.
† KDOQI Clinical Practice Guidelines for Diabetes and CKD.

Supplementary Table S4
Progression of chronic kidney disease over 2 years

	Estimated glomerular filtration rate in mL/min per 1.73 m^2 (at baseline)				
	≥90 (n=200,832)	60 to <90 (n=253,915)	30 to <60 (n=98,051)	15 to <30 (n=11,504)	<15 (n=1,507)
eGFR*≥90	—	—	—	—	—
eGFR 60 to <90	45,289 (22.6%)	—	—	—	—
eGFR 30 to <60	1,250 (0.6%)	31,951 (12.6%)	—	—	—
eGFR 15 to <30	36 (0.0%)	355 (0.1%)	7,411 (7.6%)	—	—
eGFR <15	8 (0.0%)	25 (0.0%)	212 (0.2%)	1,174 (10.2%)	—
Maintenance dialysis†	15 (0.0%)	45 (0.0%)	231 (0.2%)	774 (6.7%)	877 (58.2%)
Unknown (i.e. no dialysis codes or eGFR values found)	9,708 (4.8%)	9,443 (3.7%)	2,620 (2.7%)	206 (1.8%)	31 (2.1%)

eGFR, estimated glomerular filtration rate.
* Kidney function was based on the most recent eGFR values during the follow-up period.
† Maintenance dialysis was defined using 2 chronic dialysis codes during the follow-up period, billed between 90 to 150 days of each other.



Supplementary Figure S1. Flow diagram of included and excluded patients.