Clinical characteristics, complications, comorbidities and treatment patterns among patients with type 2 diabetes mellitus in a large integrated health system

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ABSTRACT

Purpose: To compare the prevalence of diabetes-related complications and comorbidities, clinical characteristics, glycemic control, and treatment patterns in patients with type 2 diabetes (T2D) within a large integrated healthcare system in 2008 vs 2013.

Methods: An electronic health record system was used to create a cross-sectional summary of all patients with T2D as on 1 July 2008 and 1 July 2013. Differences between the two data sets were assessed after adjusting for age, gender, race, and household income.

Results: In 2008 and 2013, 24 493 and 41 582 patients with T2D were identified, respectively, of which the majority were male (52.3% and 50.1%) and Caucasian (79% and 75.2%). The mean ages (years) were 64.8 and 64.3. The percentages of patients across the defined A1C categories were 64.3 and 66.7 for <7%, 21.1 and 18.8 for 7–7.9%, 7.8 and 7.5 for 8–8.9%, and 6.8 and 7.0 for ≥9% in 2008 and 2013, respectively. The most prevalent T2D-related comorbidities were hypertension (82.5% and 87.2%) and cardiovascular disease (26.9% and 22.3%) in 2008 and 2013, respectively. Thiazolidinedione and sulfonylurea use decreased, whereas metformin and dipeptidyl peptidase-4 inhibitor use increased in the 5-year period.

Conclusions: Patients with T2D are characterized by a high number of comorbidities. Over 85% of the patients had an A1C<8% within our integrated health delivery system in 2008 and 2013. In 2008 and 2013, metformin therapy was the most commonly utilized antidiabetic agent, and sulfonylureas were the most commonly utilized oral antidiabetic agent in combination with metformin. As integrated health systems assume greater shared financial risk in newer payment models, achieving glycemic targets (A1C) and the management of comorbidities will become ever-more important, for preventing diabetes-related complications, as well as to ensure reimbursement for the medical care that is rendered to patients with diabetes.

Key messages

- While the prevalence of hypertension has increased among patients with type 2 diabetes, the prevalence of other comorbidities decreased in 2013 when compared with 2008.
- The treatment patterns and choice of antidiabetic therapies were observed to change in 2013 vs 2008. Thiazolidinedione and sulfonylurea use has decreased, whereas metformin and dipeptidyl peptidase-4 inhibitor use increased in the 5-year period.
- Over 85% of the patients had an A1C<8% within our integrated health delivery system in 2008 and 2013.

Research questions

- What are the key barriers that prevent obtaining glycemic control in patients who continue to have a persistently elevated A1C?
- How can electronic health record systems be leveraged to further improve diabetes-related outcomes?
- How can we further improve the quality of care we render to patients with diabetes?
- How have the clinical characteristics, complications, comorbidities, and treatment patterns among patients with new-onset type 2 diabetes mellitus, managed within in a large integrated health system, changed over time?

INTRODUCTION

The prevalence of diagnosed diabetes has more than doubled over the past two decades, from 3.8% in 1990 to 8.6% in 2010.[1] Research using the USA National Health and Nutrition Examination Survey (NHANES) database reported that from

2003 to 2006 only 57% of people with diabetes, largely patients with type 2 diabetes (T2D), had a glycosylated hemoglobin (HbA1C) <7%.[2 3] Recently, from 2007 to 2010, the percentage of patients under adequate control was noted to be even lower, with only 52.5% of people with diabetes achieving an A1C<7.0%.[4] This is a matter of concern, as inadequate glycemic control not only plays a role in cardiovascular risk, but it also remains the leading cause of blindness, kidney failure, and non-traumatic lower limb amputations in the USA.[5] While reports have suggested that we continue to make progress in attaining glycemic targets and managing comorbidities, in addition to reducing the rates of diabetes-related complications, there is still substantial room for improvement.[6 7]

Over the past few decades, integrated health delivery systems have evolved, and the way that medical care is delivered has changed considerably. Integrated health delivery systems are organized, coordinated, and collaborative networks which link various healthcare providers to provide a coordinated, vertical continuum of services to a particular patient population or community.[8] Currently, there are limited real-world data describing the management of the patient population with T2D within an integrated health system. Given the variety of therapies available to treat patients with T2D, it is important to evaluate the current patterns of management and the associated clinical outcomes. The objective of this cross-sectional analysis was to analyze and compare the prevalence of diabetes-related complications and comorbidities, as well as the clinical characteristics, glycemic control, and treatment patterns in patients with T2D within a large integrated health system in 2008 vs 2013.

RESEARCH DESIGN AND METHODS

The electronic health record (EHR) system at Cleveland Clinic was used to create a cross-sectional summary of patients with T2D at two different time points (1 July 2008 and 1 July 2013). Cleveland Clinic utilizes EPIC My Practice across the entire organization. Patients with T2D were identified according to the EMERGE algorithm published by Kho et al.[9] All patients with documented International Classification of Diseases, Ninth Revision (ICD-9) codes for T1D were excluded. We included all patients with ICD-9 codes of 250.x0 or 250.x2, except for codes 250.10 and 250.12, as these are indicative of T2D with ketoacidosis, a condition that closely resembles that of T1D. Additional patients with T2D were identified via the algorithm if they had been prescribed a non-insulin T2D therapy, had at least two encounters with a T2D diagnosis entered into the EHR by a clinician, or had an abnormal glucose level consistent with a diagnosis of diabetes (but no documented ICD-9 code for T1D) as per the most recent American Diabetes Association (ADA) criteria (fasting blood glucose (BG) ≥126 mg/dL, HbA1C≥6.5%, or random BG≥200 mg/dL).[10]

Both inpatient and outpatient HbA1C values (laboratory and point of care) were included, but for fasting and random glucose values, only outpatient laboratory values were utilized. If the BG values were not ordered specifically as fasting, they were assumed fasting if obtained simultaneously with a lipid panel. All BG values obtained at the point of care, or as part of a glucose tolerance test, were excluded.

The following T2D medication classes were utilized as a means of identifying patients with T2D: biguanide (metformin), sulfonylureas, thiazolidinediones, α-glucosidase inhibitors, meglitinides, dipeptidyl peptidase-4 (DPP-4) inhibitors, glucagon-like peptide-1 (GLP-1) agonists and insulin. The remaining classes of antidiabetic medications were excluded either because they were too new (sodium glucose transporter-2 inhibitors) or non-specific for diabetes (colesevelam), or there were too few patients receiving the medication (pramlintide, bromocriptine (Cycloset)). Patient characteristics, complications, and comorbidities were extracted from the EHR dating back to 1998. Active medications were based on the current medication list as on 1 July 2008 and 1 July 2013. Laboratory values within 1 year prior to the index dates were included in the data sets. For multiple eligible values for the same patient, the most recent value prior to the index date was used. The Diabetes Complication Severity Index[11] was calculated and reported for the overall 2008 and 2013 T2D populations.

The analyses compared characteristics of patients in 2008 vs 2013 while adjusting for age, gender, race, and income (median household income by census block group derived from the 2010 US census). These four variables were chosen because they are all unmodifiable from the perspective of the clinician. The years of study, 2008 and 2013, were chosen because it was 2008 when medication reconciliation was mandated to occur at the transitions of care at our institution, and 2013 was the point in time at which the data were extracted from the EHR for analysis. The adjustment was performed using generalized estimating equations (GEE) to account for the clustering caused by the inclusion of some patients in the 2008 and 2013 data sets. Separate GEE models were fit for each of the comparison variables as outcomes using age, gender, race, income, and year as covariates. The models were used to obtain the adjusted values reported in tables 1–3.

The adjusted analysis compares the theoretical characteristics of patients in 2008 vs 2013 if the two populations were composed of similar patients in terms of age, gender, race, and income. Statistical significance between 2008 and 2013 was calculated by fitting individual regression models for each of the variables of interest as the dependent variable and age, gender, race, income, and year as the independent variables. In these models, a statistically significant coefficient for year indicates a difference in values between 2008 and 2013 after adjustment. The independent variables (age, gender, race, and income) were used to construct the regression models for comparing 2008 vs 2013. Univariate, non-

Table 1 Clinical characteristics, comorbidities, complications, and diabetes-related health maintenance at index (N, %)

Variable	2008 Index year N=24 493		2013 Index year N=41 582		p Value
	N	Per cent	N	Per cent	
Male	12 802	52.3	20 852	50.1	<0.0001*
Race					
Caucasian	18 907	79	31 251	75.2	<0.0001*
Black	3420	14.3	8189	19.7	
Other	1616	6.7	2102	5.1	
Missing	550		40		
Smoking	8806	55.0	21 108	53.3	0.0002†
Flu shot last flu season	8008	32.7	16 137	38.8	<0.0001†
Pneumonia vaccine in past 10 years	12 969	51.8	25 673	61.7	<0.0001†
A1c					
<7%	13 223	64.3	23 885	66.7	<0.0001†
7–7.9%	4326	21.1	6726	18.8	
8–8.9%	1597	7.8	2679	7.5	
>9%	1403	6.8	2521	7.0	
Statin	16 427	67.1	28 503	68.5	<0.0001†
ASA	12 556	51.3	22 285	53.6	<0.0001†
ARB or ACE	17 001	69.4	28 741	69.1	0.0001†
GFR<60 mL/min‡	3978	18.8	5977	16.3	<0.0001†
Hypertension	20 208	82.5	36 250	87.2	<0.0001†
Retinopathy	790	3.2	1425	3.4	0.1146†
Nephropathy	6565	26.8	10 753	25.9	0.56†
Neuropathy	4770	19.5	7493	18.0	<0.0001†
Cerebrovascular disease	2374	9.7	3348	8.1	<0.0001†
Cardiovascular disease	6581	26.9	9273	22.3	<0.0001†
Peripheral vascular disease	1315	5.4	2049	4.9	<0.0001†

*Compared using Pearson's χ^2 test.
†Adjusted for sex, age, race, and income using generalized estimating equations.
‡GFR calculated via CKD-EPI.
ARB, angiotensin receptor blocker; ASA, acetylsalicylic acid; CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration; GFR, glomerular filtration rate.

parametric tests were used to compare age, gender, race, and income.

For the purpose of this analysis, in order to exclude patients whose T2D was not actively being managed by providers within the Cleveland Clinic Health System, patients were required to have had at least one visit with an endocrinologist or primary care provider (family medicine, internal medicine) with an encounter diagnosis of diabetes mellitus (DM) (250.XX) at least 1 year prior to the index dates (ie, 1 July 2008 and 1 July 2013, respectively).

Table 2 Clinical characteristics, comorbidities, complications, and diabetes-related health maintenance at index (mean, SD)

Variable	2008 Index year N=24 493		2013 Index year N=41 582		p Value
	Mean	SD	Mean	SD	
Age at index dates (years)	64.8	12.9	64.3	12.9	<0.0001*
BMI (kg/m²)	32.5	7.0	32.8	7.0	<0.0001†
Systolic blood pressure (mm Hg)	129.5	17.4	129.8	17.4	0.063†
Diastolic blood pressure (mm Hg)	74.2	10.2	74.5	10.3	0.007†
LDL cholesterol (mg/dL)	92.1	32.6	88.0	32.7	<0.0001†
DCSI	1.5	1.3	1.4	1.6	<0.0001†
Number of diabetes visits in prior year (N)‡	2.6	1.6	2.5	1.6	<0.0001†
Number of canceled visits in prior year (N)	1.2	1.9	1.5	1.9	<0.0001†
Median household income (US$1000)	59.4	23.5	56.9	23.4	<0.0001*

*Compared using the Wilcoxon Mann-Whitney test.
†Adjusted for sex, age, race, and income using generalized estimating equations.
‡Endocrinology or primary care visits.
BMI, body mass index; DCSI, Diabetes Complications Severity Index; LDL, low-density lipoprotein.

Table 3 Distribution of medications

	2008 Index year* N=24 493		2013 Index year* N=41 582		Adjusted* p value
	N	Per cent	N	Per cent	
α-Glucosidase inhibitors	101	0.4	130	0.3	0.1190
Biguanides (metformin)	15 425	63.0	27 987	67.3	<0.0001
Metformin monotherapy	5640	23.0	11 735	28.2	<0.0001
Metformin+sulfonylurea†	3313	13.5	5565	13.3	0.62
Metformin+thiazolidinedione†	963	3.9	422	1.0	<0.0001
Metformin+dipeptidyl peptidase-4 inhibitor†	402	1.6	1580	3.8	<0.0001
Metformin+GLP-1†	153	0.6	264	0.6	0.86
Metformin+insulin†	411	1.7	1178	2.8	<0.0001
Dipeptidyl peptidase-4 inhibitors	1952	8.0	6566	15.8	<0.0001
Glucagon-like peptide-1 agonists	984	4.0	1563	3.8	<0.0001
Meglitinides	247	1.0	212	0.5	<0.0001
Sulfonylureas	9898	40.4	14 705	35.4	<0.0001
Thiazolidinediones	4849	19.8	2852	6.9	<0.0001
Antidiabetic combination therapy‡	11 286	46.0	18 232	43.8	<0.0001
Statin	16 427	67.1	28 503	68.5	<0.0001
Aspirin	12 556	51.3	22 285	53.6	<0.0001
ACE or ARB	17 001	69.4	28 741	69.1	0.0001
Insulin total	3711	15.2	7832	18.8	<0.0001
Human	1035	27.9	1353	17.3	<0.0001
Analog (basal or bolus)	3070	82.7	7066	90.2	<0.0001
Basal	3474	93.6	7522	96.0	<0.0001
Bolus	2205	59.4	4583	58.5	0.0003
Premix	515	13.9	150	1.9	<0.0001
Insulin+any number of oral antidiabetic medication classes§	2194	9.0	4544	10.9	<0.0001
Insulin+one oral antidiabetic medication class¶	854	3.5	2032	4.9	<0.0001

*Adjusted for sex, age, race, and income using generalized estimating equations.
†Restricted to two-drug combination therapy, metformin+one additional agent.
‡Any two of the eight antidiabetic classes.
§Insulin+any number of the six oral antidiabetic agent classes.
¶Restricted to two-drug combination therapy, insulin+one additional oral agent.
ARB, angiotensin receptor blocker; GLP-1, glucagon-like peptide-1.

This study was approved by the Cleveland Clinic's Institutional Review Board.

RESULTS

The 2008 and 2013 data sets included 24 493 and 41 582 patients with T2D, respectively. Of note, 12 728 (52.0%) patients included in the 2008 data set were also included in the 2013 data set.

Characteristics (categorical and continuous variables)

The majority of patients with T2D were male and Caucasian (52.3% and 50.1%, p<0.0001) and (79% and 75.2%, p<0.0001), in the 2008 and 2013 data sets, respectively. The mean age (years) was 64.8±12.9 in 2008, and 64.3±12.9 in 2013, p<0.0001. The mean household income (in US$1000) was observed to be higher in 2008 vs 2013, 59.4 vs 56.9, p<0.0001. The percentage of active smokers was found to be 55% in 2008, and 53.3% in 2013 (p=0.0002) (table 1). Small, non-clinically significant changes were observed between 2008 and 2013, respectively, for mean body mass index (32.5 and 32.8; p<0.0001), systolic blood pressure (BP) (129.5 and 129.8; p=0.063), diastolic BP (74.2 and 74.5; p=0.007), and low-density lipoprotein (LDL) cholesterol (92.1 and 88; p<0.0001) (table 2).

Comorbidities

The percentages (%) of patients with T2D with comorbidities in 2008 and 2013, respectively, were glomerular filtration rate <60 mL/min, calculated by the CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) formula (18.8 and 16.3; p<0.0001), hypertension (HTN) (82.5 and 87.2; p<0.0001), cerebrovascular disease (9.7 and 8.1; p<0.0001), cardiovascular disease (CVD) (26.9 and 22.3; p<0.0001), and peripheral vascular disease (5.4 and 4.9; p<0.0001) (table 1). The Diabetes Complications Severity Index (DCSI) scores (mean±SD) for patients with T2D in 2008 and 2013 were 1.5 and 1.4; p<0.0001, respectively (table 2).

Microvascular complications

The percentages (%) of patients with T2D with microvascular complications in 2008 and 2013, respectively, were retinopathy (3.2 and 3.4; p=0.11), nephropathy (26.8 and 25.9; p=0.56), and neuropathy (19.5 and 18.0; p<0.0001) (table 1).

Diabetes-related follow-up and health maintenance

In 2008 and 2013, the mean numbers of diabetes-related office visits were 2.6 and 2.5; p<0.0001, and of missed appointments were 1.2±1.9 and 1.5±1.9; p<0.0001, respectively (table 2). The percentages (%) of patients, in 2008 and 2013, who received the recommended influenza vaccine in the prior season and pneumonia vaccine within the past 10 years, were 32.7 and 38.8 and 51.8 and 61.7, respectively (table 1). Dilated eye examinations were not tracked by the EHR in 2008. This has since become more standard practice, yet the number of patients with the structured documentation of yearly dilated eye examinations remains low; only 12.9% of patients with diabetes in 2013 had a dilated eye examination documented in the structured health maintenance section of the EHR.

Glycemic control

The population was divided into four groups based on the index A1C level. The percentages of patients across the defined A1C categories were 64.3 and 66.7 for <7%, 21.1 and 18.8 for 7–7.9%, 7.8 and 7.5 for 8–8.9%, and 6.8 and 7.0 for ≥9% in 2008 and 2013, respectively (p<0.0001), (table 1).

Medications

In the 2008 and 2013 data sets, the most commonly utilized antidiabetic agents were metformin and sulfonylureas. The percentages of patients receiving metformin overall and metformin monotherapy in 2008 and 2013, were 63.0 and 67.3, p<0.0001 and 23.0 and 28.2, p<0.0001, respectively. Sulfonylureas were the most commonly utilized oral antidiabetic agent as two-drug combination therapy with metformin in 2008 and 2013 (13.5 and 13.3, p=0.62). The percentages of patients in 2008 and 2013 receiving two-drug combination therapy with metformin and a thiazolidinedione, a DPP-4 inhibitor, a GLP-1 agonist, or insulin were 3.9 and 1.0, p<0.0001, 1.6 and 3.8, p<0.0001, 0.6 and 0.6, p=0.62, and 1.7 and 2.8, p<0.0001 (table 3).

The most significant differences from 2008 to 2013 in the per cent of patients using antidiabetic medications were observed for those who were prescribed thiazolidinediones (19.8% to 6.9%, p<0.0001), and DPP-4 inhibitors (8.0% and 15.8%; p<0.0001). Sulfonylurea usage (overall) fell from 40.4% to 35.4%; p<0.0001. Insulin usage occurred in only 15.2% and 18.8% of patients, p<0.0001, while combination antidiabetic therapy (any 2 of the 8 medication classes) was used by 46.0% and 43.8% of patients, p<0.0001, in the respective years. Utilization of GLP-1 agonist therapy remained low at both index dates (≤4%). The distribution of the remaining prescribed antidiabetic medications (% of patients receiving the therapy) is shown in table 3.

Regarding the patients receiving insulin therapy, the percentage (%) of patients receiving human insulin decreased and that of analog insulin usage correspondingly increased from 2008 to 2013. Usage of basal or bolus insulin changed only slightly from 2008 to 2013, whereas the use of premixed insulin was observed to decrease rather significantly from 2008 vs 2013 (13.9 vs 1.9; p<0.0001). The percentages of patients receiving insulin in combination with any one oral antidiabetic class, or any number of oral antidiabetic classes, were 3.5 and 4.9, p<0.0001 and 9.0 and 10.9, p<0.0001, in 2008 and 2013, respectively.

The majority of patients with T2D were receiving a statin, aspirin (acetylsalicylic acid), and an ACE inhibitor or angiotensin receptor blocker, with small, albeit significant changes from 2008 to 2013.

A random chart review conducted on 100 participants supported the validity of the extraction of structured data (ICD-9 codes, medications, laboratory values, etc.).

Please see tables 1–3 for a comprehensive summary of the data provided.

DISCUSSION

Over the past few decades, integrated health delivery systems have evolved, and continue to increase in number. As a result of the evolution of these systems, the way that diabetes-related care is delivered and management of its comorbid conditions have changed considerably. This report describes the population of patients with T2D receiving care within the integrated healthy delivery system at Cleveland Clinic, which uses a single EHR system across the entire organization (EPIC). The EHR data extraction and analysis were conducted to better identify the population of patients with T2D who are receiving care in an integrated health system. Currently, the literature only includes large studies using the general population of patients with T2D, as characterized regularly via NHANES, a stratified, multistage, probability cluster survey conducted in the non-institutionalized US population.

We were able to further characterize how the profile of patients with T2D within the EHR has changed with time (ie, 2008 vs 2013). There was an increase in the number of participants who were female, Black, and from a lower socioeconomic status (SES), as per the median household income data derived from the last US census. Patients with diabetes were found to be younger in 2013 vs 2008 from a statistical standpoint; however, the very small difference in age noted is of no clinical relevance.

In terms of glycemic control, there was a higher percentage of patients with an A1C<7% in 2013 vs 2008. Overall, the percentages of patients with an A1C<7% and <8% were >64% and >85%, respectively, in 2008

and 2013. These percentages of patients with adequate glycemic control are significantly higher than what has been reported from the NHANES database; this observation may be, in part, because an integrated healthcare delivery model may assist in overcoming many of the barriers that have historically prevented obtaining glycemic control in patients with T2D. However, further studies comparing patients managed within an integrated delivery system versus a control group from a non-integrated model would be required to test this hypothesis. These findings are important, as identifying and overcoming the barriers to achieving glycemic targets (A1C) will become ever-important in the coming years, for preventing diabetes-related complications, as well as to ensure reimbursement for the medical care that is rendered to patients with diabetes as integrated health systems assume greater shared financial risk in newer payment models. A1C control is one of the quality measures used by the Center for Medicare and Medicaid Services for determining reimbursement rates to Accountable Care Organizations and incentives for the meaningful use of EHRs (http://www.cms.gov).

Hypercholesterolemia is a common comorbidity in patients with T2D, and an independent risk factor for CVD. Lipid control substantially reduces CVD, the major cause of death for individuals with diabetes. Most patients with diabetes meet the ADA recommendations for statin therapy: those with documented CVD, those aged >40 years with one or more additional cardiovascular risk factors (family history of CVD, HTN, smoking, dyslipidemia, albuminuria), or those lower-risk patients with an LDL >100 mg/dL, or those with multiple CVD risk factors.[10] In this population, the mean LDL of both the 2008 and 2013 populations with T2D was <100 mg/dL, and 67.1% and 68.5%, respectively, were receiving statin therapy. This is higher than the percentage of patients (51.4%) reported to be receiving statin therapy, from 2007 to 2010, as per a recent analysis of NHANES data.[4]

HTN is another common comorbidity of patients with T2D. In this population, 82.5% and 87.2% of patients had documented HTN, among whom the mean systolic and diastolic BPs were below the ADA recommended goal BP (<130/80),[12] recently changed to <140/80.[10] Our estimation of the prevalence of HTN among these patients with diabetes is slightly higher than what was reported in the latest Centers for Disease Control and Prevention (CDC) Diabetes Fact Sheet (2014) from 2009 to 2012, where in adults aged 18 years or older with diagnosed diabetes, 71% were reported to have a BP greater than or equal to 140/90 mm Hg, or were receiving a prescription medication(s) to lower high BP.[13]

Perhaps the most interesting data derived from this report are the utilization of antidiabetic therapies among the patients with T2D. Not surprisingly, metformin and sulfonylureas remain the most commonly utilized antidiabetic therapies, likely because of their low cost. Overall, a decrease in the utilization of sulfonylureas, and an increase in the use of metformin were

noted, however. These results are likely related to the recent recommendations by the ADA, the European Association for the Study of Diabetes, and the American Association of Clinical Endocrinologists to initiate metformin therapy as the first-line agent to manage glycemia, in the absence of contraindications or intolerability. In addition, reports have recently suggested that sulfonylureas impose increased cardiovascular risk vs metformin monotherapy.[14 15] The percentage of patients receiving metformin in combination with a sulfonylurea, however, was the same in 2008 and 2013. Not surprisingly, the use of thiazolidinediones has decreased considerably (overall, and in combination with metformin), which is clearly related to the safety concerns, risk, and contraindications/warnings that has surrounded these agents in recent years (cardiovascular risk with rosiglitazone and bladder cancer with pioglitazone).[16–19] An increase in the use of DPP-4 inhibitors overall, and in combination with metformin, was also observed. It is possible that the changes in antidiabetic medications being prescribed in 2008 vs 2013 may, in part, explain the changes in glycemic control observed in this data set. Although GLP-1 agonist therapy has now been available for nearly 10 years in the USA, and more GLP-1 agonist therapies have become available since exenatide was originally approved in 2005, the percentage of patients receiving GLP-1 agonist therapy has not increased according to these data (4.0% vs 3.8% in 2008 vs 2013).

The use of insulin therapy increased only slightly from 15.2% to 18.8%, between 2008 and 2013, respectively. The use of insulin premix formulations as well as human insulin decreased from 2008 to 2013. An increase in the use of analog and basal insulin was also observed.

The strengths of this study include the large number of participants identified, the use of the validated EMERGE algorithm[9] to properly identify the participants, and the robust amount of clinical data which allowed for an extensive depiction of the participants. In addition, we had an A1C available in the vast majority of patients, only approximately 14% of whom did not have an available A1C within 1 year prior to the index dates. However, this study is not without limitation. The biggest limitation is the inability to systematically extract data from the EHR that was not entered in a structured format (ie, clinical documentation in free-text progress notes). A significant amount of laboratory data from outside facilities was likely embedded within our clinician progress notes. As a result, not every patient had an A1C measure available in a structured format within 1 year prior to the index date. Patients without an A1C were excluded from any analysis that involved A1C. The same treatment was used for other covariates as well. In addition, with the exception of nephropathy, we relied heavily on the ICD-9 documentation of DM to ascertain microvascular complications. Many providers simply enter the code 250.02, T2D uncontrolled, uncomplicated, even if a patient has

microvascular complications. Compared with estimates derived from NHANES, we are significantly underestimating the prevalence of microvascular complications. Most significant is the underestimation of the prevalence of retinopathy. We reported the prevalence of retinopathy to be around 3%; however, from 2005 to 2008, the estimated prevalence of diabetic retinopathy in the USA, among US adults with diabetes aged 40 years and older, has previously been reported to be 28.5%.[20] Our estimate for the prevalence of neuropathy is also well below the estimates provided by the CDC National Diabetes Fact Sheets.[5] [13] These underestimations are expected to be related to inconsistent ICD-9 documentation of the microvascular complications, and with respect to retinopathy, because our ophthalmology department was not fully integrated into our EHR until 2012. Thus, until recently, the coordinated recording of dilated eye examinations within the EHR was not routinely performed. Our estimates of nephropathy (as per the DCSI definition) were within the expected range (20–30%),[21] largely because this microvascular complication can be ascertained via laboratory data in addition to ICD-9 codes.

CONCLUSIONS

This analysis characterizing the population of patients with T2D within an integrated health delivery system underscores the complexity of treating these patients, as well as managing their glycemic control and comorbidities. While the prevalence of HTN has increased, the prevalence of other comorbidities decreased in 2013 when compared with 2008. The majority (>64%) of patients had an A1C<7%, and 85% had an A1C<8%. In 2008 and 2013, metformin therapy was the most commonly utilized antidiabetic agent, and sulfonylureas were the most commonly utilized oral antidiabetic agent in combination with metformin. The ability to detect microvascular complications of diabetes from the systematic extraction of data from an EHR has significant limitations; the use of natural language processing technology may be helpful in capturing this information more reliably. An accurate capture of patient complexity (presence of comorbidities and complications) and their state of health in the EHR, coupled with the ability to use EHR data to predict outcomes, will become more important as the reimbursement model for medical care in the USA shifts away from a fee-for-service based system.

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