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ORIGINAL ARTICLE

Impact of Initiating Insulin Glargine Disposable Pen Versus Vial/Syringe on Real-World Glycemic Outcomes and Persistence Among Patients with Type 2 Diabetes Mellitus in a Large Managed Care Plan: A Claims Database Analysis

Lin Xie, MA, MS,[1] Steve Zhou, PhD,[2] Brett W. Pinsky, MPH,[3] Erin K. Buysman, MS,[3] and Onur Baser, MS, PhD[1,4]

Abstract

Background: Diabetes accounts for almost 15% of all direct healthcare expenditures. Managed care organizations try to reduce costs and improve patient outcomes. Increasing patient persistence with antidiabetes treatment could help achieve these goals.

Subjects and Methods: A retrospective study was conducted using the Optum Research Database (Optum, Eden Prairie, MN) to analyze clinical and economic outcomes associated with initiation of insulin glargine via a disposable pen (GLA-P) or vial and syringe (GLA-V) among adult, insulin-naive patients with type 2 diabetes mellitus (T2DM). Propensity-matched patient cohorts were assessed for persistence with insulin therapy, glycated hemoglobin (A1C), hypoglycemic events (based on diagnosis codes), and healthcare costs (total paid amount of adjudicated claims) after follow-up at 1 year.

Results: In 1,308 matched patients, persistence was significantly higher ($P = 0.011$) and longer ($P = 0.001$) with GLA-P. Follow-up A1C values were significantly lower ($P = 0.038$), and decreases in A1C from baseline significantly larger ($P = 0.043$), in GLA-P than in GLA-V. Significantly fewer hypoglycemic events ($P = 0.042$) were experienced, and a lower rate of diabetes-related inpatient admissions ($P = 0.008$) was reported in GLA-P than GLA-V. Despite higher study drug costs with GLA-P than GLA-V, all-cause and diabetes-related healthcare costs were similar.

Conclusions: In insulin-naive patients with T2DM, initiation of insulin glargine using the disposable pen rather than the vial and syringe is associated with higher persistence, better A1C control, and lower rates of hypoglycemia. The higher study drug costs associated with pen use do not increase total all-cause or diabetes-related healthcare costs. This may help treatment selection for patients with T2DM in a managed care setting.

Background

THE TOTAL ESTIMATED diabetes-related costs in the United States were $245 billion in 2012.[1] Most of this expenditure relates to hospitalizations and treatment of diabetes complications.[2] Improving treatment persistence[3,4] and glycemic control[3,5,6] and decreasing rates of hypoglycemia[7,8] have been identified as factors that could result in cost savings in a managed care setting. Other factors that may influence overall cost for managed care organizations are healthcare utilization (hospitalizations, inpatient/outpatient care, specialist vs. primary care),[3] pharmacy costs,[9,10] and health services costs (frequency of monitoring, laboratory testing, etc).

Many patients with type 2 diabetes mellitus (T2DM) eventually require injectable insulin therapy.[11] Long-acting analog basal insulins, such as insulin glargine or detemir, are recommended as initial insulin therapy.[11] However, conventional administration of these insulins by vial and syringe

[1]STATinMED Research, Ann Arbor, Michigan.
[2]Sanofi US Inc., Bridgewater, New Jersey.
[3]Optum, Eden Prairie, Minnesota.
[4]The University of Michigan, Ann Arbor, Michigan.

is associated with significant psychological barriers that can reduce compliance.[12,13] Medication adherence (or compliance) describes whether a patient is taking medication as prescribed. Treatment persistence refers to the proportion of patients remaining on treatment for a specified period of time. Adherence to medication regimens is generally associated with better health outcomes.[14] Insulin pen delivery systems seem to improve patient convenience and treatment persistence (and adherence), and thus outcomes, compared with vial and syringe methods of administration.[15–17] Although adherence to insulin use is a desirable concept, it is hard to measure from healthcare claims data in a reliable way. Therefore, using persistence of insulin treatment is the most feasible approach for retrospective claims studies.

Various studies have investigated clinical parameters and healthcare costs associated with different insulin administration methods for long-, intermediate-,[8,18] and fast-acting[9,10] analogs. However, only a few have researched the newer insulin pen devices.[15,19–21] Furthermore, studies published so far are limited by patient numbers, short duration, and/or the use of combined datasets from multiple insurance providers with large variability in formularies and copay schemes across plans.

The current analysis uses data from a single, large insurance provider to compare patients' real-world persistence with treatment, glycated hemoglobin (A1C) levels, hypoglycemia rates, and healthcare costs.

Subjects and Methods

Study design and patients

This retrospective study used medical data, pharmacy data, enrollment information, and laboratory results from the proprietary Optum Research Database utilized by OptumInsight (Optum, Eden Prairie, MN). This database includes claims for pharmacy services (typically submitted electronically by the pharmacy at the time prescriptions are filled) and medical claims or encounter data (which are collected from all available healthcare sites [i.e., inpatient hospital, outpatient hospital, emergency department (ED), physician's office, surgery center, etc.]) for virtually all types of provided services. Data inclusion has been ongoing since 1993. In 2011, there were data available for nearly 13 million individuals with pharmacy and medical benefit coverage.

Data from adult insulin-naive patients, ≥18 years of age, with a diagnosis of T2DM (defined as one or more inpatient stay or two ambulatory visits at least 30 days apart with a primary or secondary diagnosis of International Classification of Diseases, 9th Revision, Clinical Modification [ICD-9-CM] code 250.x0 or 250.x2) and who had one or more pharmacy claim for the index treatment—initiation of insulin glargine via a disposable pen (GLA-P) or vial and syringe (GLA-V)—between January 1, 2008 and August 31, 2010. The date of the first claim for insulin glargine was designated as the index date. SoloSTAR® (Sanofi US Inc., Bridgewater, NJ) received Food and Drug Administration approval for use with insulin glargine on May 2, 2007. Patients had to have continuous health plan enrollment for 6 months (180 days) prior to the index date (baseline period) and for 12 months following the index date (follow-up period), one or more claim for an oral antidiabetes drug or glucagon-like peptide-1 receptor agonist during the baseline period, and one or more baseline A1C value. Patients with evidence of pregnancy or gestational diabetes during the baseline or follow-up period were not eligible for inclusion in the analysis.

Study outcomes

Study outcomes were persistence with index insulin therapy, insulin use, change in A1C and achievement of A1C <7.0%, hypoglycemic events, and healthcare resource utilization and costs during the 12-month follow-up period.

Treatment persistence was defined as the patient remaining on the study drug during the follow-up period without discontinuation or switching after initiation.[19] Study medication was considered discontinued if the prescription was not refilled within the expected time of medication coverage (the 90th percentile of the time, stratified by the metric quantity supplied, between first and second fills among patients with at least one refill). (For example, among patients who filled a first prescription for a certain medication and had a refill later, 90% refilled the prescription within a certain period of time [*n* days]. A patient who had previously filled a first prescription was considered to have discontinued treatment [i.e., did not persist with their treatment] when not refilling within *n* days.) Patients who restarted their initial medication during follow-up after a period without were considered to be nonpersistent. Sensitivity analyses were also conducted using the 75th and 95th percentiles of the time. Insulin use was measured as the daily average consumption, calculated as the total number of index insulin units dispensed before the last study drug refill divided by the total number of days between initiation and last refill during the follow-up period.

The A1C was defined as the A1C value during the 90 days prior to or following the end of the follow-up period. A hypoglycemic event was defined as a healthcare encounter (outpatient, physician's office, ED or other visit, or inpatient admission) with a primary or secondary ICD-9-CM diagnosis code for hypoglycemia or a diagnosis of diabetes with other specified manifestation and no medical claims with ICD-9-CM codes for hypoglycemic co-diagnoses.[22,23] The setting of the hypoglycemic event (outpatient, physician's office, ED, hospital, or other setting) was used as a proxy for severity.

Total all-cause and diabetes-related healthcare resource utilization, healthcare costs, and index study drug costs were assessed. Healthcare utilization was counted as the number of physician's office, outpatient, and ED visits and the number of hospital admissions per patient. Visits with a diagnosis code of 250.xx were considered diabetes-related.

Healthcare costs were calculated as the combined health plan–paid and patient-paid amounts in the follow-up period. Diabetes-related healthcare costs included costs from medical claims with a primary diagnosis of diabetes (ICD-9-CM code 250.xx) or from pharmacy claims for antidiabetes medications (oral antidiabetes drugs, glucagon-like peptide-1, pramlintide, or insulin). Diabetes supply costs, such as glucose meters and test strips, were calculated separately. Costs were adjusted to 2011 dollars to reflect inflation using the medical care component of the U.S. consumer price index.[24]

Measurements and statistical methods

All study measures were assessed descriptively. To overcome selection bias, GLA-P initiators were matched with GLA-V initiators using 1:1 propensity score matching (PSM).[25] Variables included in the PSM model were

determined following review of the prematching descriptive analysis of patient characteristics and other baseline measures and are presented in Table A1 in the Appendix. Patients were only included in the PSM analysis if they had baseline A1C laboratory values available.

Following matching, bivariate comparisons of baseline characteristics and demographics were performed to assess the success of the matching procedure. Independent *t* tests (for continuous variables) and χ^2 tests (for categorical variables) were used based on the distribution of the measure. Bivariate comparisons of economic outcomes were performed using Wilcoxon signed-rank tests. Multivariate modeling was applied to persistence outcomes in the postmatched sample to adjust for potential confounding factors remaining after PSM. Multivariate analyses included Kaplan–Meier analysis, log-rank testing, and Cox proportional hazard models of time to discontinuation (90^{th} percentile).

Results

Patient selection and baseline characteristics

Overall, 118,154 patients were identified from the database, and 14,802 unmatched patients were eligible for the final study sample. Of 3,423 patients with baseline A1C data available, 1,308 were evaluated after PSM ($n = 654$ in both GLA-P and GLA-V cohorts). Baseline characteristics were well balanced (Table 1).

Treatment persistence and insulin use

More GLA-P initiators were persistent with treatment (58.4% vs. 51.4% with GLA-V, respectively; $P = 0.011$) and were persistent for longer (314 days compared with 299 days for GLA-V initiators; $P = 0.001$). The Kaplan–Meier analysis for time to discontinuation indicates that GLA-P initiators

Table 1. Baseline Characteristics for Initiators of Insulin Glargine by Disposable Pen or by Vial and Syringe Following Propensity Score Matching

Characteristic	*GLA-P initiators* (n = *654*)	*GLA-V initiators* (n = *654*)	P *value*
Age range (years) [*n* (%)]			
18–39	45 (6.9)	44 (6.7)	0.913
40–64	551 (84.3)	565 (86.4)	0.274
65–74	54 (8.3)	42 (6.4)	0.203
≥75	4 (0.6)	3 (0.5)	0.705
Female [*n* (%)]	279 (42.7)	288 (44.0)	0.616
Plan type [*n* (%)]			
Health maintenance organization	97 (14.8)	118 (18.0)	0.117
Point-of-service	354 (54.1)	323 (49.4)	0.086
Preferred provider organization	84 (12.8)	82 (12.5)	0.868
Other	119 (18.2)	131 (20.0)	0.399
Modified CCI [mean (SD)]	1.15 (1.8)	1.09 (1.6)	0.486
Any hypoglycemia [*n* (%)]	20 (3.1)	24 (3.7)	0.540
Antidiabetes therapy [*n* (%)]			
Metformin	392 (59.9)	409 (62.5)	0.335
Sulfonylureas	401 (61.3)	417 (63.8)	0.361
DPP-4 inhibitor	155 (23.7)	162 (24.8)	0.652
GLP-1 receptor analog	95 (14.5)	90 (13.8)	0.692
Thiazolidinedione	240 (36.7)	226 (34.6)	0.419
Pramlintide	1 (0.2)	1 (0.2)	1.000
α-Glucosidase inhibitor	5 (0.8)	4 (0.6)	0.738
OAD MPR [mean (SD)]	0.69 (0.3)	0.70 (0.3)	0.355
A1C (%) [mean (SD)]	9.41 (2.1)	9.48 (2.2)	0.569
A1C range [*n* (%)]			
<7.0%	76 (11.6)	65 (9.9)	0.327
≥7.0–8.0%	107 (16.4)	107 (16.4)	1.000
≥8.0–9.0%	122 (18.7)	122 (18.7)	1.000
≥9.0	349 (53.4)	360 (55.0)	0.542
All-cause healthcare utilization [*n* (%)]			
ED visit	56 (8.6)	57 (8.7)	0.922
Inpatient admission	93 (14.2)	94 (14.4)	0.937
Diabetes-related healthcare utilization [*n* (%)]			
ED visit	21 (3.2)	17 (2.6)	0.510
Inpatient admission	68 (10.4)	68 (10.4)	1.000
Total healthcare costs (U.S. dollars) [mean (SD)]			
All-cause	10,442 (25,611)	10,069 (23,567)	0.784
Diabetes-related	3,739 (9,341)	3,662 (9,933)	0.885

A1C, glycated hemoglobin; CCI, Charlson Comorbidity Index; DPP-4, dipeptidyl peptidase-4; ED, emergency department; GLA-P, insulin glargine pen; GLA-V, insulin glargine vial and syringe; GLP-1, glucagon-like peptide-1; MPR, medication possession ratio; OAD, oral antidiabetes drug; PSM, propensity score matching.

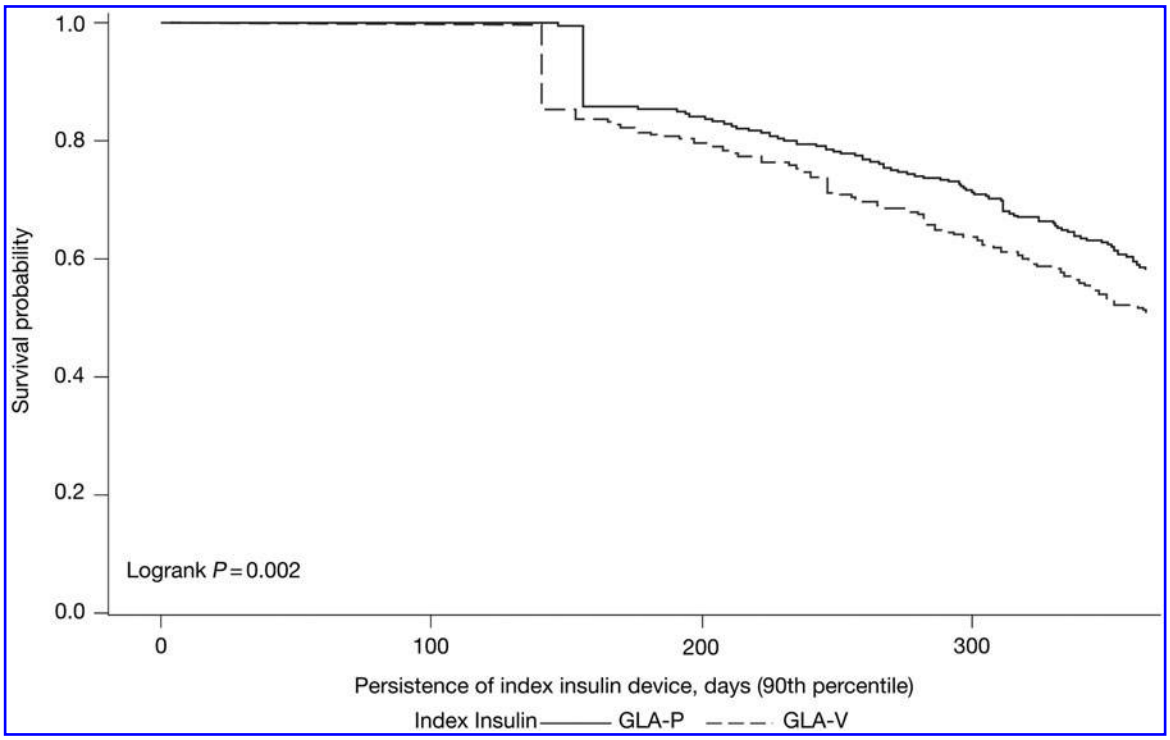

FIG. 1. Kaplan–Meier curve and log-rank test for time to treatment discontinuation (90th percentile) for matched initiators of insulin glargine by disposable pen (GLA-P) (solid line) or vial and syringe (GLA-V) (dashed line).

persisted with treatment significantly longer than GLA-V initiators ($P = 0.002$, log-rank test) (Fig. 1). Cox proportional hazards modeling for time to treatment discontinuation demonstrated a slower rate of treatment discontinuation among GLA-P initiators (hazard ratio = 0.78, $P = 0.003$).

Insulin use among the GLA-P and the GLA-V initiators was not significantly different (mean daily average consumption, 24.3 units/day with GLA-P and 23.8 units/day with GLA-V; $P = 0.750$).

Glycemic control

The A1C change from baseline was assessed in a subgroup of 996 matched patients with both baseline and follow-up A1C data available ($n = 498$ in each). In this subset of patients, mean baseline A1C was 9.5% for GLA-P initiators and 9.4% for GLA-V initiators ($P = 0.816$). GLA-P initiators had significantly lower average follow-up A1C values compared with GLA-V initiators (8.3% vs. 8.5%; $P = 0.038$). GLA-P initiators also experienced a larger decrease in A1C from baseline compared with GLA-V initiators (−1.2% vs. −0.9%; $P = 0.043$). The proportion of patients achieving an A1C <7% was similar in both cohorts (26.9% vs. 23.3%; $P = 0.188$) (Table 2).

Hypoglycemia

Medical claims showed that patients initiating GLA-P were significantly less likely to experience hypoglycemia requiring physician care than those initiating GLA-V: 5.1% of GLA-P initiators and 7.8% of GLA-V ($P = 0.042$) (Fig. 2). GLA-P initiators also had lower rates of outpatient, ED, and inpatient/ED-related hypoglycemic events (Fig. 2A). GLA-P

Table 2. 12-Month Follow-Up Glycated Hemoglobin (A1C) Parameters Among Matched Initiators of Insulin Glargine by Disposable Pen or by Vial and Syringe with Baseline and Follow-Up A1C Data Available

A1C parameter	*GLA-P initiators* (n = *498*)	*GLA-V initiators* (n = *498*)	P *value*
Baseline A1C (%) [mean (SD)]	9.5 (2.2)	9.4 (2.1)	0.816
Follow-up A1C (%) [mean (SD)]	8.3 (1.9)	8.5 (1.9)	0.038
Follow-up A1C range [*n* (%)]			
<7.0%	134 (26.9)	116 (23.3)	0.188
≥7.0–8.0%	134 (26.9)	117 (23.5)	0.215
≥8.0–9.0%	79 (15.9)	96 (19.3)	0.157
≥9.0%	151 (30.3)	169 (33.9)	0.222
Change (%) in A1C from baseline [mean (SD)]	−1.2 (2.2)	−0.9 (2.2)	0.043

A1C, glycated hemoglobin; GLA-P, insulin glargine pen; GLA-V, insulin glargine vial and syringe.

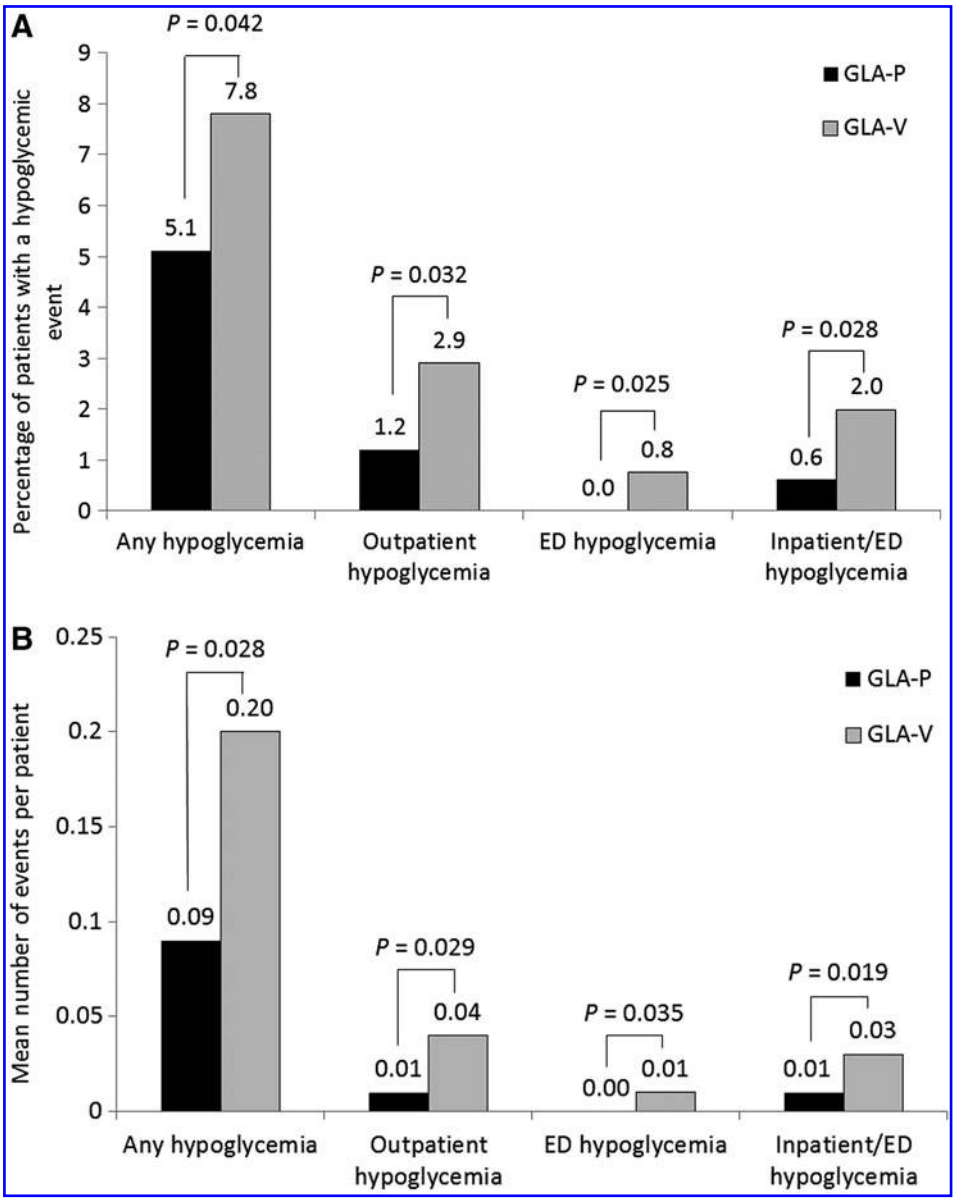

FIG. 2. Follow-up hypoglycemia among matched initiators of insulin glargine by disposable pen (GLA-P) or vial and syringe (GLA-V): **(A)** rate of hypoglycemic events and **(B)** mean number of events per patient. ED, emergency department.

initiators had significantly fewer overall mean number of hypoglycemic events per patient (0.09 vs. 0.20; $P = 0.028$), outpatient events (0.01 vs. 0.04; $P = 0.029$), ED events (0.00 vs. 0.01; $P = 0.035$), and inpatient/ED events (0.01 vs. 0.03; $P = 0.019$) compared with GLA-V initiators (Fig. 2B).

Healthcare utilization and costs

During the 1-year follow-up period, the rate of diabetes-related inpatient admissions was significantly lower among GLA-P initiators compared with GLA-V initiators (9.6% vs. 14.4%; $P = 0.008$). There were no significant differences in all-cause or diabetes-related physician office visits, outpatient visits, or ED visits (Fig. 3).

GLA-P initiators had higher study drug costs than GLA-V initiators ($1,141 vs. $927; $P < 0.001$). However, this did not translate to higher diabetes-related costs as both total all-cause and total diabetes-related healthcare costs were similar; mean total all-cause costs were $21,451 versus $21,043 ($P = 0.711$), and mean total diabetes-related costs were $7,528 versus $7,971 ($P = 0.772$) for GLA-P and GLA-V initiators, respectively (Table 3).

Discussion

This retrospective real-world analysis of information from a database associated with a single, large insurance provider compared clinical and economic outcomes among insulin-naive patients with T2DM who initiated insulin glargine using disposable pen or vial and syringe. After follow-up at 1 year, patients initiating insulin glargine using the disposable pen had higher persistence rates (58.4% vs. 51.4%), a larger decrease in A1C from baseline, and significantly lower rates of hypoglycemic events compared with those using vial and

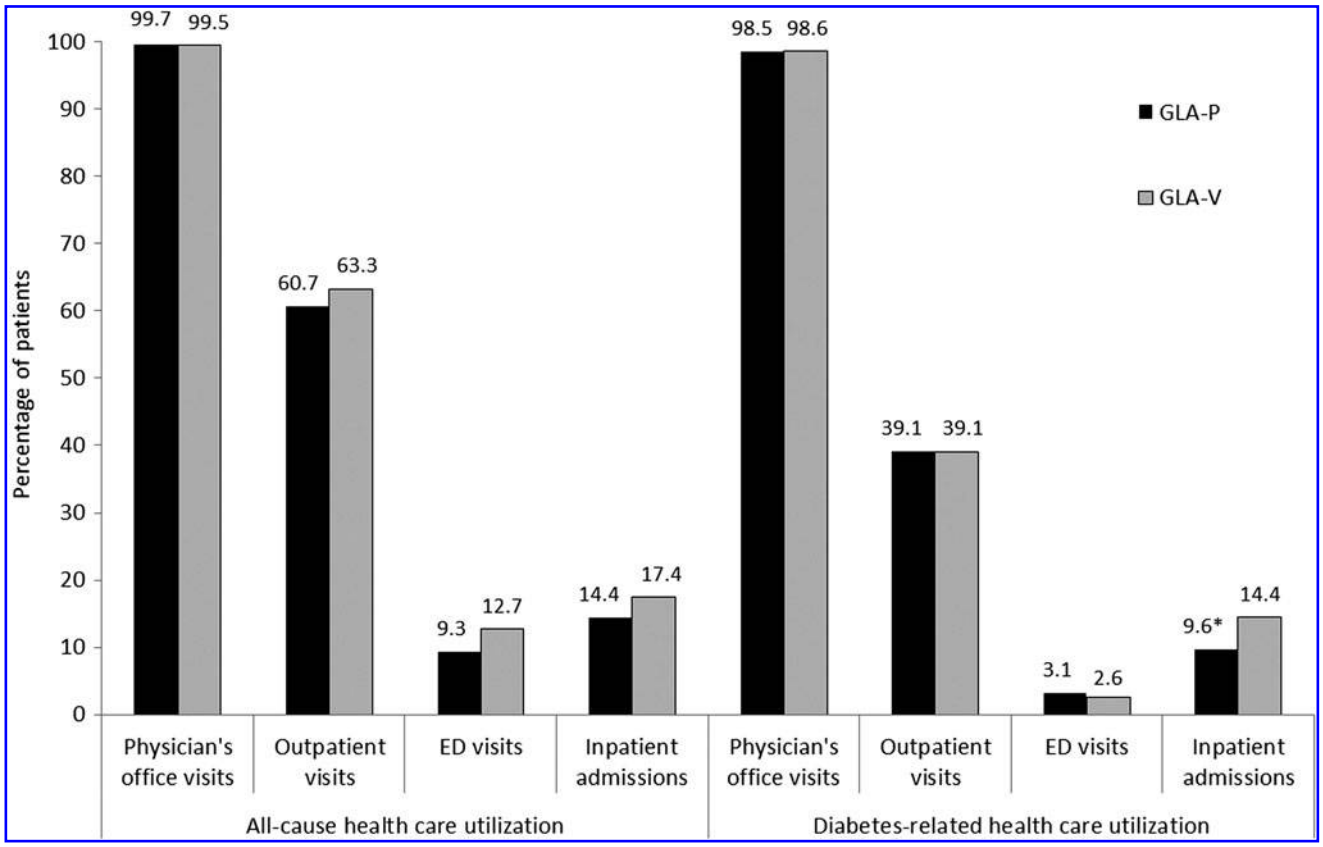

FIG. 3. Follow-up healthcare resource utilization among matched initiators of insulin glargine by disposable pen (GLA-P) or vial and syringe (GLA-V). *$P = 0.008$ versus GLA-V. ED, emergency department.

syringe. Previous studies have shown that patients find the disposable pen easy to use, allowing easy dose selection and readout, which leads to better dosing accuracy.[17,26] Improved dosing accuracy could explain the better clinical outcomes observed in patients initiating insulin glargine using the disposable pen. The ease of use and better dosing accuracy of the pen device can improve medication use behavior, including treatment persistence, thereby potentially contributing to improved clinical outcomes.[27,28] Initiation of insulin glargine therapy by disposable pen also led to a significant

Table 3. 12-Month Follow-Up Healthcare Costs Among Propensity Score–Matched Initiators of Insulin Glargine by Disposable Pen or by Vial and Syringe

	U.S. dollars [mean (SD)]		
Follow-up healthcare costs	*GLA-P initiators* (n = *654*)	*GLA-V initiators* (n = *654*)	P *value*
Total all-cause costs	21,451 (40,609)	21,043 (41,648)	0.711
Pharmacy costs	6,118 (6,254)	5,671 (5,407)	0.055
Physician office costs	2,892 (7,736)	2,597 (8,873)	0.263
Outpatient costs	4,496 (11,657)	5,423 (17,262)	0.860
ED costs	44 (320)	104 (756)	0.009
Inpatient costs	4,344 (20,765)	4,092 (17,214)	0.417
Other costs	3,556 (15,818)	3,156 (13,912)	0.719
Total diabetes-related costs	7,528 (14,281)	7,971 (16,409)	0.772
Pharmacy costs	2,554 (1,748)	2,232 (1,645)	< 0.001
Physician office costs	718 (688)	666 (727)	0.042
Outpatient costs	1,554 (6,567)	1,849 (8,991)	0.878
ED costs	7 (95)	14 (151)	0.620
Inpatient costs	1,498 (7,822)	2,009 (7,868)	0.043
Other costs	1,196 (6,780)	1,200 (6,925)	0.623
Study drug costs	1,141 (906)	927 (773)	< 0.001
Diabetes supply costs	423 (501)	373 (460)	0.046

A1C, glycated hemoglobin; ED, emergency department; GLA-P, insulin glargine pen; GLA-V, insulin glargine vial and syringe; PSM, propensity score matching.

reduction in the rate of diabetes-related inpatient admission during follow-up. Although pharmacy costs were higher for the disposable pen (5.3% vs. 4.4% of total healthcare costs, respectively), total all-cause and diabetes-related healthcare costs were similar. Other studies of managed care databases have reported similar results among patients administering insulin glargine via disposable pen: pen use was associated with higher medication costs compared with vial and syringe, whereas total healthcare resource utilization and costs were similar between the two administration methods.[19,29] The authors of these studies have suggested that this may be due to improved treatment persistence, lower rates of hypoglycemia, and fewer hospitalizations in patients using the insulin glargine disposable pen.[19,29] Thus, initiation of insulin glargine using the disposable pen rather than the vial and syringe increases patient persistence and improves clinical outcomes. The additional pharmacy costs for the disposable pen are offset by lower costs related to inpatient utilization. Therefore, the pen use has no implications for expenditure by the health insurer.

Like many other real-world claims data analyses, studies assessing the influence of copayment on treatment persistence are carried out on large, multiprovider/multiplan datasets. The large numbers of patients included in such datasets add to the robustness of the observed outcomes and to the generalizability to the U.S. population as a whole. However, it is unclear whether the outcomes of those studies are replicable in other, more specific settings. For example, multiprovider/multiplan datasets may combine data from providers/plans with different copay rates (and possibly with some variation in the formularies) and generally do not allow for the observation of concurrently implemented interventions that may have an effect on treatment persistence and healthcare resource utilization.

In the current study, copayment was included as a variable in the PSM model. The majority of patients in each treatment cohort had an average copayment of more than $31 for the index insulin. However, copayment may lead to treatment switching, treatment interruptions, or patients taking the drug less frequently than prescribed to extend its period of use.[30] In a study of oral antidiabetes drug treatment, increased copayment was a significant predictor of treatment failure.[31] Therefore, increased healthcare cost sharing between the payer and the patient, by means of higher copayments for the patient, leads to a decreased treatment persistence/adherence and may have deleterious effects on patients' health. Conversely, lower copayment ($0–9) has been reported to result in significantly higher adherence to oral antidiabetes drugs, lower total healthcare expenditure, and lower risk of hospitalization compared with patients with a higher copayment ($\geq$$20).[32] Therefore, it is paramount that cost containment approaches are value-based, to ensure both improved clinical outcomes and cost containment in the long term.[33] To confirm that copayment did not influence outcomes, we removed this variable from the PSM model and re-evaluated the results. Following the removal of copayment, overall results were similar to those obtained with the match on copayment (data not shown).

A strength of our study is that it is based on data from a single large insurance provider to maximize the robustness of the results. This approach allowed for subanalyses of issues of particular importance to decision-makers in the managed care community (such as the role of copays) and increased the generalizability of the conclusions to plans of a similar nature.

This study has several limitations, which are described in detail in the Supplementary Data (Supplementary Data are available online at www.liebertonline.com/dia). In brief, the use of administrative claims databases is associated with inherent and well-known limitations, including deficient information on dosage, duration of disease, and body weight. Furthermore, retrospective analyses of claims databases may introduce a risk of selection bias and confounding and do not allow assessment of site-specific shortages or stocking issues. Our study is based on claims data from a managed care population and may not be fully generalizable to all T2DM patients. Finally, the time frame of our study may have been too short to detect changes in the risk of complications that heavily impact costs in the longer term.

Conclusions

This real-world database study of insulin-naive patients with T2DM shows that initiation of insulin glargine treatment administered with a disposable pen improved patients' clinical outcomes without additional healthcare expenditure when compared with insulin glargine initiation using vial and syringe. Specifically, the disposable pen was associated with higher treatment persistence, better glycemic control, and lower rates of hypoglycemia but similar total all-cause or diabetes-related healthcare costs. This information may help the selection of the most appropriate treatment modality in a managed care setting.

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Author Disclosure Statement

L.X. and O.B. are employees of STATinMED Research, under contract with Sanofi US Inc. S.Z. is an employee of Sanofi US Inc. B.P. was an employee of Optum at the time of this study, and E.B. is a current employee of Optum, under contract with Sanofi US Inc.

L.X. contributed to the development of the study concept, conducted statistical analyses, and co-wrote the study report. S.Z. proposed and co-developed the study concept, co-developed the analysis plan, and interpreted the study data. B.P. is a senior researcher who contributed to the development of the study concept, co-wrote the study report, co-designed the study, and assisted in collecting, analyzing, and interpreting the study data. E.B. is a senior researcher who contributed to the development of the study concept, co-designed the study, and assisted in collecting, analyzing, and interpreting the study data. O.B. co-developed the statistical analysis plan, provided input for the study report, advised on data cleaning, and assisted in interpreting the data. All authors have provided input during manuscript development, have reviewed the manuscript, and have approved the final version prior to submission.

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Address correspondence to:
Steve Zhou, PhD
Sanofi US, Inc.
55 Corporate Drive
Bridgewater, NJ 08807-5925

E-mail: steve.zhou@sanofi.com

Appendix

Table A1. Baseline Covariates Controlled for During Propensity Score Matching

Age
Female
Plan type
HMO
POS
PPO
Geographic region
Northeast
Midwest
South
West
Copay for index insulin
$16–30
$31+
Baseline comorbidity
Modified Charlson Comorbidity Indexes
Myocardial infarction
Congestive heart failure
Cerebrovascular disease
Dementia
Paraplegia and hemiplegia
Renal disease
Cancer
Hypertension
Hyperlipidemia
Obesity
Severe mental illness
Other ischemic heart disease and angina
Amputation and ulceration
Ocular diseases that lead to visual impairment
Dyslipidemia
Baseline hypoglycemia
Any hypoglycemia
Inpatient/ER hypoglycemia
Baseline diabetes-related medication use
Sulfonylureas
DPP-4
GLP-1
Baseline concomitant medication use
Statins
ACE
ARB
α-Blocker
Calcium channel blocker
Adrenergic receptor agonists
Aldosterone antagonists
Baseline OAD MPR
Baseline all-cause healthcare utilization
Inpatient admissions
30-day hospitalization
Baseline diabetes-related healthcare utilization
Inpatient admissions
30-day hospitalization
Baseline all-cause healthcare costs
Total costs
Baseline diabetes-related healthcare costs
Total costs
ED costs
Baseline medication dispensings
Baseline A1c
<7%
≥7–8%
≥8–9%
Baseline microalbuminuria
3.5–35 g/mol for female
2.5–25 g/mol for male
Baseline serum creatinine value (flagged between 0.5 and 1.4 mg/dL)

ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker; DPP-4, dipeptidyl peptidase-4; ED, emergency department; ER, emergency room; GLP-1, glucagon-like peptide-1; HMO, health maintenance organization; MPR, medication possession ratio; OAD, oral antidiabetes drug; POS, point of service; PPO, preferred provider organization.

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