

Treatment Costs and Factors Associated with Glycemic Control among Patients with Diabetes in the United Arab Emirates

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Background: We aimed to estimate the proportion of patients with diabetes who achieved target glycemic control, to estimate diabetes-related costs attributable to poor control, and to identify factors associated with them in the United Arab Emirates.

Methods: This retrospective cohort study used administrative claims data handled by Abu Dhabi Health Authority (January 2010 to June 2012) to determine glycemic control and diabetes-related treatment costs. A total of 4,058 patients were matched using propensity scores to eliminate selection bias between patients with glycosylated hemoglobin (HbA1c) <7% and HbA1c ≥7%. Diabetes-related costs attributable to poor control were estimated using a recycled prediction method. Factors associated with glycemic control were investigated using logistic regression and factors associated with these costs were identified using a generalized linear model.

Results: During the 1-year follow-up period, 46.6% of the patients achieved HbA1c <7%. Older age, female sex, better insurance coverage, non-use of insulin in the index diagnosis month, and non-use of antidiabetic medications during the follow-up period were significantly associated with improved glycemic control. The mean diabetes-related annual costs were \$2,282 and \$2,667 for patients with and without glycemic control, respectively, and the cost attributable to poor glycemic control was \$172 (95% confidence interval [CI], \$164–180). The diabetes-related costs were lower with mean HbA1c levels <7% (cost ratio, 0.94; 95% CI, 0.88–0.99). The costs were significantly higher in patients aged ≥65 years than those aged ≤44 years (cost ratio, 1.45; 95% CI, 1.25–1.70).

Conclusion: More than 50% of patients with diabetes had poorly controlled HbA1c. Poor glycemic control may increase diabetes-related costs.

Key words: Diabetes mellitus, Blood glucose, Glycosylated hemoglobin A, Health care costs, Administrative claims

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INTRODUCTION

Diabetes mellitus is a major chronic disease affecting an estimated 382 million people globally in 2013¹, with an estimated prevalence of 20% in the United Arab Emirates (UAE).^{2,3} Therefore, it is becoming a major public health concern.

Raised glucose level or diagnosed diabetes is a critical factor in

metabolic syndrome.⁴ Improved glycemic control in diabetes is associated with a lower risk of diabetic complications and reduced all-cause and cardiovascular mortality.^{5,6} Glycemic control is typically assessed using glycosylated hemoglobin (HbA1c) levels, which reflect the average blood glucose levels over the previous 2–3-month period.^{7–9} Each 1% reduction in HbA1c in patients with type 2 diabetes mellitus (T2DM) decreases the risk for diabetes-related mor-

tality by 21% and microvascular complications by 37%.¹⁰ Because of the importance of glycemic control in patients with diabetes, the American Diabetes Association and UAE diabetes management guidelines recommend a specific HbA1c target of <7% for adults with diabetes.^{3,11} However, the proportion of patients with good glycemic control remains low, despite the importance of glycemic control. In the United States, the proportion of adults with HbA1c <7% was only 53% of patients with diabetes in 2007–2010, despite an increase over time¹², and only 33.3% of adults with diagnosed diabetes in the UAE achieve the glycemic goal.¹³

Diabetes also presents a huge economic burden, with a total estimated cost of \$245 billion in 2012 in the U.S. and treatment costs that are estimated at 2.3 times that of people without the disease.¹⁴ In Al Ain, UAE, the total annual direct medical costs of diabetes among patients without complications were estimated to be 3.2 times higher than the per capita health care expenditure, and the costs increased even further with the presence of complications.¹⁵ Furthermore, elevated HbA1c levels are associated with substantial medical costs, which increase even further with increases in HbA1c levels.¹⁶ There is considerable evidence that improved glycemic control results in medical cost savings¹⁷; a sustained reduction in HbA1c in adults with diabetes is associated with significant cost savings within the first 1–2 years of improvement.¹⁸

Although a number of studies have examined the relationship between patient characteristics, glycemic control, and the diabetes-related treatment costs^{7-9,19-21}, little is known about factors influencing glucose control and diabetes-related costs in patients with diabetes in the UAE. Therefore, the objectives of this study were to estimate the proportion of patients with diabetes who achieve the glycemic target, to identify factors associated with poor glycemic control, to estimate diabetes-related costs attributable to glycemic control, and to identify the characteristics associated with diabetes-related costs in patients newly diagnosed diabetes in the UAE.

METHODS

Data source and study population

This study is a retrospective cohort analysis using the knowledge engine of health administrative claims database handled by Abu Dhabi Health Authority. The Abu Dhabi Health Authority is the

regulatory body of the Emirate's healthcare system established to monitor the health status of its residents and ensure the quality of healthcare for its community. Knowledge engine of health administrative claims database is a platform built to collect health-related information and encounter claims data of the residents that can be analyzed for health status monitoring, regulation, and policy-making purposes. The data set consists of administrative information, diagnoses, activity, and observation elements. Administrative information describes the patients and claims, including financial data and encounters. Activity data include consultations and diagnostic and treatment activities, whereas observation data include specific observations as a result of medical activities (e.g., a lab test).²²

Data comprised all administrative health claims from January 2010 to June 2012. Eligible patients with diabetes were defined as patients (1) who met specified inclusion criteria for new diabetes diagnosis including type 1, type 2, and unspecified type during the enrollment period from July 2010 to June 2011; (2) who were not diagnosed with diabetes during the 6 months prior to the index month; (3) who can be followed up for at least 1 year from the index month; and (4) who had at least two HbA1c values, including the baseline HbA1c level during the follow-up period. The index month was defined as the first month of diagnosis for diabetes during the enrollment period, and the identified patients with diabetes were followed for 1 year from the index month.

The diagnosis of diabetes was confirmed by at least one of the following criteria: (1) diagnosis of diabetes based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code of 250.xx, (2) at least one pharmacy claim for antidiabetic medications that was classified under the anatomical therapeutic chemical class code of A10, (3) HbA1c level $\geq 6.5\%$, (4) fasting plasma glucose level ≥ 126 mg/dL (7.0 mmol/L), or (5) 2-hour plasma glucose level ≥ 200 mg/dL (11.1 mmol/L) in a 75 g oral glucose tolerance test.

Patients were excluded if they were diagnosed with human immunodeficiency virus infection (ICD-9-CM codes 042, 043, V08), organ or tissue transplants (ICD-9-CM codes 996.8, V42, V43, V49.83, V58.44, E878.0), malignancy (ICD-9-CM codes 140–239), pregnancy (ICD-9-CM codes 633–650, V22, V23), conditions originating in the perinatal period (ICD-9-CM codes 760–779), or alteration of consciousness including coma, transient alter-

ation of awareness, and persistent vegetative state (ICD-9-CM code 780.0) because these conditions could affect the study outcomes (i.e., screening rate, diagnosis rate, total treatment costs, or diabetes-related costs).

Study variables

The primary study outcome variable was glycemic control and the secondary outcome variable was annual diabetes-related costs. Glycemic control was defined as achievement of a follow-up HbA1c <7%.¹¹ Baseline HbA1c level was measured during the index month, and the follow-up HbA1c level was defined as the average of the HbA1c values measured during the follow-up period. This study examined the impact of glycemic control on diabetes-related costs. Diabetes-related costs were calculated by adding medical and prescription costs for the treatment of diabetes and diabetes-related comorbidities, such as nephropathy, neuropathy, retinopathy/macular edema, cardiovascular disease, cerebrovascular disease, and skin disease, during the follow-up period. Medical costs included costs related to hospitalization, outpatient services, and emergency department visits. The costs include net charges billed by the healthcare provider to the payer and any fee that the payer was expecting the healthcare provider to collect from the patient.

Statistical analysis

The patients were stratified based on glycemic control (HbA1c <7% vs. HbA1c ≥7%) using the mean HbA1c level measured during the 1-year follow-up period. The demographic and clinical characteristics included age, sex, nationality, health insurance plan, insulin use in the index diagnosis month, use of antidiabetic medications, and comorbidities diagnosed during the study period (i.e., the pre-index period during the 6 months prior to the index month and the 1-year follow-up period). Insulin use in the index month was an indicator variable to identify whether the patient was prescribed insulin in the index month. The use of antidiabetic medications was an indicator variable to identify whether the patient was prescribed any diabetic medication during the follow-up period. Finally, comorbidities during the study period included hypertension, hyperlipidemia, hypoglycemia, nephropathy, neuropathy, cardiovascular disease, cerebrovascular disease, obesity, rheumatoid

arthritis (RA)/osteoarthritis (OA), and asthma/chronic obstructive pulmonary disease (COPD).

The demographic and clinical characteristics of the two patient groups (HbA1c <7% vs. HbA1c ≥7%) were compared using chi-square test. To adjust for these differences, the patients with glycemic control (HbA1c <7%) were matched to those without glycemic control (HbA1c ≥7%) using a propensity score. The propensity score, which is the conditional probability of assigning a patient to the group with glycemic control, was calculated to balance the patient characteristics of the two groups and therefore reduce the selection bias.²³ A logistic regression was used to estimate the propensity score for each patient after adjusting the confounding variables such as nationality, health insurance plan, the use of insulin and oral antidiabetic medications in the index month, and comorbidities during the pre-index period.

Matching between the two groups was implemented by a 1:1 ratio using a greedy matching method, which pairs each case patient with a unique comparison patient based on the closest propensity scores without replacement.²⁴ The patients in each group were stratified by age (four blocks) and sex (two blocks) in order to enhance the precision of the matching. Within each stratified block, patients with glycemic control were initiated to match on a 1:1 ratio with those without glycemic control on the basis of identical six-digit propensity scores, and continued until patients were matched with at least identical two-digit scores. If a patient with glycemic control had more than one match in the group without glycemic control, one of the patients without glycemic control was randomly selected. The mean c-statistic, which was calculated to ensure the ability of the propensity scores to effectively differentiate between the two groups, was 0.73 (range, 0.68–0.81).

To investigate the economic impact of glycemic control, diabetes-related costs were compared between the two groups. For the matched patients, the average annual diabetes-related cost per patient was calculated, and 95% confidence intervals (CIs) were obtained using the bootstrap method because they did not follow the normal distribution.²⁵ A paired *t*-test was used to detect statistically significant differences in diabetes-related costs between the two matched patients. Additionally, to examine the influence of age on diabetes-related costs between the two groups, the costs were compared by age groups (i.e., ≤ 44, 45–54, 55–64, or ≥ 65 years).

The likelihood of controlling glycemic level was calculated using multivariable logistic regression after adjusting for age, sex, nationality, region, health insurance plan, insulin use in the index month, use of antidiabetic medications, and comorbidities during the study period. A generalized linear model (GLM) with a log link function and gamma distribution was used to determine significant factors associated with diabetes-related costs.

Diabetes-related costs attributable to glycemic control were defined as the difference in predicted diabetes-related costs between

patients with glycemic control versus those without glycemic control, which were estimated using a recycled prediction method. First, the coefficients of the covariates (i.e., HbA1c control, age, sex, nationality, region, health insurance plan, insulin use in the index month, use of antidiabetic medications, and comorbidities during the study period) were calculated using GLM for diabetes-related costs in all matched patients. Once the coefficients were calculated, the diabetes-related costs for patients with glycemic control were predicted under the assumption that all matched patients had gly-

Table 1. Characteristics of diabetic patients before and after matching using propensity scores

Variable	Total	Before matching			After matching		
		HbA1c <7%	HbA1c ≥7%	<i>P</i>	HbA1c <7%	HbA1c ≥7%	<i>P</i>
Total	6,693 (100.0)	3,117 (100.0)	3,576 (100.0)	-	2,029 (100.0)	2,029 (100.0)	-
Age (yr)	48.9±11.5	49.8±11.4	48.1±11.6	<0.001	48.3±10.7	47.9±11.0	0.253
≤44	2,280 (34.1)	991 (31.8)	1,289 (36.0)	<0.001	735 (36.2)	735 (36.2)	1.000
45–54	2,465 (36.8)	1,169 (37.5)	1,296 (36.2)		768 (37.9)	768 (37.9)	
55–64	1,581 (23.6)	748 (24.0)	833 (23.3)		446 (22.0)	446 (22.0)	
≥65	367 (5.5)	209 (6.7)	158 (4.4)		80 (3.9)	80 (3.9)	
Sex				<0.001			1.000
Male	4,629 (69.2)	2,023 (64.9)	2,606 (72.9)		1,445 (71.2)	1,445 (71.2)	
Female	2,064 (30.8)	1,094 (35.1)	970 (27.1)		584 (28.8)	584 (28.8)	
Nationality				<0.001			0.968
National	1,168 (17.5)	659 (21.1)	509 (14.2)		303 (14.9)	298 (14.7)	
Expatriate	4,723 (70.6)	2,076 (66.6)	2,647 (74.0)		1,458 (71.9)	1,465 (72.2)	
NA	802 (12.0)	382 (12.3)	420 (11.7)		268 (13.2)	266 (13.1)	
Health insurance plan				<0.001			0.985
Basic	3,040 (45.4)	1,194 (38.3)	1,846 (51.6)		941 (46.4)	944 (46.5)	
Enhanced	2,395 (35.8)	1,216 (39.0)	1,179 (33.0)		772 (38.0)	773 (38.1)	
Thiqā	1,258 (18.8)	707 (22.7)	551 (15.4)		316 (15.6)	312 (15.4)	
Insulin at index month				<0.001			1.000
None	6,159 (92.0)	3,017 (96.8)	3,142 (87.9)		1,942 (95.7)	1,942 (95.7)	
Yes	534 (8.0)	100 (3.2)	434 (12.1)		87 (4.3)	87 (4.3)	
Use of antidiabetics*				<0.001			1.000
None	2,553 (38.1)	1,601 (51.4)	952 (26.6)		770 (37.9)	770 (37.9)	
Yes	4,140 (61.9)	1,516 (48.6)	2,624 (73.4)		1,259 (62.1)	1,259 (62.1)	
Comorbidity during pre-index period [†]							
Hypertension	1,314 (19.6)	922 (29.6)	392 (11.0)	0.019	264 (13.0)	264 (13.0)	1.000
Hyperlipidemia	1,419 (21.2)	1,051 (33.7)	368 (10.3)	0.003	274 (13.5)	273 (13.5)	0.963
Nephropathy	52 (0.8)	43 (1.4)	9 (0.3)	<0.001	4 (0.2)	1 (0.0)	0.179
Neuropathy	137 (2.0)	102 (3.3)	35 (1.0)	<0.001	11 (0.5)	11 (0.5)	1.000
Cardiovascular disease	201 (3.0)	148 (4.7)	53 (1.5)	<0.001	25 (1.2)	25 (1.2)	1.000
Cerebrovascular disease	57 (0.9)	41 (1.3)	16 (0.4)	<0.001	3 (0.1)	4 (0.2)	0.705
Obesity	194 (2.9)	144 (4.6)	50 (1.4)	<0.001	20 (1.0)	21 (1.0)	0.875
RA/OA	294 (4.4)	221 (7.1)	73 (2.0)	<0.001	37 (1.8)	39 (1.9)	0.817
Asthma/COPD	274 (4.1)	179 (5.7)	95 (2.7)	<0.001	39 (1.9)	38 (1.9)	0.908

Values are presented as number (%) or mean ± standard deviation.

*Use of antidiabetic medications during 1-year follow-up period; [†]Comorbidities detected during 6 months prior to index month (i.e., pre-index period). HbA1c, glycosylated hemoglobin; NA, not available; RA, rheumatoid arthritis; OA, osteoarthritis; COPD, chronic obstructive pulmonary disease.

glycemic control (i.e., dummy variable for HbA1c control was 0). Similarly, the costs for patients without glycemic control were predicted under the assumption that all matched patients did not have glycemic control (i.e., dummy variable for HbA1c control was 1). The differences between the two predicted costs were identified as the diabetes-related costs attributable to glycemic control in patients with diabetes.²⁶⁻²⁸

All costs were converted to 2015 UAE dirhams (AED) using the consumer price index and to US dollars using the exchange rate (USD 1 = AED 3.67). Data were analyzed using SAS ver. 9.2 (SAS Institute, Cary, NC, USA) and STATA ver. 10.1 (STATA Corp., College Station, TX, USA).

RESULTS

Table 1 presents characteristics of 6,693 identified patients. The mean age was 48.9 years, 69.2% of the patients were male, and the majority were expatriates (70.6%). In terms of medical condition, 61.9% of the patients were taking antidiabetic medications and 40.8% were also diagnosed with hypertension (19.6%) and/or hyperlipidemia (21.2%). Demographic and clinical characteristics of patients were significantly different between patients who controlled HbA1c (HbA1c <7%) and patients who did not control HbA1c (HbA1c ≥7%). The patients with controlled HbA1c during the follow-up period were older and more likely to be female, a

UAE national, a Thiqa insurance plan enrollee, and not use insulin during the index diagnosis month. Furthermore, 51.4% of the patients with controlled HbA1c did not take antidiabetic medications, compared with 26.6% of the patients with uncontrolled HbA1c. However, after matching these two groups using the propensity scores, differences in all characteristics of two group patients could not be found.

Annual total treatment costs in patients with controlled glycemic level were \$3,285, while total costs were \$3,315 in patients with uncontrolled glycemic level (Table 2). Of these total costs, the diabetes-related costs were \$2,282 and \$2,667 per year for patients with HbA1c <7% and HbA1c ≥7%, respectively. In both groups, two-thirds of the diabetes-related costs were medical costs, of which outpatient visits were the biggest component. In the analysis of the diabetes-related costs stratified by patients' age after matching (Fig. 1), the difference in diabetes-related costs between patients with and without glycemic control was smallest in the 45–54 year age group (\$2,088 vs. \$2,217), and the difference increased with age. In general, Table 3 presents that the diabetes-related costs attributable to poor glycemic control were estimated at \$172 (95% CI, \$164–180), which were defined as the difference in the costs between patients with HbA1c ≥7% and patients with HbA1c <7% after adjustment for differences in covariates between matched patient groups using the recycled prediction method.

Table 4 presents that factors influencing glycemic control and di-

Table 2. Annual total treatment costs and diabetes-related costs in matched patients with diabetes

Variable	HbA1c <7% (n=2,029)		HbA1c ≥7% (n=2,029)		P
	Mean	Bootstrap 95% CI	Mean	Bootstrap 95% CI	
Total treatment cost (\$)	3,285	3,082–3,488	3,315	3,105–3,524	0.808
Medical cost	2,314	2,149–2,479	2,278	2,100–2,457	0.739
Inpatient	333	258–407	408	286–530	0.311
Outpatient	1,946	1,812–2,081	1,826	1,718–1,933	0.078
Emergency visit	35	27–42	45	34–56	0.136
Prescription cost	971	904–1,038	1,036	972–1,100	0.096
Diabetes-related cost (\$)	2,282	2,142–2,421	2,667	2,479–2,855	<0.001
Medical cost	1,530	1,423–1,638	1,778	1,616–1,940	0.005
Inpatient	262	191–332	369	244–494	0.137
Outpatient	1,255	1,181–1,329	1,387	1,300–1,473	<0.001
Emergency visit	14	10–18	22	13–31	0.084
Prescription cost	751	701–802	890	836–944	<0.001

All costs were converted to 2015 AED using the Consumer Price Index and to US dollars using the exchange rate (\$1 = AED 3.67). HbA1c, glycosylated hemoglobin; CI, confidence interval; AED, United Arab Emirates dirhams.

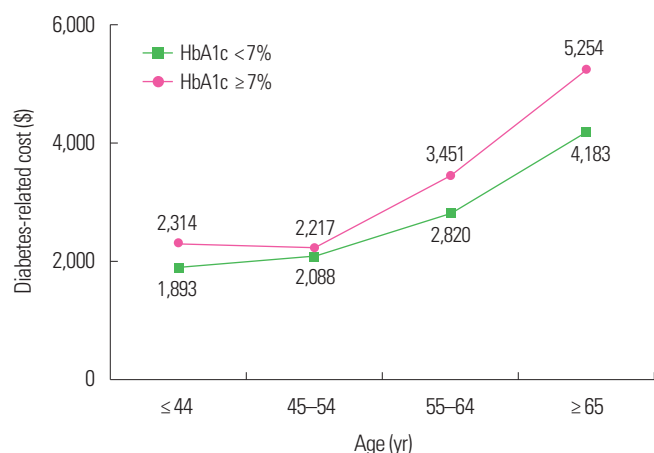


Figure 1. Diabetes-related costs by age in matched patients with diabetes. HbA1c, glycosylated hemoglobin.

Table 3. Diabetes-related treatment costs attributable to uncontrolled glycemic level

Variable	Mean (\$)	Bootstrap 95% CI
Costs attributable to uncontrolled HbA1c*	172	164–180
Predicted cost of patients with HbA1c <7%†	2,529	2,411–2,648
Predicted cost of patients with HbA1c ≥7%†	2,701	2,575–2,827

*Costs attributable to the uncontrolled HbA1c were the differences in the predicted costs between patients with controlled glycemic level (<7%) and patients with uncontrolled glycemic level; †Predicted costs were calculated using a generalized linear model with a log link function and gamma distribution. CI, confidence interval; HbA1c, glycosylated hemoglobin.

abetes related treatment costs after adjusting for the study variables respectively. After controlling for study variables, patients who were old age (age ≥ 65 years) are more likely to control their glucose level than those patient aged under 44 years (OR, 1.30; 95% CI, 1.01–1.67). In addition patients were more likely to control their glucose level during the follow-up period if they are female (OR, 1.21; 95% CI, 1.07–1.37). Patients enrolled in the Thiqa or Enhanced plan were 1.48 and 1.65 times more likely to have glycemic control than those patients who had basic insurance plan respectively. However, insulin users in the index diagnosis month (OR, 0.34; 95% CI, 0.27–0.43) and users of antidiabetic medications during the follow-up period (OR, 0.43; 95% CI, 0.38–0.47) were less likely to have glycemic control. In addition, the odds of glycemic control decreased significantly with hypoglycemia, retinopathy/macula edema, and neuropathy, but increased with RA/OA and asthma/COPD.

Table 4 also present cost ratios associated with diabetes treat-

Table 4. Factors associated with control of glycemic level and diabetes-related treatment costs

Variable	Control of HbA1c*		Diabetes-related treatment cost†	
	OR (95% CI)	P	Cost ratio (95% CI)	P
Control of HbA1c				
HbA1c ≥ 7% (uncontrolled)	-	-	1	-
HbA1c < 7% (controlled)	-	-	0.94 (0.88–0.99)	0.022
Age (yr)				
≤ 44	1	-	1	-
45–54	1.07 (0.95–1.22)	0.268	1.01 (0.94–1.08)	0.786
55–64	1.03 (0.89–1.19)	0.702	1.09 (1.01–1.18)	0.031
≥ 65	1.30 (1.01–1.67)	0.042	1.45 (1.25–1.70)	< 0.001
Sex				
Male	1	-	1	-
Female	1.21 (1.07–1.37)	0.003	1.05 (0.98–1.13)	0.139
Health insurance plan				
Basic	1	-	1	-
Enhanced	1.65 (1.45–1.88)	< 0.001	2.63 (2.45–2.82)	< 0.001
Thiqa	1.48 (1.03–2.12)	0.036	4.58 (3.59–5.83)	< 0.001
Insulin at index month				
No	1	-	1	-
Yes	0.34 (0.27–0.43)	< 0.001	1.61 (1.40–1.86)	< 0.001
Use of antidiabetic medications				
No	1	-	1	-
Yes	0.43 (0.38–0.47)	< 0.001	1.65 (1.55–1.75)	< 0.001
Comorbidity during study period				
Hypertension	0.99 (0.88–1.11)	0.802	1.20 (1.13–1.28)	< 0.001
Hyperlipidemia	1.21 (0.96–1.51)	0.101	1.11 (0.99–1.25)	0.086
Hypoglycemia	0.71 (0.55–0.93)	0.013	1.44 (1.24–1.66)	< 0.001
Retinopathy/macular edema	0.60 (0.49–0.74)	< 0.001	1.63 (1.47–1.82)	< 0.001
Nephropathy	1.09 (0.88–1.35)	0.416	1.37 (1.22–1.55)	< 0.001
Neuropathy	0.73 (0.65–0.81)	< 0.001	1.28 (1.20–1.36)	< 0.001
Cardiovascular disease	1.01 (0.86–1.18)	0.942	2.04 (1.85–2.25)	< 0.001
Cerebrovascular disease	0.98 (0.79–1.23)	0.875	1.90 (1.66–2.18)	< 0.001
Obesity	1.16 (0.98–1.36)	0.080	1.30 (1.19–1.43)	< 0.001
RA/OA	1.66 (1.42–1.96)	< 0.001	1.05 (0.96–1.16)	0.310
Asthma/COPD	1.19 (1.01–1.41)	0.039	1.06 (0.96–1.17)	0.270

*ORs of controlling of HbA1c level were estimated using logistic regression after adjusting for the study variables; †Diabetes-related costs were estimated using a generalized linear model with a log link function and gamma distribution.

HbA1c, glycosylated hemoglobin; OR, odds ratio; CI, confidence interval; RA, rheumatoid arthritis; OA, osteoarthritis; COPD, chronic obstructive pulmonary disease.

ment after adjusting for the study variables. Diabetes-related treatment costs in patients with controlled glycemic level (HbA1c < 7%) were 6% lower than those of patients with uncontrolled gly-

cemic level (HbA1c $\geq 7\%$; cost ratio, 0.94; 95% CI, 0.88–0.99). Compared with those aged ≤ 44 years, diabetes-related costs were significantly higher in patients aged ≥ 65 years (cost ratio, 1.45; 95% CI, 1.25–1.70) and in patients aged 55–64 years (cost ratio, 1.09; 95% CI, 1.01–1.18). Patients with the Enhanced or Thiqa insurance plan had significantly higher diabetes-related treatment costs (cost ratio, 2.63 and 4.58, respectively). The treatment costs for patients who used insulin in the index diagnosis month were 1.61 times higher than for those who did not. In addition, the treatment cost in patients with the use of antidiabetic medications was 1.65 times higher than those without these medications. Patients with hypertension, hypoglycemia, retinopathy/macular edema, nephropathy, neuropathy, cardiovascular disease, cerebrovascular disease, and obesity had significantly higher diabetes-related costs than those without.

DISCUSSION

In our analysis, 46.6% of patients with diabetes residing in Abu Dhabi, UAE achieved the HbA1c goal of $< 7\%$ during the 1-year follow-up period, which is higher than previous observations in other populations: 33.3% in the Al Ain Emirate of the UAE¹³, 34.9% in Jordan²⁹, 31% in the United Kingdom (HbA1c $\leq 7.5\%$)⁹, and 29% of patients with diabetes receiving medical treatment in a managed care setting in the United States.³⁰ In the present study, the higher rate of glycemic control in Abu Dhabi is primarily explained by the selection of patients with diabetes in the first year of their disease.

Several patient characteristics influenced glycemic control. Similar to previous studies that showed that younger age was associated with worse glycemic control in diabetes^{7,8,19,31}, patients aged ≥ 65 years were 30% more likely to have good glycemic control than patients < 44 years old. This might be due in part to higher HbA1c levels in early onset diabetes patients compared with late onset patients.³² Second, older adult patients with T2DM might have improved adherence to oral antidiabetic medications.³³ A 10% increase in adherence to oral antidiabetic medications was associated with a 0.1% decrease in HbA1c, when controlled for baseline HbA1c and therapy regimen.³³ In our analysis, female patients with diabetes had better glycemic control, which was consistent with a study

conducted in the United States⁸ but not with studies conducted in Finland and Saudi Arabia.^{34,35} Thus, sex-related cultural differences might also affect glycemic control.

Socioeconomic situation might also influence the patients' ability to regulate glycemic levels. The Enhanced and Thiqa insurance plans, which represent the best health insurance coverage in UAE, were significantly associated with better glycemic control than the Basic plan. Similarly, the prevalence of poor glycemic control was highest among the uninsured in the United States¹⁹, including higher HbA1c levels in the uninsured in a low-income, multiethnic population with T2DM in the San Diego County.⁷ Also, the type of insurance coverage was a risk factor for sustained poor glycemic control in patients with type 1 diabetes in Hawaii.³¹

Clinical characteristics that affected glycemic control included the use of insulin and oral antidiabetic medications. Insulin use in the index diagnosis month and use of antidiabetic medications during the follow-up period were inversely associated with glycemic control, independent of the covariates. Patients with T2DM who require insulin, alone or in combination with oral antidiabetic medications, consistently have higher HbA1c values than those taking no medication or oral medications only.^{7,9,29} Compared with the use of only oral antidiabetic agents, the odds of poor glycemic control were four times higher with insulin alone and 7.5 times higher with combined oral antidiabetic agents and insulin.²⁹ Furthermore, sustained poor glycemic control was observed in patients with diabetes taking more medication of any kind.³¹ Insulin use could represent disease severity to some extent. Diabetes duration could also be used to indicate disease severity, and there is considerable evidence indicating that longer diabetes durations are related with poor glycemic control.^{7,29,31,36} However, owing to the short follow-up period, the relationships between the onset of diabetes, diabetes duration, and glycemic control could not be examined in our analysis. Comorbidities that are diabetes-related complications, such as retinopathy/macular edema and neuropathy, could also reflect disease severity and negatively affect glycemic control, while comorbidities that are not related with diabetes could reflect increased adherence to antidiabetic medications³³, thereby improving glycemic control. In the present study, comorbidities were significantly associated with glycemic control; the differing relationship directions might reflect the different influences of diabetes-related

and non-diabetes-related comorbidities.

A mean HbA1c <7% during the follow-up period was associated with 25% lower diabetes-related costs, which supports previous research reporting significant relationships between uncontrolled HbA1c and increased health care costs in patients with T2DM.^{20,21,37} In a large managed care setting in the United States, the estimated total diabetes-related cost during the 1-year follow-up period was \$1,594 per patient with T2DM and HbA1c >7%, which was 32% higher than the costs for those achieving the glycemic target.³⁷ In our analysis, a patient with HbA1c <7% incurred 32% less prescription drug costs and 22% less medical costs related to diabetes than a patient with HbA1c ≥7%. Similarly, a patient with T2DM and HbA1c ≤7% incurred 20% less direct medical costs attributable to diabetes and 11% less antidiabetic prescription drugs costs annually than a patient with HbA1c >9% in a US-based study.²¹ The impact of glycemic control on costs may be a result of medication adherence. Previous research showed that good adherence to insulin in patients with insulin-dependent diabetes was associated with reduced hospital admissions for diabetic ketoacidosis and all hospital admissions related to acute diabetes complications in patients with insulin-dependent diabetes.³⁸

Diabetes-related costs were higher in elderly patients (≥65 years) and those of UAE nationality as well as with better health insurance coverage and the use of insulin and antidiabetic medications in the index diagnosis month. The positive association between patient's age and diabetes-related costs was previously observed in the UAE and other countries.^{15,20} The association between insurance coverage and costs in patients with diabetes was also noted in the United States²¹; compared with only Medicare insurance, additional commercial health insurance was associated with higher diabetes-related medical and prescription drug costs. In the UAE, the direct medical costs of diabetes and its complications increase with diabetes duration and the use of insulin.¹⁵ Moreover, Brandle et al.³⁹ estimated that a patient with T2DM treated with oral antidiabetic medications or insulin had 1.10 or 1.59 times, respectively, the direct medical costs of a patient with diet-controlled diabetes. In addition, most comorbidities in the present study increased diabetes-related costs, which was consistent with previous research^{20,39} that reported increased health care costs with the presence of hypertension, dyslipidemia, cardiovascular disease²⁰, dia-

betic kidney disease, cerebrovascular disease, or peripheral vascular disease.

To our knowledge, this study is the first to examine factors associated with glycemic control and diabetes-related costs in the UAE using administrative healthcare claims data. There are several strengths of this analysis, including data from patient claims records, large sample size, and representativeness of the UAE patient population with different access to health care. Nonetheless, the findings of this study should be interpreted with caution owing to certain limitations. First, this study could not examine several factors known to be associated with glycemic control and diabetes-related costs, such as compliance to medications²⁹, obesity indices including body mass index and waist circumference³⁶, patient's attitudes toward²⁹, self-care behaviors such as glucose monitoring²⁹ and lifestyle (diet, exercise, smoking, drinking)^{29,36} because the information was not available in the data set. Second, we could consider the time from the initial diagnosis of diabetes, which can influence the response to antidiabetic medication, level of glycemic control, onset of complications, and diabetes-related costs. Instead, we attempted to include only new patients with diabetes; however, the length of the pre-index period (6 months) may be too short to exclude patients with a previous diagnosis of diabetes. Third, this study may be subject to misclassification bias in the claims database. Also, the cost analysis was based on diagnostic codes of diabetes and the use of antidiabetic drugs. This may have resulted in underestimation of total costs associated with diabetes. Further studies using large datasets and longer follow-up periods are needed to determine causality and control for important confounders such as diabetes severity.

In the capital of the UAE (Abu Dhabi), 46.6% of patients with mild diabetes were able to maintain their HbA1c level below the recommended 7% over the first year of the disease. Diabetes-related costs were higher in patients with poorly controlled diabetes, which significantly increased with age. Glycemic control was associated with lower costs in patients enrolled in the Enhanced or Thiqa insurance plan. However, diabetes-related costs were higher for the patients enrolled in these plans, compared with the Basic plan, suggesting that financial situation might limit the ability to delay disease progression. Thus, it may be advantageous to improve the coverage of the Basic plan at an affordable cost for low-income

patients to reduce the future expenses associated with the treatment of severe disease complications.

CONFLICTS OF INTEREST

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