Medical Expenditures Associated With Diabetes Acute Complications in Privately Insured U.S. Youth

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OBJECTIVE — To estimate medical expenditures attributable to diabetes ketoacidosis (DKA) and severe hypoglycemia among privately insured insulin-treated U.S. youth with diabetes.

RESEARCH DESIGN AND METHODS — We analyzed the insurance claims of 7,556 youth, age ≤19 years, with insulin-treated diabetes. The youth were continuously enrolled in fee-for-service health plans, and claims were obtained from the 2007 U.S. MarketScan Commercial Claims and Encounter database. We used regression models to estimate total medical expenditures and their subcomponents: outpatient, inpatient, and drug expenditures. The excess expenditures associated with DKA and severe hypoglycemia were estimated as the difference between predicted medical expenditures for youth who did/did not experience either DKA or severe hypoglycemia.

RESULTS — For youth with and without DKA, respectively, predicted mean annual total medical expenditures were $14,236 and $8,398 (an excess of $5,837 for those with DKA). The excess was statistically greater for those with one or more episodes of DKA ($8,455) than among those with only one episode ($3,554). Predicted mean annual total medical expenditures were $12,850 and $8,970 for youth with and without severe hypoglycemia, respectively (an excess of $3,880 for those with severe hypoglycemia). The excess was greater among those with one or more episodes ($5,929) than among those with only one ($2,888).

CONCLUSIONS — Medical expenditures for potentially preventable DKA and severe hypoglycemia in U.S. youth with insulin-treated diabetes are substantial. Improving the quality of care for these youth to prevent the development of these two complications could avert substantial U.S. health care expenditures.

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Diabetes ketoacidosis (DKA) and severe hypoglycemia are two common acute diabetes complications in youth. DKA, which results from absolute or relative insulin deficiency, can be the initial clinical presentation of both type 1 and type 2 diabetes or can occur in those with an established diabetes diagnosis. Severe hypoglycemia is a serious side effect of insulin treatment, especially for children and adolescents with type 1 diabetes. Despite substantial progress in diabetes management and care over the last 20 years (1), incidence and prevalence of these potentially preventable complications remain high (2,5). In 2006, among people in the U.S. with diabetes aged 0–17 years, 64% of the first-listed hospital discharge diagnoses included DKA (http://www.cdc.gov/diabetes/statistics/hosp/kidtable1.htm, accessed on 26 April 2010). An estimated 15–29% of youth with diabetes had DKA at the onset of diabetes (4–7). Among those aged <19 years with established type 1 diabetes, the overall incidence of DKA and severe hypoglycemia was estimated to be 8 and 19 per 100 patient-years, respectively (2).

In addition to the risk for premature death and lower quality of life associated with these conditions, both DKA and severe hypoglycemia impose large economic burdens on the health care system (2,3,8,9). Medical expenses attributed to DKA and severe hypoglycemia have been estimated in diabetic adults (9–13), but similar estimates are not available for U.S. youth (age <20 years). We are aware of no studies that examine excess medical expenditures in youth experiencing recurrent DKA or severe hypoglycemia episodes.

To evaluate the economic efficiency of programs aimed at improving quality of care and to establish health care policies for youth with diabetes, estimates of excess medical expenditures associated with these acute complications are needed. Thus, our study's objectives were to *1*) estimate the excess medical expenditures associated with DKA and severe hypoglycemia among youth with insulin-treated diabetes (ITDM) and *2*) to examine the extent to which the excess expenditures are associated with the number of episodes of these complications.

RESEARCH DESIGN AND METHODS

Data source

We used the 2007 MarketScan Commercial Claims and Encounters (CCE) Database (MarketScan Database; Thompson Medstat, Ann Arbor, MI). This database, which has been used extensively in studies of health care costs, including studies of diabetes costs (12,14–16), contains fully adjudicated and paid claims for several million people with employer-sponsored health plans, including employees, spouses, and dependents (17). The CCE database includes patient-level data on inpatient, outpatient, and drug claims that can be linked using encrypted enrollee information. Types of health plans from which enrollees obtain services can be divided into fee-for-service (FFS) plans and fully or partially capitated plans. FFS plans include preferred provider organization (PPO) plans, exclusive provider organization plans,

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point-of-service (POS) plans, consumer-directed health plans, and indemnity plans. Fully or partially capitated plans include HMO plans and capitated POS plans (18). Cost estimation for those enrolled in FFS health plans is straightforward, because claims represent the payments for each service. For those enrolled in capitated plans, payment records often reflect encounter status and not the actual payment (18). Therefore, we limited our analysis to youth in FFS plans. All expenses are in 2007 U.S. dollars.

Study population

Our study population consisted of U.S. youth who had health care service and prescription drug coverage through an FFS plan between 1 January and 30 December 2007.

Identification of youth with DKA and severe hypoglycemia

Youth with DKA and severe hypoglycemia were identified in three steps. First, following criteria used in a previous study (19), enrollees were identified as having diabetes if during calendar year 2007 they had at least one claim for diabetes-related drugs and supplies and at least two outpatient encounters ≥30 days apart in which diabetes was a primary or secondary diagnosis or at least one inpatient admission with diabetes as a primary or secondary diagnosis. The requirement of at least two outpatient encounters excludes those who were misdiagnosed at the first encounter but later determined not to have diabetes (16). We used the ICD-9-CM codes 250.00–250.93, 357.2, 362.0–362.02, and 366.41 (18) as diabetes indicators in the outpatient and inpatient claims. In the second step, youth with DM were identified to have ITDM if they had at least one drug claim for insulin as indicated by therapeutic class code 172. Last, youth with ITDM were identified to have DKA if they had any claims coded with ICD-9-CM code 250.1 (2) and with severe hypoglycemia if they had any claims coded with ICD-9-CM codes 251.0, 251.1, 251.2, or 250.8 (12).

To determine the extent to which the number of episodes of DKA or severe hypoglycemia was associated with excess expenditures, we dichotomized youth with these complications into those having one episode and those having more than one episode. We considered an individual to have had one episode of DKA if they received one service with a DKA code during the study period and to have had more than one episode if they had received at least two such services at least 30 days apart. We used the same approach to determine the number of severe hypoglycemia episodes.

Complete records were available for 7,724 youth with ITDM. We excluded 39 with missing census region or urbanity of residence (urban versus rural). We also excluded 129 people with uncommon chronic conditions (congenital heart failure, hemiplegia, lymphoma, Down's syndrome, autism, leukemia, liver diseases, and congenital heart defects). We could not consider these conditions because the number of youth experiencing each condition was very small (e.g., ≤10 among DKA or severe hypoglycemia youth). Thus, our final analytic database had 7,556 youth. Because of its relative high prevalence and possible interaction with diabetes expenditures, we did not exclude 309 (4.1%) youth with asthma.

Statistical analyses

We used Stata version 10.1 (Stata, College Station, TX) for all analyses. We estimated four expenditure models (outpatient, inpatient, drug, and total). The presence or absence of DKA or severe hypoglycemia were modeled using two indicator variables in each of the four models. Covariates included age, sex, census region (midwest, south, west, and northeast), residence urbanity, health benefit plan type (PPO versus non-PPO), and presence of asthma. We also estimated models including the DKA/severe hypoglycemia interaction term.

We compared the unadjusted means of the characteristics of youth by their DKA or severe hypoglycemia status with Student *t* tests. We used a generalized linear model with log link and gamma distribution to model total, outpatient, and drug expenditures because all youth had positive expenditures and expenditures were highly skewed and right tailed (20). We used a two-part model to model inpatient expenditures to account for those with no inpatient expenditures (21,22). In the first part of the two-part model, we used logistic regression to estimate the probability that someone would have had any inpatient expenditures, and, in the second part, we used a generalized linear model with log link and gamma distribution to estimate the inpatient expenditures for those who had such expenditures.

We calculated model-based predicted marginal medical expenditures by DKA status. In this approach, predictions were made for all observations assuming no DKA status for all observations and then again assuming DKA. All other variables remained at their original values. The predicted excess expenditure associated with DKA was calculated as the difference between the predicted expenditures for youth with and without DKA. We used the same approach to estimate mean medical expenditures for youth by severe hypoglycemia status and predicted excess expenditure associated with severe hypoglycemia. We used 100 nonparametric bootstrap replications to calculate the estimates' standard errors. We considered results significant if $P < 0.05$.

RESULTS — Of 7,556 youth with ITDM, 1,126 (14.9%) experienced at least one DKA episode. Of those, 600 (53.3%) experienced one episode and 526 (46.7%) experienced more than one (mean 2.6). Of all youth with ITDM, 595 (7.9%) experienced at least one severe hypoglycemic episode. Of those, 400 (67.2%) had one episode and 195 (32.8%) had more than one (mean 3.5).

The study population characteristics by DKA or severe hypoglycemia status appear in Table 1. The mean age was 13 years, and those who experienced DKA were significantly younger than those who did not ($P < 0.05$). The proportion of girls was significantly greater among those with DKA or severe hypoglycemia than among those with neither ($P < 0.05$). Those with DKA were more likely to reside in the south but less likely to reside in the midwest region; those with severe hypoglycemia were less likely to reside in the west ($P < 0.05$). About four-fifths of the youth, regardless of DKA or severe hypoglycemia status, lived in urban areas. Asthma was significantly more prevalent among youth who had DKA or severe hypoglycemia than among those with neither ($P < 0.05$).

Unadjusted mean medical expenditures

Unadjusted total mean medical expenditures were $6,191 more for youth with at least one DKA episode than for those with none and $5,151 more for those with at least one severe hypoglycemia episode than for those with none ($P < 0.05$) (Table 2). Except for drug expenditures by severe hypoglycemia status, the unadjusted means for all expenditure categories were also significantly greater among youth with DKA

Table 1—*Characteristics of the study sample by DKA and severe hypoglycemia status (n = 7,556)*

Characteristics	DKA (n = 1,126)	No DKA (n = 6,430)	Severe hypoglycemia (n = 595)	No severe hypoglycemia (n = 6,961)
Mean age (years)	**12.05** ± 0.13	**12.81** ± 0.05	12.92 ± 0.19	12.68 ± 0.05
Sex (% female)	**51.42** ± 1.49	**47.01** ± 0.62	**51.76** ± 2.05	**47.32** ± 0.60
Census regions				
Midwest (%)	**26.38** ± 1.31	**31.48** ± 0.58	31.76 ± 1.91	30.63 ± 0.55
South (%)	**50.53** ± 1.49	**41.43** ± 0.61	44.20 ± 2.04	42.67 ± 0.59
West (%)	**13.77** ± 1.03	**17.22** ± 0.47	**13.11** ± 1.38	**17.01** ± 0.45
Urbanity of residence				
(% urban)	81.17 ± 1.17	80.26 ± 0.50	**77.14** ± 1.72	**80.68** ± 0.47
Type of health plan				
(% non-PPO)	23.53 ± 1.26	24.79 ± 0.54	23.19 ± 1.73	24.72 ± 0.52
Asthma (%)	**6.04** ± 0.71	**3.75** ± 0.24	**5.88** ± 0.97	**3.94** ± 0.23

Data are means ± SE. Differences significant at $\alpha = 0.05$ by DKA or severe hypoglycemia status are shown in bold.

or severe hypoglycemia than among those without ($P < 0.05$). A total of 83% of the youth in our sample had zero inpatient expenditures (Table 2).

Factors associated with medical expenditures

Total medical expenditures were significantly less among youth residing in the midwest and south than in those residing in the northeast ($P < 0.05$) (Table 3). Expenditures were significantly greater among youth with asthma, DKA, or severe hypoglycemia compared with their counterparts ($P < 0.05$). Outpatient expenditure was greater among girls than among boys ($P < 0.05$). Those in the south and west had significantly lower outpatient expenditures than those in the northeast ($P < 0.05$). Outpatient expenditures were significantly greater among youth with asthma, DKA, or severe hypoglycemia than among their counterparts ($P < 0.05$). The probability of having inpatient expenditures decreased with age; however, the expenditure increased with age ($P < 0.05$). Those residing in the midwest and south were significantly less likely to be admitted to the hospital than those in the northeast ($P < 0.05$). Both probability of having inpatient expenditure and expenditures were greater among youth with asthma than those without and greater among those with at least one severe hypoglycemia episode than among those with none ($P < 0.05$). Those with DKA were significantly more likely than those without to be admitted to the hospital ($P < 0.05$). Prescription drug expenditures decreased with age and were greater among boys than among girls ($P < 0.05$). Residents of other regions had significantly less prescription drug expenditures than northeastern residents ($P < 0.05$). Prescription drugs expenditures were greater in urban areas than in rural areas, greater among youth with asthma than those without, and greater among those with at least one severe hypoglycemia episode than among those with none but significantly lower among those with DKA than those without DKA ($P < 0.05$). The terms for the DKA/severe hypoglycemia interaction were not significant and therefore excluded in all the analyses.

Table 2—*Per capita unadjusted mean annual medical expenditures (U.S. $) in 2007 for U.S. youth with ITDM, by DKA and severe hypoglycemia status*

Complication status	Expenditures (in U.S. $)			
	Total	Outpatient	Inpatient	Drug
DKA				
DKA	14,562 ± 328	5,021 ± 153	6,387 ± 250	3,154 ± 57
No DKA	8,370 ± 153	3,797 ± 63	871 ± 105	3,703 ± 50
Excess DKA	6,191 ± 391*	1,224 ± 164*	5,515 ± 272*	−548 ± 123*
Severe hypoglycemia				
Severe hypoglycemia	14,040 ± 833	5,894 ± 269	4,295 ± 638	3,851 ± 163
No severe hypoglycemia	8,887 ± 135	3,815 ± 59	1,471 ± 93	3,601 ± 45
Excess severe hypoglycemia	5,153 ± 523*	2,079 ± 217*	2,824 ± 368*	250 ± 163
Youth with zero expenses (%)	0.0	0.0	83.2	0.0

Data are means ± SE. *$P < 0.05$.

Medical expenditures associated with DKA

The predicted mean total medical expenditure was $8,398 for youth with no DKA episodes and $5,837 more for those who had at least one ($P < 0.05$). Mean outpatient and inpatient expenditures were significantly greater among youth who had at least one DKA episode ($P < 0.05$) (Table 4). Inpatient expenditures accounted for slightly >40% of the total medical expenditures incurred by youth who had DKA, but excess inpatient expenditures were >90% of the excess expenditure attributable to DKA. In contrast, mean prescription drug costs were lower among youth who had DKA than those who did not ($P < 0.05$). The mean excess total medical expenditure for youth who had one episode of DKA was $3,554, which was about half than that of youth who had more than one ($8,455). Excess inpatient expenditures accounted for >90% of the excess medical expenditures associated with both one and more than one episode of DKA. The mean annual total medical expenditure for those who had DKA was 1.7 times greater than for those without and was even greater for those with multiple DKA episodes.

Medical expenditures associated with severe hypoglycemia

The predicted mean total medical expenditure was $8,970 for ITDM youth who had no severe hypoglycemia and $3,880 more for those who had at least one severe hypoglycemia ($P < 0.05$) (Table 4). Compared with youth who had no severe hypoglycemia episodes, the mean excess total medical expenditure was $2,888 among those who had one episode and $5,929 among those who had more than one episode. Excess outpatient expenditures accounted for 46.7% of the total excess expenditures associated with severe hypoglycemia. The mean annual total medical expenditure for youth who experienced at least one severe hypoglycemia episode was 1.4 times greater than for

Table 3—*Parameter estimates for medical expenditure models for youth in the U.S., 2007*

Parameters	Total#	Outpatient#	Inpatient† (first part)	Inpatient (second part)#	Drug#
Constant	9.04 ± 0.07*	8.26 ± 0.07*	−1.52 ± 0.18*	8.66 ± 0.16*	8.34 ± 0.04*
Mean age (years)	−0.003 ± 0.003	−0.01 ± 0.004	−0.06 ± 0.01*	0.03 ± 0.01*	−0.005 ± 0.002*
Sex: Girl (= 1)	0.04 ± 0.03	0.10 ± 0.03*	−0.04 ± 0.08	0.14 ± 0.08	−0.05 ± 0.02*
Census regions					
Midwest (= 1)	−0.09 ± 0.04*	0.02 ± 0.05	−0.26 ± 0.14*	−0.03 ± 0.10	−0.16 ± 0.03*
South (= 1)	−0.14 ± 0.05*	−0.13 ± 0.05*	−0.28 ± 0.13*	0.04 ± 0.12	−0.16 ± 0.03*
West (= 1)	−0.08 ± 0.06	−0.12 ± 0.06*	−0.06 ± 0.15	0.06 ± 0.15	−0.09 ± 0.04*
Health plan					
Non-PPO (= 1)	0.06 ± 0.04	0.03 ± 0.03	0.13 ± 0.09	0.13 ± 0.13	0.01 ± 0.02
Urbanity of residence					
Urban (= 1)	0.05 ± 0.03	−0.01 ± 0.03	−0.08 ± 0.09	−0.003 ± 0.08	0.09 ± 0.02*
Asthma (= 1)	0.49 ± 0.09*	0.43 ± 0.10*	0.55 ± 0.17*	0.39 ± 0.15*	0.30 ± 0.07*
DKA (= 1)	0.53 ± 0.03*	0.25 ± 0.03*	3.17 ± 0.08*	−0.10 ± 0.10	−0.17 ± 0.02*
Severe hypoglycemia (= 1)	0.36 ± 0.05*	0.39 ± 0.05*	0.72 ± 0.12*	0.33 ± 0.10*	0.08 ± 0.04*
−Log likelihood	76,328	70,036	2,443	12,939	69,426
Likelihood ratio χ^2			1,960		

Data are coefficients ± SE. *$P < 0.05$. Boys, northeast region, rural residence, PPO health plan, and without asthma are treated as references. #Estimated using generalized linear model with log link and gamma distribution. †Estimated using logistic regression model.

those without severe hypoglycemia episodes.

CONCLUSIONS — Our study showed that the excess medical expenditures associated with DKA and severe hypoglycemia were substantial among U.S. youth with ITDM. However, both DKA and severe hypoglycemia can be prevented or incidences reduced. Posters in school and family pediatricians' office settings and providing guidelines for testing type 1 diabetes to pediatricians reduced the incidence of DKA at diabetes diagnosis (23). Behavioral therapy and parent trainings have reduced postdiagnostic DKA hospital admissions (24). Thus, preventing DKA or severe hypoglycemia by delivering appropriate and timely prevention and patient care programs could avert substantial healthcare expenditures.

We found that excess inpatient expenditures attributed to DKA accounted for >90% of the total excess medical expenditures attributed to DKA. Thus, DKA was treated primarily in hospital settings. In comparison, total excess expenditures associated with severe hypoglycemia were fairly evenly divided between excess inpatient and outpatient expenditures (46.7 and 42.4%, respectively), indicating that severe hypoglycemia was treated on both an out- and inpatient basis. Differences in treatment settings likely reflect differences in the complications' nature and complexity.

Although more health care resources were spent to care for youth who had more than one episode of DKA or severe hypoglycemia than for those who had one episode, the average excess expenditure per episode of DKA or severe hypoglycemia was higher among youth who had only one episode. This higher cost is likely attributed to expenditures associated with the initial diagnosis.

One somewhat unexpected finding was that expenditures for prescription drugs were less among youth who experienced DKA than among those who did not. One plausible explanation is that diabetic youth who use an inadequate quantity of insulin might be at higher risk of DKA. Alternately, DKA episodes among youth with ITDM might have occurred at diabetes onset when they were still

Table 4—*Predicted mean annual medical expenditures (U.S. $) in 2007 for U.S. youth with ITDM, by DKA and severe hypoglycemia status*

Complication status	Total	Components		
		Outpatient	Inpatient	Drug
DKA				
DKA	14,236 ± 322	4,886 ± 148	6,228 ± 214	3,135 ± 56
No DKA	8,398 ± 139	3,815 ± 62	852 ± 90	3,707 ± 53
Excess DKA	5,837 ± 353	1,071 ± 161	5,376 ± 233	−572 ± 75
Excess DKA (by number of episodes)				
1 episode	3,554 ± 360	793 ± 211	3,354 ± 255	−504 ± 92
>1 episode	8,455 ± 529	1,388 ± 228	7,694 ± 390	−650 ± 87
Severe hypoglycemia				
Severe hypoglycemia	12,850 ± 127	5,644 ± 266	3,166 ± 452	3,896 ± 151
No severe hypoglycemia	8,970 ± 642	3,831 ± 59	1,522 ± 96	3,598 ± 38
Excess severe hypoglycemia	3,880 ± 649	1,813 ± 264	1,644 ± 421	298 ± 157
Excess severe hypoglycemia (by number of episodes)				
1 episode	2,888 ± 707	1,488 ± 265	1,067 ± 372	220 ± 194
>1 episode	5,929 ± 1,369	2,478 ± 522	3,035 ± 963	458 ± 243

Data are means ± bootstrap SEs with 100 replications. Excess = the difference between mean medical expenditures for youth with complications and those for youth with no complications. Covariates included in the model are age, sex, census regions, urbanity of residence, health plan, and asthma. The amount of all the excess expenditures was statistically significant ($P < 0.05$).

secreting some endogenous insulin and thus required less exogenous insulin. Data limitations prevented us from differentiating DKA episodes occurring at the onset of diabetes from those among people with an established diabetes diagnosis.

Our estimate of mean total medical expenditure associated with DKA ($5,837) was less than half than that reported for adults ($13,046 [2007 dollars]) with type 1 diabetes (11). The higher medical expenditures for adult diabetic patients with DKA could be attributed to disease severity. For instance, the mean length of hospital stay among DKA patients in our youth sample was 1.6 days, about one-fourth of adult hospital stays (6.6 days) (9). The presence of other comorbidities, such as cardiovascular diseases and chronic diabetes complications among adults, could contribute to the severity of DKA in adults.

Our $ 3,880 estimate of excess annual expenditures associated with severe hypoglycemia was slightly lower than an estimate of excess annual expenditures associated with severe hypoglycemia among insured employees with FFS and capitated health plans in 1999–2000 ($4,355 [2007 dollars]) (12) and a corresponding estimate among patients under managed care health plans in southern U.S. states in 2002 ($4,319 [2007 dollars]) (13). The higher medical expenditure associated with severe hypoglycemia among adults could be associated with the severity of disease and chronic diabetes complications.

Our study is subject to several limitations. Our population was a convenience sample of youth with insurance coverage through large employer-sponsored health care programs. Those in our study were likely to have a better access to health care than those uninsured or covered under Medicaid. Thus, our expenditure estimates may not be applicable to all U.S. youth with ITDM. Our estimates pertain to youth enrolled in FFS plans without uncommon chronic conditions. In sensitivity analyses that included these conditions, medical expenditures associated with DKA or severe hypoglycemia changed significantly (results not reported). Therefore, our results cannot be extrapolated to this group of patients. In addition, our estimates do not reflect medical expenditures for youth insured under capitated plans. Finally, because we restricted our analysis to medical expenditures from administrative claims data, we did not capture the total cost of DKA or severe hypoglycemia, including the cost of medical care not paid for by health insurance plans, other out-of-pocket costs, the cost of care provided by family members and by schools, and human capital losses.

To the best of our knowledge, this was the first study of medical expenditures associated with acute diabetes complications among a large sample of privately insured U.S. youth with ITDM. The medical expenditures associated with treating both DKA and severe hypoglycemia were substantial. Our estimates may be useful in evaluating the economics of pre- and postdiagnostic diabetes interventions that reduce DKA and severe hypoglycemia in U.S. youth.

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