# Economic Impact of Diabetic Ketoacidosis in a Multiethnic Indigent Population

## Analysis of costs based on the precipitating cause

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**OBJECTIVE** — Diabetic ketoacidosis (DKA) is a common complication of diabetes. We analyzed the inpatient costs of treating DKA in a multiethnic, indigent population in Houston, Texas.

**RESEARCH DESIGN AND METHODS** — We measured the cost of resources utilized for all patients admitted to our hospital with DKA from 1 January to 31 December 1998. We also analyzed their medical records to determine the factors that precipitated the episode of DKA and then grouped them into three categories: acute illnesses, noncompliance with diabetes treatment, and new-onset diabetes. The data were analyzed by one-way ANOVA. The Tukey-Kramer procedure was used for post hoc multiple comparisons.

**RESULTS** — There were 167 admissions for DKA. The mean age was 40 ± 13 years. The ethnic distribution was 49% African American, 32% Hispanic American, and 18% white. The total inhospital cost of treating DKA was $1,816,255. The mean cost per hospitalization was $10, 876 ± 11,024. The frequency distribution by category of DKA-precipitating factor was 18% acute illness, 59% noncompliance, and 23% new onset. There were differences in mean cost of DKA associated with the three categories: $20,864 ± 17,910 for acute illness, $11,863 ± 8,701 for new onset, and $7,470 ± 6,300 for noncompliance ($P < 0.0001$). The total cost for each category was $671,375 for acute illness, $694,082 for noncompliance, and $450,798 for new onset.

**CONCLUSIONS** — DKA is an expensive complication among indigent, multiethnic diabetic patients. Although the mean cost per admission was lowest for DKA precipitated by noncompliance, this causal category was responsible in sum for the greatest portion of the economic burden.

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Diabetic ketoacidosis (DKA) is a common and serious acute metabolic complication that affects patients with diabetes. In 1994, DKA was listed as the primary diagnosis for 89,000 hospital admissions and as an additional diagnosis for 113,000 admissions. It was the underlying cause of death in1,701 patients with an age-adjusted mortality rate of 20.2 per 100,000 people with diabetes (1). DKA remains the prominent cause of mortality in diabetic patients (2).

According to the American Diabetes Association (ADA), the expense of treating diabetes in 1997 was $98 billion, including both direct and indirect costs. Of this amount, $44 billion was expended in direct costs and accounted for 5.8% of total U.S. health care expenditure, despite the fact that at the time only 3.8% of the population of the country carried a diagnosis of diabetes. Of the direct costs of diabetes care, 62% was attributable to inpatient care, including treatment of DKA (3). DKA is an expensive complication of diabetes (4–6). The precipitating cause of an episode of DKA (e.g., noncompliance with medications, acute illness, or previously undiagnosed diabetes) could be an important determinant of the costs incurred in the management of patients admitted to the hospital with DKA. Currently, no comprehensive studies exist that analyze the cost of DKA based on the specific, underlying precipitating factor. Furthermore, as the spectrum of ketosis-prone diabetes has expanded beyond the traditional categories of "type 1" and "type 2" diabetes (7,8), it is important to reexamine the financial impact of DKA as it presents in multiethnic populations with heterogeneous forms of diabetes. In this study, we analyzed the determinants of the cost of treating DKA, based on the precipitating factors, in a large, multiethnic cohort of patients with heterogeneous forms of diabetes.

## RESEARCH DESIGN AND METHODS

Adult patients (≥18 years old) were identified using the Health Information System (HIMS) of the medical records department of the Harris County Hospital District (HCHD), Houston. The HCHD provides care to >40,000 multiethnic, mostly indigent diabetic patients in the Houston area. It is the largest indigent health care system in Texas, and it is the fourth largest in the U.S. The Ben Taub General Hospital (BTGH), one of the two tertiary care hospitals of the HCHD, admits 150–200 patients with a diagnosis of DKA every year.

The following information was obtained from the computerized records of the HCHD HIMS: name, medical record number, date of birth, sex, ethnicity, diagnosis, and visit date.

ICD-9-CM codes 250.10 (DKA in

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**Abbreviations:** BTGH, Ben Taub General Hospital; DKA, diabetic ketoacidosis; DRG, diagnosis-related grouping; HCHD, Harris County Hospital District; HIMS, Health Information System; RVU, relative value unit.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

type 1 diabetes) and 250.11 (DKA in type 2 diabetes) were used to identify potential DKA patients admitted to BTGH from 1 January to 31 December 1998. The complete medical chart of every patient thus identified was reviewed to ascertain if the patient indeed met clinical criteria for DKA. DKA was determined by the following criteria at the time of the patient's admission: *1*) serum bicarbonate <20 mEq/l; *2*) anion gap >14; *3*) pH <7.30; and *4*) serum ketones positive at any dilution, or urine ketones present at a level of ≥2+.

Detailed information regarding inpatient resource utilization for treating each patient with DKA during that hospitalization was obtained through the HCHD Resource Utilization Department, and itemized costs were recorded. As is common in many health care institutions, as described by Finkler (9), the Resource Utilization Department of HCHD utilizes several methods to determine the individual costs incurred during each hospitalization. Costs for laboratory tests and radiologic procedures are calculated using the "weighted procedure method." In this method, a procedure or test is assigned a certain number of relative value units (RVU), and each RVU is assigned a certain monetary value, so the costs are calculated by multiplying the RVU of a procedure or test by the dollar amount per RVU and by the number of procedures or tests performed on a patient. The costs for pharmacy, intravenous therapy, and supplies are calculated using the "surcharge method"; the HCHD has a surcharge of 25% for each item. The costs for emergency room and intensive care unit care were calculated using the "hourly rate method," in which each hour spent in the intensive care unit and emergency room costs $65 and $45, respectively. The costs for room and board (such services as maintenance, laundry, nutrition, nursing, and housekeeping) are calculated using the "per diem method," in which each day of hospitalization is assigned a cost of $385.

A common method of assessing the cost of medical care is to base it on "diagnosis-related grouping" (DRG). The DRG system was introduced by Medicare in the 1970s in order to control inpatient costs. The goal was to reimburse hospitals for inpatient care in a standardized and reasonable manner by calculating the appropriate length of stay for treatment of a given disease or condition. To assess the costs of inpatient DKA treatment based on DRGs, the DRG for each DKA hospital stay was calculated utilizing the Information Resource Products, Inc., Web IRP Refined DRG/Calculator (http://www.apc-solutions.net/drgcalc.htm). Using this tool, the ICD-9 codes for diagnoses, procedures, and length of stay were taken into account to calculate the DRG cost for each hospitalization.

If clinical data in the chart were insufficient to confirm a diagnosis of DKA by the criteria listed above, or if billing information was absent, the subject was excluded from the analysis. No outpatient charges were included in the analysis. The precipitating factor associated with the DKA admissions of each eligible patient was obtained from recorded data in the hospital chart. If the chart did not document a specific precipitating factor, that subject was excluded from the analysis.

Case information was entered into data forms designed for the study. Recorded variables included age, race, sex, type of diabetes, dates of admission and discharge, number of past DKA episodes, years with diabetes, cause of onset, number of days in intensive care unit, number of days of intravenous insulin treatment, and relevant biochemical values upon admission.

Cost information for inpatient care at BTGH was recorded in the following charge categories: laboratory, hospital room, intensive care unit days, radiologic tests, medical supplies, electrocardiograms, respiratory therapy, emergency room, operating room, physical therapy, occupational therapy, cardiologic tests, renal dialysis, and anesthesia.

### Statistical analysis

Data analyses were performed using the JMP 5.0 statistical package (SAS Institute). Statistical tests of patient demographics (including costs, clinical variables, and DKA-precipitating factors) were analyzed using Wilcoxon rank scores test for nonparametric distributions, ANOVA, and $\chi^2$ tests. *P* values were calculated using the likelihood ratios method. Pairwise testing with a post hoc multiple comparison procedure (Tukey-Kramer) was used when the three-group comparison indicated significant group differences. Descriptive values are presented as means ± SD, and as medians with the 25 and 75% quartiles. Results were considered statistically significant at $P < 0.05$.

**RESULTS** — A total of 185 admissions with ICD-9-CM codes 250.10 and 250.11 were identified. Seven admissions were excluded because they did not meet all criteria for DKA upon review of the hospital charts, and 11 admissions were excluded because a precipitating factor for the DKA episode could not be determined reliably from the information in the hospital charts. After these exclusions, 167 admissions for 136 patients fulfilled all entry criteria for the study. Of these, 31 (19%) represented repeat episodes of DKA in 12 patients (9%).

Based on substantial published information on the pathophysiology of DKA (10), three different categories of DKA-precipitating factors were defined a priori: noncompliance with diabetic treatment, acute illness or physical stress, and new-onset diabetes (i.e., DKA occurring in a patient without a prior diagnosis of diabetes and without acute illness or physical stress). Noncompliance was the most common precipitating factor with 99 admissions (59%), while acute illnesses accounted for 30 admissions (18%) and new-onset diabetes accounted for 38 admissions (23%) (Fig. 1*A*).

Men outnumbered women in a ratio of 2.3:1. A total of 66 patients (49%) were African American, 44 (32%) were Hispanic American, 24 (18%) were Caucasian American, and 2 (1%) were Asian American. The mean age was 40 ± 12.7 years.

The total number of hospital days was 1,095, with an average length of stay of 6.6 ± 6.4 days, with a median of 4 days. Death resulted in five of the admissions during the hospital stay (3%).

The total cost incurred by the 167 admissions for DKA was $1,816,255. There was a wide range of costs per hospitalization. The lowest hospitalization cost was $1,238 and the highest was $83,993. The average cost per admission was $10,875.78 ± 11,023.70 (median $7,501; range: $4,753–12,854), and the mean cost per day was $1,978.86 ± 1,524.65 ($1,875.25; $1,225–2,314).

Costs were analyzed for each precipitating cause of DKA. The mean cost for DKA admissions precipitated by acute illnesses was $20,863.9 ± 17,910.3 (median $19,502; range $8,222–27,218); for admissions precipitated by noncompliance, the mean cost was $7,470.1 ±

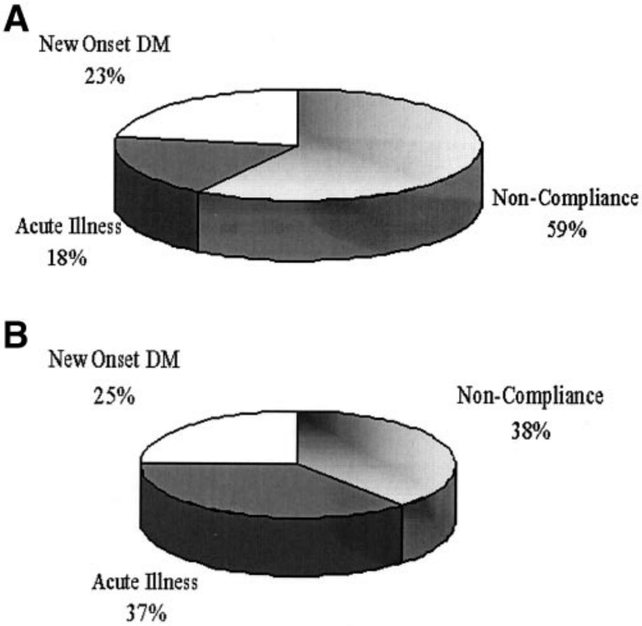


**Figure 1—**A: *Distribution of DKA admissions by precipitating factor.* B: *Distribution of total costs of DKA by precipitating factor.*

6,300.8 ($6,098; $3,697–9,773); and for admissions in persons with new-onset diabetes, the mean cost was $11,863.1 ± 8,701.1 ($10,014; $7,703–14,048). The cost difference in DKA hospital treatment between patients admitted for these three underlying causes was significant ($P <$ 0.0001). Pairwise, post hoc, multiple comparison (Tukey-Kramer) analysis of the cost data also yielded significant differences among the three groups.

Table 1 shows an itemized comparison of the mean costs by the precipitating cause of the DKA episode. Mean costs were significantly higher in patients with DKA secondary to acute illnesses in all of the items except for emergency room costs. The mean costs for treatment of patients with new-onset diabetes were generally higher than for patients with noncompliance in most of the items, but the difference was statistically significant only for the cost of intravenous therapy.

Although mean cost per admission was lowest for patients with noncompliance, the total cost of treating DKA in patients with noncompliance was greatest overall, $694,082.00, due to the high number of admissions among patients in this category. The overall cost associated with patients with DKA precipitated by acute illness was $671,375.00, which was lower than in patients with DKA associated with noncompliance. The overall cost for new-onset diabetes was $450,798 (Fig. 1*B*).

The total DRG-calculated cost for all the 167 admissions was $1,032,557, with a mean value of $6,182.98 ± 6,011.43 and a median of $3,524. These DRG-calculated costs were significantly lower then the costs calculated by the recourse utilization department of HCHD ($P <$ 0.0001). The mean DRG-calculated cost was $4,173.63 ± 3,249.42 (median $3,524) for the noncompliance group, $5,054.16 ± 3,056.57 ($4,405) for the new-onset group, and $14,243.67 ± 11,294.46 ($10,498) for the acute illnesses group.

**CONCLUSIONS—** The calculation of the costs of hospitalization is not an exact science; Finkler (9) in 1982 described the inaccuracies and flaws of these calculations. Many times, the charges that are included in the patient's bill do not reflect the cost of the resources utilized to treat the patient. In fact, it is extremely difficult to calculate the exact cost of the resources used to treat a particular patient during one hospitalization. Many health care institutions utilize several methods to calculate the cost of the resources used for each hospitalization. The Resource Utilization Department of HCHD (billing department) uses the methods that have been described to calculate the cost of a hospitalization. It is also important to distinguish hospital costs (which are derived from the calculation of resource utilization) and hospital charges (which are billed to Medicare, Medicaid, private insurance companies, or directly to the patient). The hospital charges usually are higher then the actual costs (9). For the

**Table 1—*Itemized comparison of mean costs by precipitating diabetes factor of DKA***

| | Acute illness | New-onset diabetes | Noncompliance | *P* |
|---|---|---|---|---|
| Room and board | 4,440 ± 3,521 | 2,274 ± 1,516 | 1,800 ± 1,446 | <0.0001* |
| Intensive care unit | 2,912 ± 4,185 | 1,011 ± 1,555 | 540 ± 928 | <0.0001* |
| Radiology | 1,645 ± 1,772 | 698 ± 1,226 | 341 ± 602 | <0.0001* |
| Laboratory | 5,638 ± 5,134 | 3,670 ± 4,266 | 2,302 ± 1,617 | <0.0001* |
| IV therapy | 1,821 ± 1,472 | 807 ± 812 | 426 ± 512 | <0.0001† |
| Pharmacy | 1,140 ± 1,464 | 830 ± 1,620 | 382 ± 577 | <0.0001* |
| Emergency room | 416 ± 361 | 351 ± 296 | 351 ± 287 | 0.3 |
| Supplies | 743 ± 907 | 390 ± 384 | 282 ± 256 | 0.0001* |
| Miscellaneous costs | 1,336 ± 1,555 | 539 ± 985 | 185 ± 418 | <0.0001* |
| Total costs | 20,864 ± 17,910 | 11,863 ± 8,701 | 7,470 ± 6,301 | <0.0001† |

Data are U.S. dollars (means ± SD). *Pairwise significant differences between AI vs. NO and AI vs. NC; †pairwise significant differences between AI vs. NO; AI vs. NC; and NO vs. NC. Legend: AI = acute illness, NO = new-onset diabetes, NC = noncompliance

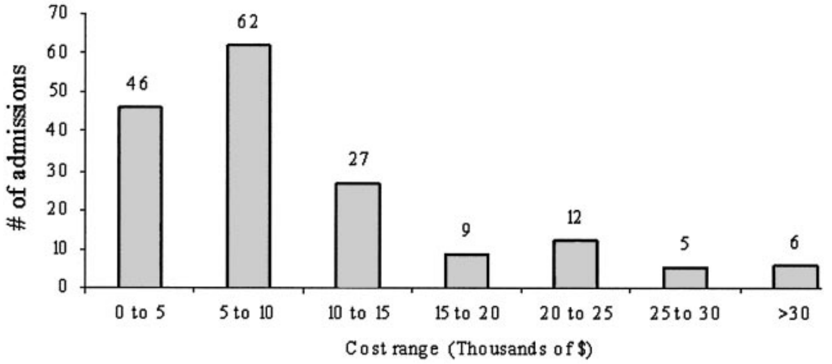


**Figure 2**—*Distribution of admissions by cost ranges.*

current study we used the calculated cost per admission, not the charges. HCHD is the fourth largest public metropolitan health system in the U.S.; <25% of the patients are covered by Medicare, Medicaid, or a private insurance, and this percentage is even lower (15%) among the patients who are admitted with DKA (mostly because they represent a younger population). HCHD recovers very little from Medicare, Medicaid, and private insurances. Its income depends mostly on the property taxes of the county.

DKA is an expensive and serious but preventable complication of diabetes. It has been estimated that the annual cost of treating DKA in the U.S. exceeds $1 billion (10). Javor et al. (4) quantified the costs of treating DKA relative to the costs of treating diabetes without DKA during a 6-month period. They determined that the average cost per DKA episode was $6,444, and that the annual cost of medical treatment in a diabetic patient with a prior episode of DKA was $13,096, as compared with $4,907 for a diabetic patient with no history of DKA. Hence, it would appear that patients with a history of DKA have a greater impact on health care costs than those who are not ketosis-prone. In a previous study of a mixed population of type 1 and type 2 diabetic adult patients with DKA, we estimated that the mean cost of treating DKA in the HCHD, Houston, during a 2-year period was $5,500 (6). Levetan et al. (5) showed that the average cost of inpatient treatment of DKA during a 3.5-year period was $5,463 when the treatment was supervised by an endocrine specialist, as compared with $10,109 when a general physician treated the patient. Those costs, however, did not include emergency room charges. The present study is the first to analyze the inpatient cost of treating DKA in an ethnically mixed population of patients with different forms of diabetes.

Our results show that the average cost per admission for treating DKA, in a large American urban public hospital with a multiethnic, indigent population, was $10,509.15 ± $11,107.84 using the costing method of the Resource Utilization Department of the HCHD, and it was $6,182.98 using the DRG-based costing method. The former amount is higher than some previous estimates (4,6) of the inpatient cost of treating DKA, but is similar to that estimated by Levetan et al. (5) for DKA treated by general physicians ($10,109). The total annual cost of inpatient DKA treatment in our study population was very high, $1,816,255. It is likely that this is a conservative figure, as it does not account for HCHD patients who obtained emergency treatment for DKA in other hospitals. Although BTGH is the primary referral center for HCHD patients, acutely ill patients may be taken to other hospitals closer to their homes for emergency treatment; hence, the cost of their treatment would not be included in our analysis. The range of costs per hospitalization was wide (Fig. 2), perhaps in part because of differences in precipitating factors underlying the DKA episodes. Some patients required less diagnostic and therapeutic interventions than others. This explains why the standard deviations are sometimes larger then the means. Javor et al. (4) also reported standard deviations larger then the means in their earlier study of DKA outcomes.

We have analyzed the costs of DKA treatment in a way that permits comparison of the expenses of DKA occurring due to different precipitating causes. Patients who were admitted with DKA secondary to noncompliance with diabetic treatment (most commonly, inappropriate discontinuation of insulin) incurred the lowest mean cost per admission ($7,470.10 ± 6,300.80). However, due to its high frequency, the noncompliant group represented the most expensive DKA category to treat, accounting for $694,082, or 38% of the total costs for inpatient treatment of DKA during 1998. Considering that the mean annual cost of intensive diabetes care per diabetic patient in the U.S. is $4,000.00 (11), there is significant potential for cost reduction by preventing or reducing these episodes of DKA in noncompliant patients. Since 1999, we have implemented a successful scheme to achieve this goal using a dedicated team of endocrine specialists at BTGH. This intervention has already resulted in a significant reduction in readmission rate for DKA as well as the overall cost of treating patients with DKA (12).

Early detection and treatment of acute precipitating factors in patients with a history of diabetes, through improved access to medical care, is yet another important strategy in the prevention of DKA (10,13). Lack of access to medical care can also lead to the development of ketoacidosis in patients without a prior history of diabetes. Overcoming barriers to treatment adherence is also an important intervention in the prevention of recurrent DKA episodes. In the present study, 38 patients (23%) were first diagnosed with diabetes when they presented with DKA (new-onset diabetes). None of these patients had a clinically detectable precipitating factor. The average $HbA_{1c}$ on admission of these patients was 14.9 ± 2.4%, suggesting that they had had unsuspected hyperglycemia for several months preceding the DKA admission. This severe and expensive complication could potentially have been prevented if these patients had had better access to outpatient medical care and diabetes screening programs.

In conclusion, DKA is an expensive but preventable complication in indigent, multiethnic diabetic patients with heterogeneous forms of diabetes. The average cost of treating one hospital admission for DKA in our institution was $10,875.78. There were significant differences in the costs depending on the precipitating cause of the episode of DKA. Even though the average cost per admission for DKA was lowest for DKA precipitated by noncompliance, this preventable precipitating factor made the largest contribution to the economic burden of DKA because of the high number of admissions associated with it. Improved access to basic diabetes care can prevent the majority of admissions for DKA and can significantly reduce inpatient costs of treating diabetes.

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