Variation in Resource Use and Readmission for Diabetic Ketoacidosis in Children’s Hospitals

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**ABSTRACT**

**OBJECTIVE:** We sought to characterize variation in hospital resource utilization and readmission for diabetic ketoacidosis (DKA) across US children’s hospitals.

**METHODS:** The study sample included a retrospective cohort of children aged 2 to 18 years with a diagnosis of DKA at 38 children’s hospitals between 2004 and 2009. The main outcomes were resource utilization as determined by total standardized cost per hospitalization, overall and non-ICU length of stay (LOS), and readmission for DKA within 30 and 365 days.

**RESULTS:** There were 24,890 DKA admissions, and 20.3% of these were readmissions within 1 year. The mean hospital-level total standardized cost was $7,142 (range $4,125–$11,916). The mean hospital-level LOS was 2.5 days (1.5–3.7), and the non-ICU portion was 1.9 days (0.7–2.7). The mean hospital-level readmission within 365 days was 18.7% (6.5%–41.1%) and within 30 days was 2.5% (0.0%–7.1%). Hospital bed days overall, and in particular the non-ICU portion, accounted for the majority of the total standardized cost per hospitalization (overall 57%, non-ICU 36%) and explained most of the variation in resource use. Even after adjusting for differences in patient characteristics across hospitals, widespread differences existed across hospitals in total standardized cost, LOS, and readmission rates ($P < .001$).

**CONCLUSIONS:** Readmission for DKA within a year of hospitalization is common. US children’s hospitals vary widely in resource use, hospital LOS, and readmission rates for patients with DKA. Our study highlights the need for additional research to understand these differences and to identify the most cost-effective strategies for managing diabetes across the continuum of care. *Pediatrics* 2013;132:229–236

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**WHAT’S KNOWN ON THIS SUBJECT:** Diabetic ketoacidosis (DKA) is a short-term complication of type 1 diabetes and is a major cause of preventable hospitalization in children. Hospital resource utilization and readmission rates for DKA across the US are not known.

**WHAT THIS STUDY ADDS:** Readmission for DKA within a year of hospitalization is common, accounting for one-fifth of all DKA admissions. Resource use, hospital length of stay, and readmission rates vary widely across major US children’s hospitals, even after adjusting for hospital differences in patients.
Type 1 diabetes is a common chronic condition of childhood and adolescence. It currently affects 1.54 per 1000 people under age 20 in the United States, and the global incidence in children is increasing worldwide by 3% to 5% per year.\(^1\)\(^-\)\(^3\) Although research indicates that intensive diabetes management reduces the risk of acute and chronic complications of type 1 diabetes, medical expenditures for its complications remain substantial.\(^4\)\(^-\)\(^6\) Short-term complications from type 1 diabetes represent one of the most potentially preventable causes of hospitalization in children, accounting for $67 million in hospital costs per year.\(^7\) Health care reform efforts in the United States emphasize identification of areas in which better patient outcomes and lower costs intersect, especially in children and adults with chronic diseases associated with preventable complications.\(^8\)

Diabetic ketoacidosis (DKA), a short-term complication of type 1 diabetes that results in acidosis and dehydration, is the most common reason for hospitalization and mortality in children with diabetes.\(^9\)\(^-\)\(^15\) In a single-center prospective study of children with established type 1 diabetes, the incidence of DKA was 8 per 100 person-years and even higher in patients with previous episodes.\(^14\) In fact, 80% of DKA episodes occurred among 20% of those children with recurrent events, indicating greater resource needs for certain patient populations such as adolescents, females, the underinsured, and patients with higher hemoglobin A1c. Although resource intensive, comprehensive diabetes education can improve self-management and is associated with a subsequent reduction in inpatient hospital services.\(^15\)

In children and other higher-risk groups, physicians and hospitals may use the inpatient setting, even after DKA has resolved, as an opportunity to ensure that patients and families adequately understand diabetes self-management before discharge. However, differences in hospital-based resource utilization and readmission rates across major US children’s hospitals remains unknown. The goal of this study was to characterize variability in hospital-level resource utilization, hospital length of stay (LOS), and readmissions at 30 and 365 days for children hospitalized with DKA.

**METHODS**

**Data Source**

This multicenter retrospective cohort study used the Pediatric Health Information System (PHIS), which contains administrative data from 43 freestanding children’s hospitals affiliated with the Children’s Hospital Association. This study included 38 hospitals, with 11 located in the North Central United States, 5 in the Northeast, 13 in the South, and 9 in the West. PHIS data include detailed information about hospital encounters such as patient demographics, admission and discharge date, payers, physicians, diagnoses, procedures, service location, and charges. The charges at each hospital are mapped to a common set of clinical transaction codes (CTCs), which are categorized into imaging studies, bed utilization, laboratory tests, pharmacy, supplies, and clinical therapies (e.g., respiratory therapy). Bed utilization, or the daily room and nursing costs accumulated over the LOS, is further categorized into service location (e.g., ICU or inpatient).

**Study Subjects**

The study included children aged 2 to 18 years discharged (inpatient or observation status) between January 1, 2004, and December 31, 2009, with an International Classification of Diseases, Ninth Revision, Clinical Modification principal discharge diagnosis of DKA (250.11 and 250.13). We also included patients with a secondary discharge diagnosis of DKA, but to reduce misclassification, the patients must have had a principal diagnosis indicating a diabetes-related condition or complication such as cerebral edema (Supplemental Table 3). To further minimize overclassification of DKA, patients who did not have a billing code for intravenous or subcutaneous insulin were excluded because insulin is necessary to treat DKA (Fig 1).

**Patient Covariates**

In each model, we included variables for patient age, gender, primary insurance, and binary measures for the presence or absence of diagnoses indicating complex chronic conditions (CCCs) and mental health conditions (Supplemental Table 4).\(^16\) We excluded discharge diagnosis codes from the CCC classification that represented potential renal complications of type 1 diabetes (ICD-9 codes 585.\(\times\)). Patients with International Classification of Diseases, Ninth Revision codes indicating eating disorders, psychiatric conditions, and substance abuse were classified as mental health conditions (Supplemental Table 4).

We classified a patient’s medical severity by using the All Patient Refined Diagnosis-Related Group (APR-DRG) Classification System 3M. The APR-DRG system classifies patients into 1 of 4 severity levels (minor, moderate, major, or extreme) by using a proprietary algorithm that incorporates all discharge diagnosis and procedure codes.\(^17\) For analyses, patients were categorized as either minor/moderate or major/extreme.

**Hospital Characteristics**

Hospital-level characteristics included the number of ICU and inpatient beds, annual DKA admissions, number of endocrinology attending physicians,
and presence and size of an endocrinology fellowship program. Fellowship data were identified in the FRIEDA database annually updated by the American Medical Association survey of accredited programs.18

**Primary Outcome: Standardized Costs**

To use hospital costs as a marker of resource utilization, we needed to standardize the cost of individual items to remove the high interhospital variation in item costs. To accomplish this, we used a Cost Master Index developed for an earlier study of resource utilization in PHIS hospitals.19 The Cost Master Index assigns a standardized cost to every CTC code in the PHIS database (n = 20,903). The standardized cost for each item is based on the across-hospital median of within-hospital medians of costs for that item, calculated from charges and hospital and department-specific ratio of costs to charges in the PHIS database from 2004 through 2009. To calculate standardized costs of the entire hospital visit (emergency department through discharge) for each record in our DKA cohort, we multiplied the units of each item by its standardized costs and then summed these costs in each hospital bill. All standardized costs were inflated to 2009 dollars by using the medical care services component of the Consumer Price Index.

**Secondary Outcomes**

**LOS**

We considered any day in which an ICU bed was billed to be an ICU-level hospital day. Non-ICU hospital days were determined by subtracting the total number of ICU-level hospital days from the total LOS.

**Readmission**

We identified subsequent readmissions after an index admission for DKA at 30 and 365 days after discharge for DKA by using the inclusion and exclusion criteria previously described. For children with multiple readmissions during the study period, each hospitalization was considered an independent index admission, regardless of the number of days since the previous DKA admission.

We excluded the top 1% of most frequently admitted patients from the readmission analysis to prevent the skewing of a hospital's readmission rate by the rare patient with extreme medical or social complexity requiring frequent readmissions. We coded the 30- and 365-day readmission variables as binary values (yes/no) based on the number of days between the date of discharge and the date of the next admission for DKA. Patients readmitted within 30 days were included among those readmitted within 365 days.

**Data Quality**

Forty-three hospitals submitted discharge data to the PHIS database for the entire study period. Five of these hospitals were excluded from the study because of incomplete or missing itemized billing data. Four hospitals began to submit data to PHIS in 2005 and 2 in 2006. No hospitals withdrew from the database during the study period. We excluded all encounters from 149 billing quarters from 9 hospitals in which >10% of hospitalizations had missing or incomplete data on resource utilization (n = 2405, 7.3%; Fig 1). In addition, 1634 (4.9%) encounters from 2 hospitals were excluded due to coding inconsistencies in their data.

**Statistical Analysis**

**Variation in Total Standardized Cost, LOS, and Readmission**

To model the variation across hospitals in standardized costs, LOS, and readmissions, we first constructed mixed-effects linear and logistic regression models with hospital as a random intercept and patient-level factors (age, gender, government insurance, CCCs, mental health conditions, APR-DRG severity) as fixed effects. Race was not used as a covariate in the models because it was not reliably classified across all hospitals. These analyses produced an expected outcome (based...
on all admissions across all hospitals), predicted outcome (based on a weighted average of hospital-specific and all-hospital estimates), and predicted versus expected ratios for each of the 38 hospitals. For the cost outcome, the ratios were then multiplied by the overall mean costs across all patients in all hospitals to represent the hospital-specific adjusted costs. We estimated 95% confidence bounds for hospital-specific adjusted costs by means of 999 bootstrap samples. For LOS, we used a log linear model and for readmission at 30 days and 365 days, we used a logit model. These models fit patient-level factors and hospital-level effects together and over many iterations produced the distribution of hospital-specific estimates of each hospital’s departure from average, after adjustment for patient-level factors. As with the models for costs, we generated plots of variability by using the overall means across all patients at all hospitals. Each of these mixed-effects models was then repeated to estimate hospital-specific average costs, LOS, and risk of readmission but without any adjustment for patient-level factors. By comparing the results with and without adjustment for patient-level factors, we were then able to determine whether variation might change after controlling for case mix (Supplemental Technical Appendix).

**Components of Variance**

We used a mixed-effects linear regression model with hospital as a random intercept and cost category (ie, CTC) as fixed and random effects to estimate the relative contribution to the variability of total hospital standardized cost from each of the cost categories (Supplemental Technical Appendix).

This study was considered exempt from regulatory review according to 45 CFR 46.101(b4). A data use agreement between the Children’s Hospital of Philadelphia and the Children’s Hospital Association and the Children’s Hospital Association and the Children’s Hospital of Philadelphia protected participant privacy required under Health Insurance Portability and Accountability Act regulations.

**RESULTS**

**Patient and Hospital Characteristics**

During the 6-year study period, 32,800 children were discharged with ICD-9 codes for DKA. After applying exclusion criteria, 24,890 children comprised the final study population (Fig 1).

**TABLE 1  Encounter Characteristics, Resource Utilization, and Outcomes**

<table>
<thead>
<tr>
<th>Patient Characteristics</th>
<th>Encounter Level (n = 24 890), %</th>
<th>Hospital Level (n = 38): Mean, Median (min, max), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>55.3</td>
<td>55.5, 55.7 (47.0, 64.8)</td>
</tr>
<tr>
<td>Age, y, mean (SD)a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>7.3</td>
<td>7.6, 7.2 (5.9, 12.3)</td>
</tr>
<tr>
<td>5–11</td>
<td>35.3</td>
<td>34.9, 34.9 (29.2, 42.5)</td>
</tr>
<tr>
<td>≥12</td>
<td>57.4</td>
<td>57.5, 57.9 (49.0, 65.1)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>64.5</td>
<td>65.8, 70.1 (2.4, 98.4)</td>
</tr>
<tr>
<td>Black</td>
<td>25.7</td>
<td>22.8, 18.9 (0.8, 88.5)</td>
</tr>
<tr>
<td>American Indian</td>
<td>0.3</td>
<td>0.3, 0.0 (0.0, 2.2)</td>
</tr>
<tr>
<td>Asian</td>
<td>0.7</td>
<td>0.9, 0.5 (0.0, 6.1)</td>
</tr>
<tr>
<td>Other</td>
<td>6.4</td>
<td>7.1, 5.1 (0.0, 33.0)</td>
</tr>
<tr>
<td>Missing</td>
<td>2.7</td>
<td>3.1, 0.1 (0.0, 54.9)</td>
</tr>
<tr>
<td>Principal payer, governmentb</td>
<td>43.1</td>
<td>44.8, 46.1 (19.3, 68.2)</td>
</tr>
<tr>
<td>Mental health conditionsc</td>
<td>9.4</td>
<td>9.8, 9.8 (3.3, 16.4)</td>
</tr>
<tr>
<td>CCCd</td>
<td>5.7</td>
<td>5.9, 5.7 (2.7, 14.1)</td>
</tr>
<tr>
<td>APR-DRG severity level 1 and 2</td>
<td>93.8</td>
<td>93.6, 94.7 (66.3, 98.1)</td>
</tr>
<tr>
<td>APR-DRG severity level 3 and 4</td>
<td>6.2</td>
<td>6.4, 5.3 (1.9, 33.7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource utilization</th>
<th>Mean, median (min, max)</th>
<th>Mean, median (min, max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chargesa</td>
<td>$14 719, $12 136 ($617.7, $511 287)</td>
<td>$15 292, $14 699 ($6583, $27 253)</td>
</tr>
<tr>
<td>Total standardized costs</td>
<td>$7162, $5848 ($258.9, $346 007)</td>
<td>$7142, $6922 ($4125, $11 916)</td>
</tr>
<tr>
<td>LOS, d</td>
<td>2.4, 2.0 (1.0, 109.0)</td>
<td>2.5, 2.4 (1.5, 3.7)</td>
</tr>
<tr>
<td>Non-ICU LOS</td>
<td>1.9, 2.0 (0.0, 99.0)</td>
<td>1.9, 2.0 (0.7, 2.7)</td>
</tr>
<tr>
<td>ICU LOS</td>
<td>0.5, 0.0 (0.0, 26.0)</td>
<td>0.6, 0.5 (0.1, 1.4)</td>
</tr>
<tr>
<td>Outcomes</td>
<td>%</td>
<td>Mean, Median (min, max)</td>
</tr>
<tr>
<td>Readmission for DKAf</td>
<td>≤30 d</td>
<td>2.8</td>
</tr>
<tr>
<td>≥365 d</td>
<td>20.3</td>
<td>18.7, 17.5 (6.5, 41.1)</td>
</tr>
<tr>
<td>Readmission for all causesf</td>
<td>≤30 d</td>
<td>3.7</td>
</tr>
<tr>
<td>≥365 d</td>
<td>24.3</td>
<td>23.0, 21.4 (9.5, 45.6)</td>
</tr>
</tbody>
</table>

a Mean age: 11.6 y (SD 4.0).

b Defined as Medicare, Medicaid, Title V, in-state Medicaid (managed care), in-state Medicaid (other), out-of-state Medicaid (all), Tricare, other government source, and no charge.

c See Fig 1 (eg, eating disorder and depression).

d See Fig 1. Does not include type 1 diabetes or complications of type 1 diabetes (eg, pancreatitis).

e Adjusted for wage index.

f Admission defined as an encounter after index visit within specified time period using the same inclusion and exclusion criteria previously described (ie, “same cause”).

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Resource Utilization

Total Standardized Hospital Cost

The overall mean total standardized cost per patient encounter was $7162 (Table 1). Bed utilization (daily room and nursing costs accumulated over the LOS) accounted for the majority of these costs (54.4%), followed by laboratory testing (19.3%), clinical therapies (15.0%), pharmacy (8.2%), supplies (2.3%), and imaging (0.9%). At the hospital level, mean total standardized costs were $7142 with a wide range across hospitals of $4125 to $11,916. Table 2 describes the wide variability across hospitals in resource use tabulated by CTC-based service category. The clinical therapies CTC service category contributed most to the overall variability in total standardized costs, whereas the bed utilization CTC contributed the most to total standardized cost and second most to the overall variability in total standardized cost. Figure 2A depicts the variation in total standardized cost across hospitals. Variation across hospitals was similar for both adjusted and unadjusted estimates of standardized costs, and the degree of variation was greater than what would be expected at random (P < .001). Those institutions that had lower than average costs in the unadjusted analyses remained low after adjustment, and the high-cost hospitals remained high.

LOS and Standardized Costs for Bed Utilization

The mean LOS for all encounters was 2.4 days with the non-ICU portion of bed days accounting for 79.2% of the overall LOS (1.9). By hospital, the mean overall LOS was variable (median: 2.5, range: 1.5–3.7), as was the mean non-ICU LOS (median: 1.9, range: 0.7–2.7; Table 1). The mean standardized cost for the bed utilization CTC-service category was $3384 ($2740 for non-ICU and $1145 for ICU; Table 2). As the estimates of random effects in Table 2 suggest, variation across hospitals in the standardized costs for non-ICU bed utilization (0.34) was 4 to 5 times the comparable variability for laboratory services (0.07) or pharmacy (0.08). Figure 2B demonstrates the persistent and statistically significant across-hospital variation in hospital LOS after adjusting for patient characteristics (P < .001). Adjustment for patient-level factors tended to reduce the variation in LOS, but the general rankings of high versus low hospitals remained unchanged.

Readmission

Of the 24,890 encounters, many were readmissions at 30 days (2.8%) and 365 days (20.3%) after discharge (Table 1). There was wide variation in these proportions by hospital at both 30 days (0%–7.1%) and 365 days (6.5%–41.1%). Figure 2C demonstrates the hospital variability in readmission at 30 and 365 days. After adjusting for patient characteristics, the variability in 30- and 365-day hospital readmission proportions remained statistically significant (P < .001). Again, adjustment for patient-level factors did not tend to change the general rankings of high versus low hospitals.

DISCUSSION

Overall, readmission for DKA within a year of discharge is common. Widespread differences across US children’s hospitals exist in resource use and readmissions rates. These findings raise concern for the consistency and quality of care delivered to children with type 1 diabetes in the US.
utilization, particularly the non-ICU portion of the hospitalization, was a main driver of variability in resource use and overall standardized cost. We identified widespread variation in total standardized costs, LOS, and readmissions across 38 children’s hospitals. Even after accounting for differences in hospitals’ patients, the variation remains substantial as well as significant. Notably, the adjusted mean standardized cost at the most costly hospital is nearly $8000 higher than the least costly hospital, and the mean adjusted 1-year readmission rate at 1 hospital was 6.0%, whereas at another it was 40%. Although these models suggest that the ranking of hospitals relative to one another is sensitive to the choice of patient-level covariates, hospitals that were at either the high or low end of the spectrum in unadjusted analyses remained at either the high or low end after accounting for patient-level factors.

To identify opportunities for more cost-effective resource use, we evaluated the major CTC categories and identified bed utilization, and in particular the number of bed days for the non-ICU portion, to be the major contributor to standardized cost. This resource use pattern is consistent with the expected management of DKA. After medical stabilization and resolution of the acidosis in the first 24 to 36 hours, hospital care typically focuses on optimizing insulin dosing and patient education for self-management. When we evaluated this resource use across hospitals, the variation in the standardized cost for non-ICU bed utilization cost was several

FIGURE 2
Unadjusted and adjusted variability in standardized costs, mean LOS, and readmission with 95% confidence intervals. Each figure reports hospital-level raw data (x), hospital estimates based on models that adjusted only for the instability of raw data (square symbols), and estimates that adjusted for patient-level factors (+): age group, gender, government insurance, mental health conditions (yes/no), CCCs (yes/no), and patient APR-DRG (v. 20) severity level (1 and 2 vs 3 and 4). The 95% confidence bounds reflect not only patient-level factors but also uncertainty of adjusted for patient-level factors and then comparing hospitals in a single model. Analyses were performed by using mixed-effects models: (A) linear with log-transformed costs, (B) for negative binomial for LOS, and (C) logistic for readmission. (See Supplemental Technical Appendix.)
times that for laboratory or pharmacy cost categories.

In the outpatient setting, patients with type 1 diabetes self-manage serum glucose through appropriate monitoring, nutrition, and insulin dosing.\textsuperscript{21,22} However, this study demonstrates, by virtue of a 20.3% readmission rate with a range of 6.5% to 41.1% across 38 children’s hospitals, that diabetes control and self-management is not optimal in the United States. Although hospital-based education programs for self-management are effective in certain settings, they are controversial because they can prolong hospitalization.\textsuperscript{23–25} The hospital resources allocated to this education, although perhaps leading to higher average cost for some hospitals, can improve the overall value of care by decreasing future risk for DKA. However, some diabetes programs have successfully addressed these same issues in the outpatient setting.\textsuperscript{22–26} This study highlights the need for future research to determine the most cost-effective strategies, whether in the inpatient or outpatient setting, to improve diabetes self-management and prevent DKA.

There are limitations to our study. First, clinical data are preferable to administrative data using International Classification of Diseases, Ninth Revision, Clinical Modification codes. We were unable to reliably assess some patient characteristics such as social complexity, hemoglobin A1c level, and insulin regimen and adherence, as well as some clinical care such as diabetes education and psychological or social services. Second, although we adjusted for differences across hospitals in patient characteristics, unobserved differences might remain. For instance, we were unable to identify patients with a first-time diagnosis of type 1 diabetes. Compared with patients with established disease, patients with a new diagnosis might require longer hospitalization for education or, due to the “honeymoon period,” might be less likely to have DKA in the next year. We adjusted for this in our models by using patient factors previously reported to be more commonly associated with the presence of DKA at first diagnosis of type 1 diabetes (eg, young age and government insurance).\textsuperscript{27} Inadequate adjustment for differences in hospitals’ rates of patients with new-onset DKA would lead us to overestimate the degree of variability in standardized costs, LOS, and readmission. Third, these data are limited to children hospitalized within participating hospitals. Our study may have not included less severe episodes of DKA, such as patients treated and discharged from the ED. We also did not include those readmitted to non-PHIS hospitals. Finally, we cannot determine how much of the variability in readmission rates is attributable to outpatient care, where much of childhood diabetes management lies.

CONCLUSIONS

Interventions are needed to decrease the high readmission rates for DKA. This study demonstrates vast differences in how hospitals use resources and in readmission outcomes for children hospitalized for DKA in the United States. By benchmarking against similar hospitals, these data models can be used to inform hospital administrators, quality leaders, and clinicians to identify and drive local opportunities for improvements in terms of effective resource use and outcomes (eg, as part of a quality improvement collaborative). Our findings also highlight the complex relationship among clinical management, health care cost, and patient outcomes, emphasizing the need to evaluate both how a health care system spends money and, perhaps more important, how physicians deliver the most cost-effective care for patients with a chronic disease over the continuum of the disease.

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