

Treating the Most Vulnerable and Costly in Diabetes

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Abstract Diabetic ketoacidosis (DKA) is associated with negative health outcomes and high costs for patients, families, and communities. Interventions developed to effectively reduce DKA and related costs should target the multiple risk factors associated with DKA and adherence difficulties. Certain demographic, psychological, and family factors are associated with increased risk for adherence problems and DKA. Individuals with a combination of risk factors (e.g., mental health problems, low socioeconomic status, high family conflict) may be particularly vulnerable to DKA. Although several different interventions have demonstrated promise in improving adherence and/or decreasing the risk of DKA, the generalizability of treatment results to those individuals most vulnerable to DKA is limited. Approaches which include multiple evidence-based components of care, are flexible in treatment delivery (e.g., home- and community-based, utilize technology), and target the multiple risk factors across relevant systems (e.g., individual, family, school, medical) are warranted to effectively reduce DKA in vulnerable populations.

Keywords DKA · Type 1 diabetes · Treatment · Vulnerable · Risk factor · Cost

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Introduction

Diabetes ketoacidosis (DKA) is a life-threatening, preventable complication of type 1 diabetes that imposes considerable health, psychosocial, and financial costs on patients, families, and medical systems. DKA is the most common reason for hospitalization and mortality in children and adolescents with type 1 diabetes [1, 2], and resulted in 2361 deaths in adults age 20 years and older in 2010 [3]. In 2011, hyperglycemic crisis (e.g., DKA) was the first-listed diagnosis for a total of approximately 175,000 emergency room visits in youth and adults [3]. In addition, readmission for DKA is common, as approximately 20 % of DKAs in youth per year are readmissions, further exacerbating the economic burden of this complication [4]. For example, the mean cost for one DKA hospitalization is estimated to be approximately US\$13,000 [5]. Furthermore, the treatment of DKA continues to be costly, accounting for an estimated total cost of US\$2.4 billion per year [6].

Given these well-documented costs, it is imperative that psychosocial interventions are evidence-based and target the needs of vulnerable populations, with the goal of reducing DKA admission and emergency department visits. In this review, we describe the risk factors for adherence problems and associated repeated hospitalizations for DKA in youth and adults with type 1 diabetes. We then summarize existing healthcare approaches to assisting patients with complex healthcare needs, such as type 1 diabetes, and conclude with a discussion of our impressions of the literature. Our goal is not to conduct a systematic review; rather, we aim to highlight the most relevant studies and to describe salient themes in order to inform future practice in vulnerable populations.

Risk Factors

To improve diabetes management, it is important to define and understand why adherence problems occur [7]. Patients with

diabetes are especially prone to significant treatment regimen adherence problems [8]. Furthermore, omission of insulin has been cited as the most common precipitant of DKA [9]. Therefore, it is of interest to identify subgroups at risk for adherence problems and associated repeated hospitalizations for DKA, with the ultimate goal of improving patient care and reducing costs.

Demographic Factors

Certain demographic characteristics, such as age, socioeconomic status, and race/ethnicity have been shown to be associated with adherence problems and repeated DKAs in youth and adults with type 1 diabetes. Examples of related studies are described below.

Existing work suggests that the teenage years are associated with particular vulnerability to adherence problems and associated hospitalizations. Adolescence is often a time of inherent challenges and can be the most difficult time in regard to diabetes management [10]. A subgroup of teens experience significant setbacks in their metabolic control and are vulnerable to repeated hospitalization for DKA [10]. Emerging adulthood (ages 18 through 25 years) is also a period of increasing interest to researchers of type 1 diabetes. This period marks the point at which youth transfer from pediatric to adult diabetes services, which can bring considerable challenges. Emerging adults face a host of psychosocial issues as they seek to individuate from their parents and transition to college or to the workforce. Patients in this age range are often lost to follow-up and thus may be at risk for the development of poor glycemic control and diabetes-related complications [11]. Taken together, patient age is a significant demographic characteristic to consider in developing appropriate preventative interventions to reduce adherence problems and repeated hospitalizations.

Lower socioeconomic status and ethnic minority status have also been associated with diabetes-related complications. For example, within a sample of children with type 1 diabetes hospitalized for diabetes-related complications, those who were nonwhite and had Medicaid insurance were more likely to be hospitalized for DKA and were more likely to have prolonged hospital stays (equal to or greater than one week) [2]. Further, among children hospitalized for diabetes-related complications, nonwhite children and those with Medicaid insurance were overrepresented when compared to the general population. In addition, a disproportionate number of adolescents repeatedly hospitalized for DKA have been shown to live in single-parent families and tend to have parents who are unemployed or underemployed [10]. These findings are in line with other work which suggests that lower socioeconomic status and homelessness are risk factors for repeated hospitalizations in patients with type 1 diabetes [12, 13].

Psychological Factors

Psychological factors have also been shown to increase risk for diabetes management issues, as well as subsequent hospitalizations for DKA. For example, depression and anxiety have been associated with poor glycemic control [14, 15]. In addition, patients with diabetes and comorbid mental health problems tend to adhere less to treatment regimens [16] and experience higher rates of complications [15]. Specifically, comorbid diabetes and depression has been associated with decreased metabolic control, suboptimal adherence, lower quality of life, and increased healthcare costs [17]. Eating disorders and illegal substance use have also been shown to be risk factors for DKA in adults with diabetes [13, 18].

It is important to consider the impact of developmental factors on the association between mental health issues and diabetes management. Given that DKA episodes in adolescents are likely due to suboptimal adherence, and the association between mental health symptoms and poor adherence [14, 16], patient psychological functioning could be conceptualized as a risk factor for preventable diabetes-related complications, such as repeated hospitalization for DKA. Other studies suggest that both adolescent and parent psychosocial, behavioral, and mental health problems put youth at risk for repeat DKA [19]. Strikingly, patients with diabetes who also experience depression have been shown to experience worse health outcomes than other combinations of chronic disease [20]. Therefore, it is critical that psychological factors are taken into consideration when screening for risk of adherence problems and developing appropriate interventions for youth and adults with type 1 diabetes.

Family Factors

Family factors are also significant in the context of risk factors for diabetes-related complications and medical costs. Research has demonstrated that family cohesiveness and conflict are linked with patient adherence and glycemic control [21, 22]. Youth with optimal control report greater parent-child agreement regarding treatment responsibility [21]. Several prospective studies have produced similar results. For example, low levels of family cohesion, expressiveness, and organization have been linked with suboptimal metabolic control in children and adolescents [23, 24]. Within an adolescent sample, parental over-involvement in diabetes management has been shown to be a stronger predictor of metabolic control than age, gender, or insulin treatment regimen [25]. Taken together, it is clear from these studies and others that approaches that address family level variables (e.g., family conflict, parental supervision) are warranted to promote adherence [e.g., 26, 27]. Further, if we use suboptimal metabolic control as a proxy for risk of hospitalization for DKA,

family variables may be a critical component of preventative interventions, particularly in youth.

Given that psychological variables (e.g., quality of life, life satisfaction), family factors (e.g., parent marital status, parental involvement), and demographic characteristics (e.g., ethnicity, socioeconomic status) all appear to be correlated with metabolic control [28, 29], it is likely that these factors produce combined effects. For example, in a predominantly African-American, inner-city sample of patients hospitalized for DKA, those presenting with recurrent DKAs had higher rates of depression, as well as alcohol and drug abuse, compared to first-time DKA patients [13]. Family factors, such as family conflict and cohesion, may interact with socioeconomic status to determine the vulnerability of youth with type 1 diabetes to poor glycemic control [30]. Such interactions between risk factors could confer increased risk for adherence difficulties and DKA.

The aforementioned findings illuminate several factors that likely contribute to repeated DKAs in youth and adults, including demographic characteristics, psychological wellbeing, and family variables. These risk factors should inform preventative interventions and shape future research with the goal of reducing the overall burden to patients and the healthcare system.

Treatment for Recurrent DKAs: Existing Approaches

Beyond repeated emergency department (ED) visits and hospital admissions, there are several existing interventions designed to address repeated DKAs. These interventions vary in intensity (psychiatric inpatient stay vs. single office visit) and take place in a range of settings (e.g., medical clinics, mental health offices, patient homes) [31]. Here, we present key examples of existing approaches to specialized care for individuals with recurrent DKA and particularly highlight interventions that aim to decrease DKA recurrence (Table 1).

Education

Education about illnesses and symptom management is a standard part of medical practice, including healthcare related to type 1 diabetes. However, educating individuals and families may not be sufficient for preventing DKA in all families. For example, more than half of youth receiving an educational intervention that focused on their illness and DKA prevention were readmitted for DKA following treatment [32]. Education was administered by medical team nurse educators and dietitians within an interdisciplinary diabetes center. While some youth were not readmitted for DKA following additional education, a larger number required more intensive medical support and care coordination to decrease ED visits. Beyond that,

several children required even more intensive supports and were placed outside of the home due to family inability to adequately address healthcare needs. In the adult population, individuals who receive extra education about type 1 diabetes care do not differ from control patients in actual diabetes management [33]. Overall, intensive education about type 1 diabetes and DKA does not appear to prevent DKA on a large scale and, importantly, it may not suffice in treating especially vulnerable individuals or families.

Care Coordination Approach

Treatment approaches that consider various contexts of an individual's life have shown success in decreasing DKA for youth. In a seminal study on the topic approximately 40 years ago, Giordano and colleagues reported on the utility of a nurse-managed pediatric type 1 diabetes program [34]. Nursing specialists provided 24-hour call support and coordination of the broader medical team, as well as occasional home visits, as needed. Cooperation of various contexts (e.g., school, medical) was also sought for plans to target ongoing medical and social problems. Additionally, the program included a camp that provided intensive training about type 1 diabetes care to families, referring agencies, students, and teachers. ED visits were markedly decreased, especially in the second year of the program, wherein zero type 1 diabetes-related ED visits were recorded for any of the 76 enrolled youth.

Giordano and colleague's study marks an important early contribution to type 1 diabetes management via systems-based case management and has been replicated or partially replicated by subsequent studies for youth [e.g., 17] and adults [e.g., 18], although such approaches for adults appear less popular. The study illustrates the importance of care coordination and personalized type 1 diabetes-related care that exceeds the usual care of the medical system. However, only a portion (approximately one third) of the youth enrolled in this program represented especially challenging cases, and the authors note that patients who did not engage in the program were not reported on in the article. These limitations render a sample that may not best represent the population of youth who are most vulnerable to DKAs and who may need especially intensive and specialized intervention. It is unclear why such care coordination programs have not been more widely adopted. Likely, financial factors (e.g., difficulty billing for care coordination, lack of cost-analyses to support use) have resulted in significant barriers to expansion of these programs.

Cognitive-Behavioral Interventions

Cognitive-behavioral treatment (CBT), which focuses on changing thought and behavioral patterns to improve functioning, has also been modified to specifically target

Table 1 Summary of existing approaches to treatment for recurrent DKAs

Approach	Examples of interventions	Targeted effects
Care coordination	24-hour call support Coordination of medical team Cooperation of care systems	Reduced ED visits
Cognitive-behavioral	Diabetes education Coping skills training Cognitive restructuring Behavioral role-play Motivational interviewing	Improved adherence Reduced A1c levels Improved quality of life
Family systems	Contingency management Behavioral parent training Problem solving Strategic family therapy Structural family therapy	Improved adherence Reduced A1c level Improved relationships Improved communication
Telemedicine	Diabetes education Motivational support	Improved adherence Reduced A1c levels Reduced ED visits

adherence issues related to type 1 diabetes. One study compared the effects of intensive diabetes management alone in the medical setting versus the same care with additional coping skills training for adolescents with type 1 diabetes [35]. Coping skills training consisted of problem solving and behavioral role-play of difficult social situations related to diabetes management. Youth assigned to the intensive diabetes management plus coping skills group demonstrated higher self-reported quality of life and improved A1C levels as compared to youth who received intensive diabetes management alone. With ongoing booster sessions, these effects were maintained at 1-year follow-up. While this approach was not specifically examined as it relates to recurrent DKA, findings may be extrapolated regarding benefits for DKA-vulnerable youth. Other CBT-related approaches, such as a treatment which combined motivational interviewing with contingency management interventions, have also evidenced promising results in addressing suboptimal adherence [36••].

Family Systems Approaches

Interventions targeting the family and other systems have demonstrated success in intervening with a variety of difficult-to-treat youth, including youth with type 1 diabetes. One example, Behavioral Family Systems Therapy (BFST), addresses obstacles to health behaviors by utilizing a combination of family and skills-based interventions (i.e., family systems interventions, communication skills training, problem solving, and cognitive restructuring). BFST for Diabetes (BFST-D) has demonstrated efficacy and effectiveness in directly and indirectly improving adherence in youth with type 1

diabetes [37, 38], with an estimated moderate effect (i.e., 0.21) on improving glycemic control [26••]. Of note, BFST alone has been identified as improving family relationships and communication strategies [38] but only BFST-D has demonstrated effectiveness in improving type 1 diabetes management. Again, this treatment approach did not specifically target DKA recurrence but may suggest a component of intervention that is useful for vulnerable populations.

Multisystemic therapy (MST), a treatment initially developed for youth involved in juvenile delinquency, has been adapted for youth with chronically poor metabolic control. MST is an intensive, home-based family treatment that has demonstrated improved treatment adherence [39] and decreased episodes of DKA [40] in comparison to a non-treatment group for youth with type 1 diabetes and elevated A1C levels, with an estimated modest effect (i.e., 0.10) on glycemic control [26••]. As part of MST, patients received frequent home visits, ongoing phone contacts, and cognitive-behavioral therapy strategies per each family's particular needs. This program was implemented by trained MST therapists as a treatment that operated in addition to the youth's standard medical care.

Novel Interventions in Children's Healthcare [NICH: 41] was specifically developed for youth with type 1 diabetes who are repeatedly hospitalized for DKA. NICH services include a combination of family based problem solving, care coordination, and case management. NICH interventionists deliver services in the youth's natural environment (e.g., home, school, clinic, community), are available to families 24 h per day, 7 days per week, and utilize telecommunication to increase frequency of service provision. NICH appears to differ from other systemic approaches by specifically targeting youth with

repeated DKA, placing increased emphasis on the provision of care coordination, and utilizing daily telecommunication (e.g., text messages, phone calls, web-based video chat) to increase engagement with youth while maximizing efficiency. Telecommunication is individualized based on youth and family characteristics and is commonly used to monitor blood glucose levels and insulin intake, to provide frequent positive reinforcement for adherence, and to problem solve during crises (e.g., DKA events).

Preliminary data (Table 2) suggest that NICH is likely effective in reducing ED visits and hospital admissions for a subgroup of youth who appear particularly vulnerable to repeat DKAs [42••]. In addition, a pilot study of the NICH model found that participation in NICH was associated with improved glycemic control (i.e., mean decrease of 1 % in HbA1c). This pilot work also demonstrated reduced costs, including approximately \$13,000 less spent in yearly health care costs per patient while in NICH [43], resulting in a moderate treatment effect (i.e., 0.44). Although these results are promising, future evaluation of the NICH model would benefit from inclusion of a control group as well as a larger sample size.

Telemedicine

Current technology has also been incorporated into specialized care for type 1 diabetes, allowing for more frequent patient contact. While improved A1C levels have been demonstrated in a telemedicine intervention for adults [44], videoconferencing may be especially relevant to treating adolescents. One study identified a telemedicine program as an effective means of decreasing yearly ED visits of youth with type 1 diabetes [45]. Nurses provided ongoing videoconferencing with youth with type 1 diabetes who, for various reasons, had difficulty attending their regularly scheduled doctor's appointments. The program also included child-friendly type 1 diabetes education programs that could be accessed over the Internet. After 2 years,

the average number of ED visits decreased from 13 to 3.5 per year. In another investigation, intensive carbohydrate counting education and a personalized text messaging program ("Sweet Talk") was associated with improved adherence and self efficacy in adolescents, with results that were superior to usual care or text messaging alone [46]. These studies and others [e.g., 47, 48] demonstrate the potential utility of incorporating current contemporary modes of communication for improving the health status of youth with type 1 diabetes. However, these studies did not include patients based on DKA occurrence or ED visits and, importantly, some studies excluded cases with psychosocial risk factors.

Conclusions

Diabetes is a costly chronic health condition that places immense strain on patients, families, providers, and medical systems. Considerable resources are devoted to diabetes-related complications and repeated hospitalizations for preventable DKAs in both youth and adults with type 1 diabetes. Given the substantial financial burden associated with treatment of DKAs [6] and the high risk for DKA readmission, it is imperative that efficacious approaches are disseminated. Furthermore, priority should be placed on the evaluation of the cost effectiveness of current treatments and broader application of those treatments which demonstrate both improved health outcomes and cost savings.

Based on our impressions of the literature, certain demographic, psychological, and family factors may make subsets of the population particularly vulnerable to adherence problems and associated hospitalizations for diabetes-related complications, such as DKA. Adolescents and emerging adults, for example, are at risk for diabetes management difficulties, suboptimal glycemic control, and preventable hospitalizations for DKA [10, 11]. Ethnic minority status and lower socioeconomic status have also been associated with heightened susceptibility to diabetes-related complications and repeated hospitalizations for DKA [2, 12, 13]. Psychological problems, including depression, anxiety, and substance use appear to put individuals with diabetes at greater risk for adherence problems and complications [13–15]. Finally, family systems factors, such as cohesion, communication, and conflict, may also contribute to the likelihood of diabetes management difficulties [21, 24]. Ultimately, further research is needed to more thoroughly identify risk factors for low adherence and related DKA [49].

Although several different interventions have proven useful or potentially useful in decreasing the risk of DKA in individuals with type 1 diabetes, these interventions and related research present some common limitations to generalizing these results to the broader population. Several of the studies reviewed here included themes of exclusion of extreme or particularly complex cases. Given that those patients with multiple

Table 2 Summary of NICH Outcomes

	Prior to NICH enrollment	Post NICH enrollment
HbA1c		
M	11.6	10.7
SD	2.1	2.0
Hospital days		
M	7.0	2.6
SD	5.2	4.4
Cost of care		
M	US\$17,624.00	US\$4,633.56
SD	US\$1,175.92	US\$297.69

Sample size for HbA1c and hospital days: $n=12$; sample size for cost of care: $n=9$. Hospital days and cost of care are per year

risk factors appear most likely to display suboptimal adherence, these cases likely represent those at greatest risk for repeated DKAs and most in need for specialized care for DKA prevention. In addition, many of these programs appear to be office-based. Because those at greatest risk often experience a high level of financial insecurity and other barriers to appointment attendance (e.g., substance abuse/dependence, mental health problems, high family stress), interventions which are flexible (e.g., home- and community-based, provider availability outside of typical business hours) to meet the needs of these patients are more likely to be successful with this vulnerable population. Furthermore, many of these studies focused on singular components of care. Multiple components of care, and especially systems-based care [50], may be required to promote adherence [25] and successfully reduce DKA in vulnerable populations with type 1 diabetes.

Several different intervention strategies have been shown to be useful in reducing preventable hospitalizations associated with DKA in individuals with type 1 diabetes. Examples of existing approaches include education about illness and symptom management, behavioral interventions, systems-based approaches, and telemedicine. Our examination of the literature revealed several common limitations to generalizing these intervention strategies to the broader population. Given that existing approaches to promote adherence typically have modest effects on HbA1C [26••], it is imperative that the field continues to develop and evaluate novel and innovative treatment programs with the intent of having a more significant impact on youth health. Interventions designed to reduce recurrent DKA would benefit from flexible utilization of multiple evidence-based approaches to best combat the multiple combinations of risk factors experienced by individuals with type 1 diabetes and recurrent DKA. In addition, it is our belief that approaches which include 24/7 care coordination, are flexible in treatment delivery (e.g., home- and community-based, utilize technology), and target multiple risk factors across the many relevant systems (e.g., individual, family, school, medical), are warranted to effectively reduce preventable DKA in vulnerable populations. The further development, evaluation, and dissemination of such interventions will likely improve functioning in vulnerable populations and reduce the overall burden of type 1 diabetes on the healthcare system.

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Compliance with Ethics Guidelines

Conflict of Interest David V. Wagner, Maggie Stoeckel, Megan E. Tudor, and Michael A. Harris declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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