Predictors of type 1 diabetes mellitus outcomes in young adults after transition from pediatric care

Highlights
- Several predictors of type 1 diabetes outcomes in young adults after transition from pediatric care have been investigated separately in different studies and in various study participants; the present study assessed these predictors and outcomes in the same individuals.
- The present study shows that poor glycemic control and hospitalization for hyperglycemia track from before to after transition.
- Having less education and the presence of comorbidities increase the risk of poor outcomes in young adults with type 1 diabetes.

Abstract
Background: Type 1 diabetes (T1D) is a common chronic disease. Poor health outcomes are often noted after transfer to adult health care. It is important to determine the predictors of such outcomes to decrease morbidity and mortality.

Methods: The present retrospective study included patients followed for ≥ 1 year before and ≥ 1 year after transfer to adult care in a Canadian tertiary diabetes center. Data including demographics, education, comorbidity and pediatric diabetes management-related factors were analyzed as possible independent predictors of adult HbA1c, number of adult diabetes-related hospitalizations, and clinic visits.

Results: In all, 102 youths were followed to a mean (±SD) age of 21.8 ± 1.5 years. Predictors of mean adult HbA1c using linear regression were the presence of any comorbidity (0.71%; 95% confidence interval [CI] 0.15–1.27; \( P = 0.01 \)) and pediatric HbA1c (0.67% per 1% increase in HbA1c; 95% CI 0.51–0.84; \( P < 0.001 \)). Predictors of hospitalization for hyperglycemia were a history of pediatric hospitalization for hyperglycemia (incidence rate ratio [IRR] 1.20; 95% CI 1.02–1.41; \( P = 0.029 \)) and high school vs university education (IRR 3.13; 95% CI 1.12–8.73; \( P = 0.030 \)).

Conclusion: Young adults with complicated health histories and less education are more likely to experience poor diabetes outcomes in the years after transfer to adult care. These features may highlight youth requiring closer attention or may be targets for intervention.

Keywords: hospital visits, metabolic control, transition, type 1 diabetes mellitus.

Introduction
Type 1 diabetes mellitus (T1DM) is a common chronic disease in children and adolescents with complications that cause substantial disability and death.\(^1,2\) Because the incidence of T1DM is increasing worldwide, in both low- and high-incidence populations,\(^3\) an increasing number of children will be transitioned from pediatric to adult care.

Transition to adult care for those with childhood-onset chronic diseases occurs during a critical period...
marked by both psychological and physiological changes associated with adolescence. Consequently, young adults with T1DM are at particularly high risk for poor glycemic control, recurrent admissions due to diabetic ketoacidosis and loss to follow up.

Several health outcomes have been studied in young adults with T1DM emerging from transition. Clinic attendance rates decrease significantly and diabetes-related hospitalizations increase after transition to adult care, but participants who continue with the same diabetes physician have been shown to be less likely to experience post-transition diabetes-related hospitalization. Glycemic control (HbA1c) before and after transition has also been assessed and was not significantly different between time points. Most of these outcomes have been investigated separately in different studies, and none of the studies attempted to analyze the possible predictors of all these outcomes and to investigate the association between these outcomes before and after transition in the same individuals.

The aim of the present study was to assess the predictors of T1DM outcomes in young adults who were transitioned from the pediatric diabetes clinic to the adult diabetes clinic in one tertiary diabetes center with relatively uniform pediatric diabetes care, method of transition and adult diabetes care, allowing isolation of the effect of patient characteristics to help us predict who will have poorer outcomes and, accordingly, to adopt modified strategies and closer follow-up for those participants during the transition period. Similarly, the study would enable identification of predictors of favorable outcomes, which could be incorporated into pediatric diabetes care if they are modifiable.

Methods

The present study was a descriptive retrospective cohort study of young adults with T1DM followed at a single Canadian tertiary care adult diabetes clinic. The study received institutional ethics approval and was conducted in accordance with the Declaration of Helsinki. Youths were included in the study if they were at least 1 year post-transfer to adult care, had participated in the transition clinic (a single visit during their final year in pediatric care to prepare them for the different approach in adult care) and had received at least 1 year of pediatric diabetes care in the pediatric diabetes clinic at the same institution before the transition clinic visit. The observation time was divided into three periods: (i) pediatric care (the time from the diagnosis of diabetes to the first transition visit); (ii) transition (1 year following the transition clinic visit); and (iii) adult care (the time from the end of the transition year until the latest adult diabetes clinic visit before data abstraction).

Data were abstracted from clinical records and from a prospective transition database. Four outcomes of interest were assessed: (i) mean HbA1c during the latest year of adult care in the study; (ii) the number of hospital visits (including emergency room [ER] visits and hospital admissions) due to hyperglycemia during adult care; (iii) the number of hospital visits (including ER visits and hospital admissions) due to hypoglycemia during adult care; and (iv) the number of diabetes clinic visits during the latest year of adult care.

Several independent variables were analyzed as possible predictors of the outcomes, including age at diagnosis with diabetes, gender, body mass index (BMI) at the end of pediatric follow-up, the presence of any comorbidity (e.g. hypothyroidism, Graves’ disease, celiac disease, asthma, hypertension, single kidney), educational level at the latest adult visit (university, college, or high school), upgraded insulin regimen (whether the patient switched from two or three injections of insulin per day to a basal-bolus injection regimen, or from any injection regimen to an insulin pump from the last pediatric visit to the latest adult visit, and metabolic control in pediatric life as reflected by the mean of HbA1c values measured during the pediatric year preceding the first transition visit. A history of any hospital visits (admissions or ER visits) due to hyperglycemia or diabetic ketoacidosis during pediatric care, a history of any hospital visits (admissions or ER visits) due to hypoglycemia during pediatric care, and the number of diabetes clinic visits during the pediatric year preceding the first transition visit were also analyzed as possible predictors.

Data were analyzed using SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). Data are presented as n (%) or as the mean ± SD. To assess for tracking of characteristics into adult life, Pearson correlation was used to measure the strength of the association between variables in pediatric and adult life, and paired t-tests were used to test for significant differences between variables in pediatric and adult life. Linear regression was used to analyze the HbA1c outcome. Negative binomial regression was used to assess frequency of hospital and clinic visits, with the duration of adult care included as an offset variable in analyses of adult hospital visits to account for varying follow-up time. Potential predictors of interest were assessed first using univariate regression and then multiple regression including all variables in the model. Two-sided $P < 0.05$ was considered nominally significant.
Results

The characteristics of the 102 participants who fulfilled the inclusion criteria are given in Table 1. A large proportion had post-secondary education (73%) and 68% were students at the time of the latest adult visit. Overall, 39% of participants had comorbidities including hypothyroidism, Graves' disease, celiac disease, asthma, and hypertension.

Table 1  Participant characteristics (n = 102)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pediatric care (n = 102)</th>
<th>Adult care (n = 102)</th>
<th>P-value (paired t-test)</th>
<th>Pearson r</th>
<th>Correlation P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at time of diabetes diagnosis (years)</td>
<td>9.5 ± 4.2</td>
<td>9.1 ± 4.2</td>
<td>0.037</td>
<td>0.73</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Occupational (n) (%)</td>
<td>27 (27)</td>
<td>21 (21)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of education of the participant</td>
<td>High school</td>
<td>College</td>
<td>University</td>
<td>Working</td>
<td>Student</td>
</tr>
<tr>
<td>At latest adult visit</td>
<td>21 (21)</td>
<td>51 (52)</td>
<td>49 (48)</td>
<td>24 (23.5)</td>
<td>70 (68.6)</td>
</tr>
<tr>
<td>Presence of any comorbidity at end of</td>
<td>40 (39)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI at end of pediatric follow-up (kg/m²)</td>
<td>Mean ± SD</td>
<td>24.5 ± 4.2</td>
<td>0.17</td>
<td></td>
<td>0.14</td>
</tr>
</tbody>
</table>

Relationships between diabetes management outcomes during pediatric care and adult care are summarized in Table 2. There were correlations between pediatric and adult HbA1c values (r = 0.73, P < 0.001), as well as between pediatric and adult frequency of hospital visits for hyperglycemia (r = 0.38, P < 0.001). Clinic attendance frequency declined significantly from pediatric to adult care (from 2.71 ± 1.18 to 2.09 ± 0.72 visits/year; P < 0.001), but was not correlated between the two time frames (r = 0.09, P = 0.37).

Univariate and multivariate associations between HbA1c during the latest year of follow-up in adult care and various potential predictors are given in Table 3. In multiple linear regression, the whole model was statistically significant (adjusted R² = 0.54, P < 0.001), with only two variables identified as significant predictors of HbA1c in the latest year of adult follow-up: (i) the presence of any comorbidity (HbA1c difference 0.71% [95% confidence interval {CI} 0.15, 1.27] or 7.8 mmol/mol [95% CI 1.6, 13.9]; P = 0.01) and mean HbA1c during the last year of pediatric care (HbA1c difference 0.67% [95% CI 0.51, 0.84] or 7.3 mmol/mol [95% CI 5.6, 9.2]; P < 0.001).

The relationships between the frequency of hospital visits for both hyperglycemia and hypoglycemia and various potential predictors are given in Table 4. For adult hospital visits for hyperglycemia, the multivariable model was significant (P = 0.002), and the significant predictors were lower education level (for high school vs university, incidence rate ratio [IRR] 3.13; 95% CI 1.12, 8.73; P = 0.030) and a history of pediatric hospital visits for hyperglycemia (IRR 1.20; 95% CI 1.02, 1.41; P = 0.029). However, in multivariate analysis of adult hospital visits for hypoglycemia, the whole model was not significant (P = 0.303) and none of the independent variables had a statistically significant
effect on the incidence of adult hospital visits due to hypoglycemia.

Adult diabetes clinic visit frequency was not predicted by the measured variables (model not shown; $P = 1.00$).

**Discussion**

The present study of young adults with T1DM shows that glycemic control and the tendency for acute hyperglycemic decompensation track strongly from before transition to adult care to the early post-transition years.

In the single-center clinic population studied herein, there was no significant change in glycemic control from late pediatric to early adult care ($\text{HbA1c} 8.82\% \pm 1.84\% [73 \pm 20 \text{ mmol/mol}]$ vs $8.95\% \pm 1.82\% [74 \pm 20 \text{ mmol/mol}]$, respectively; $P = 0.317$), and there was a strong correlation suggesting that 53% of variation in young adult HbA1c is explained by HbA1c values during childhood. This issue is contentious in the literature, with some studies corroborating our findings, whereas others show no difference in HbA1c between pediatric and adult care.

In assessing the predictors of glycemic control represented by HbA1c in early adulthood, two variables exerted a statistically significant effect. First, the difference in mean young adult HbA1c was $0.67\% (7.3 \text{ mmol/mol})$ per $1\% (10.9 \text{ mmol/mol})$ difference in the mean pediatric HbA1c after adjusting for other variables. This value is lower than the $1.2\%$ per $1\%$
(13.1 per 7.3 mmol/mol) estimated in a pilot trial at the end of a 1-year follow-up post-transfer from pediatric care\(^1\) (vs a mean duration of adult care of 2.08 years in the present study). One interpretation is that the association between metabolic control in pediatric and adult periods may wane over time. Second, the presence of any comorbidity was associated with a 0.71\% (7.8 mmol/mol) higher mean HbA1c in adulthood. One study revealed similar results in terms of a higher probability of worsening in HbA1c with the presence of a comorbidity;\(^1\) another study showed no relationship between comorbidities and glycemic control in adults.\(^1\) These discrepancies may be due to the differences in the types and duration of other diseases present in the other studies. If the presence of comorbidities has a deleterious effect on metabolic control, it may occur through psychological effects, disease interactions, or adverse effects of medications.

The frequency of diabetes-related ER visits and hospital admissions due to either hypoglycemia or hyperglycemia did not change from the pediatric to adult follow-up periods, similar to what has been seen in another study.\(^1\) Persistent risk of acute decompensation may be due to maintenance of similar glycemic control and similar diabetes management habits through the transition from pediatric to adult care, and challenges the notion that transition is a universally vulnerable time. Nevertheless, hospital encounters were reported quite frequently in the present study and are of concern because diabetic ketoacidosis is the main cause of death in children with T1DM.\(^1\)

The number of clinic visits per year shows a decline of almost 23\% from the last pediatric year to the latest adult year down to a frequency of clinic visits below what is recommended by Canadian practice guidelines.\(^1\) However, there was no concomitant deterioration in HbA1c, which is consistent with other studies.\(^9,16\) The decline in the frequency of clinic visits may be affected by the patient–doctor relationship or reduced parental supervision. Despite the fact that in the present study this decrease was not accompanied by a change in metabolic control or acute hospital visits, regular follow-up visits are still important to detect and prevent long-term complications.\(^21\)

The two statistically significant variables affecting the incidence of adult hospital visits due to hyperglycemia were the level of education and pediatric hospital visits due to hyperglycemia. Participants with only a high school education had a 213\% higher incidence of hospital admissions than participants with university education after adjusting for other variables. Similar non-significant trends were seen for college education. This may be explained, in part, by the association seen in univariate analysis between lower education level and poorer glycemic control. This association between education and better glycemic control has been demonstrated before.\(^22\) Furthermore, participants with a history of pediatric hospital visits had a higher incidence of adult hospital visits, although this was only detected for hospital visits due to hyperglycemia. Other studies showing an increase in pre-transition (pediatric) diabetes-related hospitalization leads to an increase in diabetes-related hospitalization in the adult period did not assess differences between hyper- and hypoglycemic hospitalizations.\(^11\)

The present study has some limitations. First, the study was only able to assess outcomes in young adults who attended the adult clinic, and could not evaluate

### Table 4

**Frequency of diabetes-related adult hospital visits due to hyperglycemia and hypoglycemia (negative binomial regression)**

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Adult hospital visits for hyperglycemia</th>
<th></th>
<th>Adult hospital visits for hypoglycemia</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at diagnosis</td>
<td>IRR (95% CI)</td>
<td>0.99 (0.89, 1.11)</td>
<td>P-value</td>
<td>1.09 (0.90, 1.33)</td>
</tr>
<tr>
<td>Female gender</td>
<td>IRR (95% CI)</td>
<td>1.27 (0.48, 3.41)</td>
<td>P-value</td>
<td>2.75 (0.56, 13.49)</td>
</tr>
<tr>
<td>Body mass index</td>
<td>IRR (95% CI)</td>
<td>1.02 (0.92, 1.13)</td>
<td>P-value</td>
<td>0.98 (0.82, 1.16)</td>
</tr>
<tr>
<td>Presence of any comorbidity</td>
<td>IRR (95% CI)</td>
<td>0.62 (0.23, 1.67)</td>
<td>P-value</td>
<td>2.91 (0.64, 13.21)</td>
</tr>
<tr>
<td>Most recent level of education (vs university)</td>
<td>IRR (95% CI)</td>
<td>0.66 (0.34, 5.44)</td>
<td>P-value</td>
<td>1.13 (0.15, 8.66)</td>
</tr>
<tr>
<td>College</td>
<td>IRR (95% CI)</td>
<td>0.03 (1.12, 8.73)</td>
<td>P-value</td>
<td>1.57 (0.28, 8.87)</td>
</tr>
<tr>
<td>High school</td>
<td>IRR (95% CI)</td>
<td>2.72 (0.02, 2.19)</td>
<td>P-value</td>
<td>0.12 (0.20, 7.05)</td>
</tr>
<tr>
<td>Upgraded insulin regimen</td>
<td>IRR (95% CI)</td>
<td>0.11 (0.85, 1.45)</td>
<td>P-value</td>
<td>0.06 (0.52, 1.41)</td>
</tr>
<tr>
<td>Mean HbA1c (%) during last pediatric year</td>
<td>IRR (95% CI)</td>
<td>0.13 (0.84, 2.10)</td>
<td>P-value</td>
<td>1.10 (0.54, 2.26)</td>
</tr>
<tr>
<td>Pediatric hospital admissions due to hypoglycemia</td>
<td>IRR (95% CI)</td>
<td>1.20 (1.02, 1.41)</td>
<td>P-value</td>
<td>1.24 (0.97, 1.60)</td>
</tr>
<tr>
<td>Pediatric hospital admissions due to hyperglycemia</td>
<td>IRR (95% CI)</td>
<td>0.82 (0.55, 1.24)</td>
<td>P-value</td>
<td>0.83 (0.42, 1.65)</td>
</tr>
</tbody>
</table>

CI, confidence interval; IRR, incidence rate ratio.
risk factors among the most vulnerable, namely those who were lost to follow-up before arriving in adult care. In addition, the small sample size and the short duration of adult follow-up resulted in limited power to assess associations with hospital visit events, particularly visits for hypoglycemia, which were quite uncommon. Furthermore, due to less-than-systematic clinical documentation of additional potential predictors of interest, such as distance from the medical center, participants’ psychological condition, and diabetes management skills, the scope of the retrospective chart review was limited to routinely documented variables. In light of these limitations, prospective studies should be conducted on a larger number of participants for longer periods of follow-up to identify other meaningful and potentially modifiable risk factors for poor outcomes of youth with diabetes after transition to adult care.

Conclusion

Poor glycemic control and hospital visits for hyperglycemia track from pre- to post-transition to adult care. Furthermore, having less education and having to manage other comorbidities increase the risk of poor outcomes in young adults with T1DM. There were no identified pre-transition predictors of hypoglycemic hospital visits or adult clinic visit frequency. The identified predictors draw attention to particularly high-risk youth who may benefit from closer monitoring after transition, or further interventions to manage their diabetes and other health concerns before transition to reduce their risk after transfer to adult care.

Disclosure

None declared.

References

