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Disparities in Continuous Glucose Monitor Use Between Children With Type 1 Diabetes Living in Urban and Rural Areas

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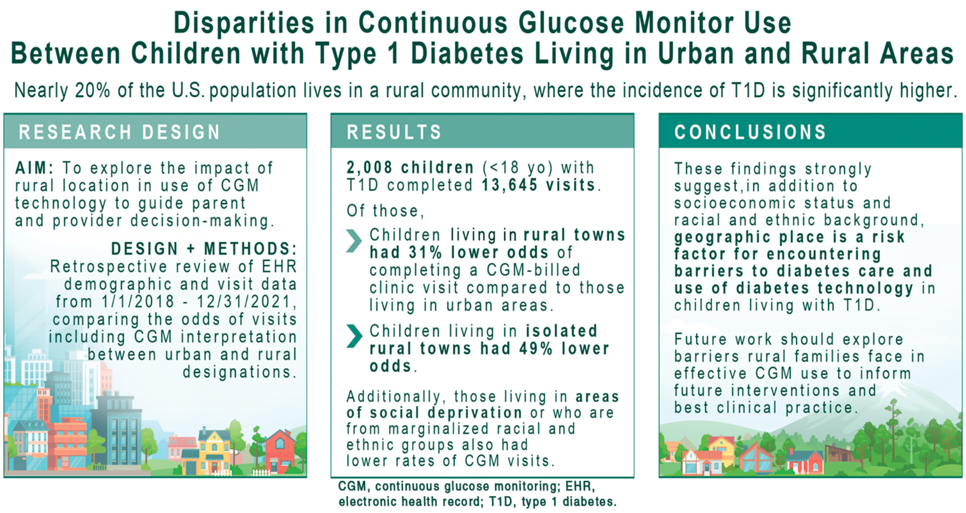

ARTICLE HIGHLIGHTS

- **Why did we undertake this study?**
  Evidence suggests that rural geography is a barrier to accessing health care among adults with diabetes, but little is known about care for children with type 1 diabetes.
- **What is the specific question we wanted to answer?**
  We wanted to assess differences in continuous glucose monitor use between children living in rural areas compared with their urban peers.
- **What did we find?**
  Children living in small and isolated rural towns had significantly lower odds of completing continuous glucose monitor-billed clinic visits compared with their urban peers.
- **What are the implications of our findings?**
  Rural geography is an underrecognized barrier to care among children with type 1 diabetes—future research should evaluate barriers to care faced by these patients and their families.

ORIGINAL ARTICLE

Disparities in Continuous Glucose Monitor Use Between Children With Type 1 Diabetes Living in Urban and Rural Areas

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OBJECTIVE

Despite evidence that continuous glucose monitoring (CGM) use is associated with lower HbA_{1c} among children with type 1 diabetes, uptake of this technology remains lower among those with difficulty accessing health care, including those from lower socioeconomic status backgrounds and racial and ethnic minorities. In this study, we sought to explore the impact of rural location in use of CGM technology to guide patient and provider decision making.

RESEARCH DESIGN AND METHODS

In this retrospective study of electronic health record demographic and visits data from a single diabetes program from 1 January 2018 through 31 December 2021, we compared the odds of completing a visit with (+) and without (−) CGM interpretation between rural-urban commuting area (RUCA) designations.

RESULTS

Among the 13,645 visits completed by 2,008 patients with type 1 diabetes younger than age 18 years, we found children living in small rural towns had 31% lower odds (6.3% of CGM+ visits, 8.6% of CGM− visits; adjusted odds ratio [aOR] 0.69, 95% CI 0.51–0.94) and those living in isolated rural towns had 49% lower odds (2.0% of CGM+ visits, 3.4% of CGM− visits; aOR 0.51, 95% CI 0.28–0.92) of completing a CGM-billed clinic visit compared with those living in urban areas (70.0% of CGM+ visits, 67.2% of CGM− visits). We also found significant differences in CGM-billed visits by neighborhood deprivation as well as race/ethnicity and insurance payor.

CONCLUSIONS

Geographic location presents a meaningful barrier to access to care for patients living with type 1 diabetes. Further work is needed to identify and address the needs of children and families living in rural areas to improve the care of these patients.

Continuous glucose monitor (CGM) use by children and adolescents with type 1 diabetes has been shown to improve glycemic outcomes in numerous, high-quality studies (1–3). CGMs decrease barriers to glucose monitoring by providing noninvasive, nearly real-time data to people with diabetes and their caregivers to inform daily insulin treatment decisions. In addition, online, cloud-based portals display long-term trends in blood glucose and provide important longitudinal data to providers, caregivers, and people with diabetes to guide adjustments in insulin regimens

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See accompanying article, p. 344.

and optimize glycemic outcomes. Despite these benefits in both short- and long-term outcomes associated with CGM use, previous studies have suggested substantial socioeconomic disparities in CGM prescriptions (4–6). Specifically, studies based on medical record review and CGM prescription data indicate that people with diabetes from lower socioeconomic status (SES), those who have public health insurance, and those from historically minoritized racial/ethnic groups lagged in important diabetes outcomes in general and use of CGM technology in particular (4,5,7–9).

While rural patients often face many of these same barriers to care access, such as limited access to broadband internet and difficulty with travel to urban or suburban medical clinics, disparities in CGM access by rurality remain underinvestigated (10–13). This is despite nearly 20% of the U.S. population living in rural areas, where the incidence of type 1 diabetes is significantly higher than in urban communities (14–16). Disparities in outcomes and increased care utilization among children with type 1 diabetes and other chronic diseases suggest that rural geography may contribute to adverse outcomes (17–26). Notably, results from the Type 1 Diabetes (T1D) Exchange—a national, clinic-based registry of people with type 1 diabetes—showed significantly higher average HbA_{1c} among rural residents of all ages, with the largest disparities among children and young adults (25). These data highlight the need to better understand the causes of these disparities in order to address the needs of this population.

An important limitation of previous evaluations of CGM use among children and adolescents with type 1 diabetes was the reliance of these studies on prescription and medical record review to identify CGM use. Given substantial barriers to obtaining and using the devices, including cost, health system barriers, and diabetes-related stigma, there is likely a significant gap between being provided a CGM prescription and clinical CGM use. These barriers to use that occur after a prescription is written mean that a substantial number of people who receive a prescription for a CGM will not actually use the device. In this retrospective cohort study, we sought to better understand patterns of CGM use, defined by provider CGM billing codes, among a single-center cohort of pediatric patients with type 1 diabetes living in rural areas compared with those living in urban settings. We hypothesized that pediatric patients with type 1 diabetes living in rural or socioeconomically deprived areas would have lower rates of clinic billing-defined CGM use compared with their urban and/or socioeconomically advantaged counterparts.

RESEARCH DESIGN AND METHODS

We performed a retrospective cohort study of patients with type 1 diabetes identified in the Research Derivative, a database derived from Vanderbilt University Medical Center's clinical data systems and restructured for research. For this study, patients were included if they had a clinic visit in the Vanderbilt Pediatric Diabetes Program, which includes sites at an urban tertiary care hospital campus as well as four satellite clinics across middle and west Tennessee. Patients were included in the analysis if they completed at least one clinic visit with a pediatric endocrine provider each calendar year between 1 January 2018 and 31 December 2021. Patients were identified as having type 1 diabetes using the provider-assigned ICD-10, Clinical Modification diagnosis code (E10.*), a highly specific predictor of diabetes diagnosis that has been used in previous, similar analyses (27,28). Patients were excluded if they died prior to study completion or if they had a co-occurring diagnosis of cystic fibrosis to exclude patients with cystic fibrosis-related diabetes. To exclude certified diabetes care and education specialist or registered dietitian visits, we required a documented point-of-care HbA_{1c} result or a telemedicine specific billing code to be present on the day of a visit, both of which are done by protocol at every at medical doctor or nurse practitioner visit and with no other visit types. All eligible patients and patient visits were included in the final analysis. Visits at any of these care sites, as well as telemedicine visits conducted during the study period, were included in this analysis. Demographic data were extracted at the date of data extraction (30 April 2022) and used for analysis. This study was approved by the Vanderbilt University Institutional Review Board (IRB no. 201015). This manuscript follows the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines for cohort data reporting (29).

We assigned each patient a Rural-Urban Commuting Area (RUCA) 2010 code based on U.S. Census Tracts of their home address. Level 2 RUCA codes were then coded using the University of Washington's RUCA Categorization C (30,31). Similar methods were used to assign each patient a neighborhood deprivation index (NDI) value based on their home census tract (32). NDI is a composite score of 10 measures of socioeconomic status available as a part of the American Community Survey and developed to reflect U.S. Census Tract-level deprivation. NDI values range from -3.6 to 2.8, with higher values indicating higher deprivation (lower socioeconomic status). Visits were included for analysis among eligible patients if all demographic data were present, insurance information was available in the calendar year, and an HbA_{1c} value was obtained within 3 months of the visit date.

The primary outcome was the presence or absence of the CGM interpretation Current Procedural Terminology (CPT) code (95251) with a completed pediatric endocrinology patient visit. Centers for Medicare & Medicaid Services guidelines require that providers review at least 72 h of CGM data in order to assign this code to a clinical visit. Starting in July 2017, division administrative policy was changed to require assignment of this CPT code for patient visits where CGM data were interpreted. For this study, data were included starting 1 January 2018 to minimize variation in CPT-based billing. During the study period, CGM prescribing was left to the discretion of the treating provider and available to all children treated in the practice.

During the 5-year study period, patients were seen at multiple clinic visits. Therefore, our analysis leveraged data from all patient visits and considered visits to be clustered within a patient. Descriptive statistics were used to compare characteristics between patient visits with and without the CGM billing code. Generalized estimating equations with a logit link for the binary outcome of completing a CGM-coded visit were used to estimate adjusted odds ratios (aORs) and 95% CIs across demographic characteristics. The models used a robust variance estimator to account for within-person correlation and were weighted by the total number of visits to account for potentially informative imbalances in the number of visits across patients (33). Covariates were selected based on previous evaluations in nonrural populations, which have shown several demographic factors, including electronic health record-documented sex, race, and insurance type, are associated with significant differences in CGM use (6). Given increasing CGM adoption across the study period and strong evidence of decreasing HbA_{1c} with sensor use, we also adjusted for these factors in our final model (1). Analyses were completed using Stata 17.0 software (StataCorp, College Station, TX).

Data and Resource Availability

The data sets generated during and/or analyzed in the current study are available from the corresponding author upon reasonable request.

RESULTS

Visit and Patient Demographics

Across this 52-month study, a total of 2,008 children with type 1 diabetes were seen across 13,645 patient visits, of which 5,485 visits (40.2%) had a billing code for CGM interpretation. Among these 2,008 patients, more than two-thirds (1,356; 67.5%) had at least one encounter where a CGM was interpreted. Overall patient and visit-level characteristics were similar (Table 1), reflecting relatively uniform visit frequencies across captured demographic categories. Approximately two-thirds (9,308; 68.2%) of patient visits were completed by patients living in RUCA-designated urban areas, while 2,907 visits (21.3%) were from those residing in large rural towns. Just over 10% of visits were completed by those living in small rural towns (1,046; 7.7%) or isolated small rural towns (384; 2.8%). Male patients made up a slight majority of visits (52.9%; 7,219), while White, non-Hispanic patient visits were more than three-quarters (10,751; 78.8%) of visits, reflecting the overall demographics of type 1 diabetes nationally (34). Our sample included ~10% of patient visits from Black, non-Hispanic patients (1,399; 10.3%), while Hispanic patients (408; 3.0%) as well as patients from other racial and ethnic backgrounds (1,087; 8.0%) made up a smaller percentage of visit totals. There were 4,098 visits (30.0%) completed by patients with Medicaid as the primary insurer. Year-to-year visit numbers were stable from 2018 to 2019 (3,737 vs. 3,861), with fewer visits meeting inclusion criteria in 2020 (2,614), corresponding with the onset of the coronavirus disease 2019 (COVID-19) pandemic. Visits numbers increased again in 2021 but did not return to prepandemic levels (3,433). Visits with CGM use rose as a proportion of all visits across the 4 years with complete data (19.9% of visits in 2018 vs. 57.2% in 2021) (Fig. 1), although the absolute number of CGM-billed visits fluctuated due to decreased overall visits in 2020 during the COVID-19 pandemic.

Table 1—Demographic characteristics of patients and patient visits

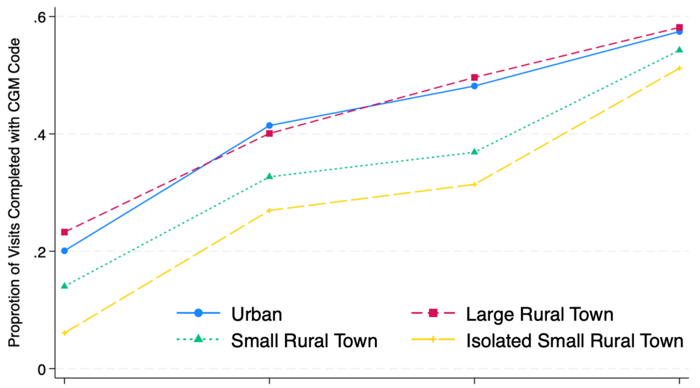
	All patient visits (*N* = 13,645)	All patients (*N* = 2,008)
No. with CGM billing code*	5,485 (40.2)	1,356 (67.5)
NDI, mean (SD)	−0.026 (0.904)	0.023 (0.900)
RUCA (geographic) designation		
Urban	9,308 (68.2)	1,337 (66.6)
Large rural city/town	2,907 (21.3)	447 (22.3)
Small rural town	1,046 (7.7)	168 (8.4)
Isolated small rural town	384 (2.8)	56 (2.8)
Sex		
Female	6,426 (47.1)	940 (46.8)
Male	7,219 (52.9)	1,068 (53.2)
Race/ethnicity		
White, non-Hispanic	10,751 (78.8)	1,505 (75.0)
Black, non-Hispanic	1,399 (10.3)	198 (9.9)
Hispanic	408 (3.0)	63 (3.1)
Other	1,087 (8.0)	242 (12.1)
Age (years), mean (SD)	16.0 (4.3)	15.6 (4.7)
Visit insurance type		
Commercial	9,547 (70.0)	1,370 (68.2)
Medicaid	4,098 (30.0)	638 (31.8)
Year†		
2018	3,737 (27.4)	1,220 (60.8)
2019	3,861 (28.3)	1,298 (64.6)
2020	2,614 (19.2)	1,182 (59.0)
2021	3,433 (25.2)	1,342 (66.8)
HbA_{1c} (%), mean (SD)	8.8 (2.0)	8.8 (1.8)
HbA_{1c} (mmol/mol), mean (SD)	73 (22)	73 (20)

Data are presented as *n* (%), unless indicated otherwise. *Shown is the number of visits with a CGM billing code or the number of patients with at least one visit with a CGM billing code. †Shown is the number of visits that year or the number of patients with a visit in the listed study year.

Visit-Level Associations of Rurality With CGM Use

We first compared crude rates of CGM visits by RUCA code (Fig. 1). Despite an increasing proportion CGM-billed visits from each RUCA designation, in each complete year of data from 2018 to 2021, we observed a lower proportion of CGM-billed visits being completed by those in the two most rural RUCA designations (small rural and isolated rural towns). On average, from 2018 to 2020, people with type 1 diabetes from small rural towns completed eight fewer CGM-billed visits per 100 visits compared with those from larger rural towns. In 2020, likely due to the effects of the COVID-19 pandemic, this difference grew to >13 CGM-billed visits per 100 total visits. Rates of CGM-billed visits from the most rural RUCA designation significantly lagged those in the largest two RUCA designations from 2018 to 2020, with ~13 fewer CGM-billed visits per 100 total visits coming from these most rural patients. While this gap narrowed in 2021 for both of the two most rural patient groups, these patients still completed these visits at a notably lower rate their more urban counterparts.

To assess these differences more carefully, we conducted our primary regression analysis. In our adjusted primary analysis, increasing rurality was associated with significantly lower odds of CGM use (Table 2). Specifically, the odds of a CGM-billed visit were 31% lower among those living in small rural towns (odds ratio [OR] 0.69, 95% CI 0.51–0.94) and 49% lower among those living in isolated small rural towns (OR 0.51, 95% CI 0.28–0.92) compared with those living in urban areas



Year	2018	2019	2020	2021
Total Visits	3,737	3,861	2,614	3,433
Total CGM Visits (%)	744 (19.9)	1,545 (34.7)	1,232 (47.1)	1,964 (57.2)
Urban CGM Visits (%)	500 (20.1)	1,085 (41.4)	877 (48.2)	1,366 (57.4)
Large Rural CGM Visits (%)	194 (23.3)	329 (40.1)	262 (49.6)	421 (58.1)
Small Rural CGM Visits (%)	44 (14.0)	100 (32.7)	66 (36.9)	134 (54.3)
Isolated Rural CGM Visits (%)	6 (6.1)	31 (27.0)	27 (31.4)	43 (51.2)

Figure 1—Proportion of visits with CGM billing by study year and rurality.

after adjusting for sex, race/ethnicity, HbA_{1c}, visit year, and insurance type. Prior to adjustment, similar statistically significant trends and estimates of effect size were observed.

We also observed associations between visit-level CGM use with multiple covariates of interest. In both adjusted and unadjusted models, those with public insurance had significantly lower odds of CGM use during clinic visits (unadjusted OR 0.44, 95% CI 0.38–0.52; aOR 0.58, 95% CI 0.48–0.69) compared with those with private insurance coverage. Similarly, people with diabetes from historically marginalized racial and ethnic backgrounds had lower observed odds of CGM-billed visits compared with white patients, with non-Hispanic Black (OR 0.32, 95% CI 0.24–0.42) and Hispanic (OR 0.47, 95% CI 0.28–0.80) patients having significantly lower odds of

Table 2—Visit-level associations between CGM billing code and rurality of home address

	Visit type		OR of CGM use for patient visits (95% CI)			
	CGM+	CGM−	Unadjusted	*P* value	Adjusted*	*P* value†
Rurality						
Urban	3,828 (70.0)	5,480 (67.2)	Reference		Reference	
Large rural town	1,206 (22.0)	1,701 (21.0)	1.05 (0.88–1.25)	0.618	1.07 (0.90–1.29)	0.444
Small rural town	344 (6.3)	702 (8.6)	0.73 (0.55–0.98)	0.033	0.69 (0.51–0.94)	0.018
Isolated small rural town	107 (2.0)	277 (3.4)	0.57 (0.34–0.97)	0.037	0.51 (0.28–0.92)	0.025
Sex						
Female	2,661 (48.5)	3,765 (46.1)	Reference		Reference	
Male	2,824 (51.5)	4,395 (53.9)	0.91 (0.79–1.06)	0.234	0.87 (0.75–1.02)	0.082
Race/ethnicity						
White, non-Hispanic	4,657 (84.9)	6,094 (74.7)	Reference	<0.001	Reference	<0.001
Black, non-Hispanic	271 (5.9)	1,128 (13.8)	0.32 (0.24–0.42)		0.48 (0.35–0.65)	
Hispanic	100 (1.8)	308 (3.8)	0.47 (0.28–0.80)		0.54 (0.33–0.86)	
Other	457 (8.3)	630 (7.7)	0.86 (0.65–1.13)		0.64 (0.48–0.85)	
Age (years), mean (SD)	15.0 (4.4)	16.7 (4.0)	0.92 (0.90–0.93)	<0.001	0.93 (0.92–0.95)	<0.001
Insurance type						
Commercial	4,404 (80.3)	5143 (63.0)	Reference	<0.001	Reference	<0.001
Medicaid	1,081 (19.7)	3017 (37.0)	0.44 (0.38–0.52)		0.58 (0.48–0.69)	
Visit year						
2018	744 (13.3)	2993 (36.7)	Reference	<0.001	Reference	<0.001
2019	1,545 (27.8)	2316 (28.4)	2.65 (2.37–2.96)		2.79 (2.47–3.14)	
2020	1,232 (22.1)	1382 (16.9)	3.51 (3.08–4.01)		3.78 (3.29–4.36)	
2021	1,964 (35.2)	1469 (18.0)	5.43 (4.75–6.61)		6.04 (5.21–7.00)	
HbA_{1c} (%), mean (SD)	8.0 (1.4)	9.3 (2.2)	0.68 (0.65–0.70)	<0.001	0.72 (0.69–0.74)	<0.001

Data are presented as *n* (%), unless indicated otherwise. *Adjusted for sex, age, child race/ethnicity, HbA_{1c}, private vs. public insurance, and visit year. †Grouped test evaluating equivalence in ORs over all groups except primary exposure.

CGM use in unadjusted analyses. These findings persisted in our adjusted analyses, with lower odds of CGM-billed visits among patients from non-White racial or ethnic backgrounds (non-Hispanic Black: OR 0.48, 95% CI 0.35–0.65; Hispanic: OR 0.54, 95% CI 0.33–0.86; other racial/ethnic backgrounds: OR 0.64, 95% CI 0.48–0.85). Consistent with data suggesting CGM use is associated with improvements in HbA_{1c}, we also observed a significant association between odds of a CGM-billed visit and lower HbA_{1c}, with unadjusted (OR 0.68, 95% CI 0.65–0.70) and adjusted analyses (OR 0.72, 95% CI 0.69–0.74) both demonstrating lower odds of CGM use during visits among those with higher HbA_{1c} measurements at the time of their visit.

Visit-Level Associations of NDI and CGM Use

Similar to our primary analysis, we first evaluated rates of CGM-billed visits across NDI by first stratifying by NDI quartiles (Supplementary Fig. 1). As in our primary analysis, we found overall consistent increases in CGM-billed visits as a proportion of total visits, but with persistently lower rates among those from areas of higher deprivation. Between 2018 and 2019, the top three NDI quartiles rose year over 1 year at similar rates, despite higher CGM-billed visit rates among those from less deprived areas (Q1: 26.2% to 48.9%; Q2: 22.6% to 44.3%; Q3: 14.3% to 34.3%), while the lowest quartile saw a more modest increase in CGM-visit rates (16.6% to 31.2%). However, despite continued steady increases in CGM-billed visits among those in the higher NDI quartile, those in the lowest three quartiles saw more modest increases in these visits both in 2020 and 2021. In order to further evaluate these differences, we conducted our secondary analysis of visit data (Table 3), which demonstrated a significant association between neighborhood deprivation and odds of a CGM-billed visit (unadjusted OR 0.75, 95% CI 0.69–0.81; aOR 0.84, 95% CI 0.77–0.92) with lower odds of CGM visits among patients living in neighborhoods with higher deprivation. As with the primary analysis, all covariates, with the exception of sex, demonstrated statistically significant associations with neighborhood deprivation, including race/ethnicity, age, insurance type, and HbA_{1c}.

Table 3—Visit-level associations between CGM billing code and NDI

	OR of CGM use for patient visits (95% CI)	
	Adjusted model*	*P* value†
NDI	0.84 (0.77–0.92)	<0.001
Sex		
Female	Reference	
Male	0.88 (0.75–1.03)	0.104
Race/ethnicity		
White, non-Hispanic	Reference	<0.001
Black, non-Hispanic	0.52 (0.38–0.70)	
Hispanic	0.58 (0.36–0.93)	
Other	0.67 (0.50–0.90)	
Age (years)	0.93 (0.91–0.95)	<0.001
Insurance type		
Commercial	Reference	<0.001
Medicaid	0.62 (0.52–0.74)	
Visit year		
2018	Reference	<0.001
2019	2.76 (2.44–3.12)	
2020	3.79 (3.28–4.38)	
2021	6.05 (5.20–7.04)	
HbA_{1c} (%)	0.72 (0.69–0.74)	<0.001

*Adjusted for sex, age, child race/ethnicity, HbA_{1c}, private vs. public insurance, and visit year. †Grouped test evaluating equivalence in ORs over all groups except primary exposure.

CONCLUSIONS

Consistent with prior data in type 1 diabetes and other pediatric chronic disease populations (23,25), our findings suggest that pediatric patients with type 1 diabetes living in rural areas experience significant disparities in accessing diabetes care. After adjusting for sex, race/ethnicity, HbA_{1c}, visit year, and insurance type, we found statistically significant and clinically meaningful lower odds of CGM-billed clinic visits among those living in small and isolated rural towns compared with those living in urban areas. Furthermore, we found that patients living in areas with more social deprivation, as measured by the NDI, also had significantly lower odds of completing visits with CGM data. Importantly, by using CGM billing codes as our outcome, our findings more closely reflect real-world device use and may account for known barriers to diabetes technology uptake in this population (25,35). Given accumulating evidence demonstrating significant improvements in glycemic outcomes among people with type 1 diabetes who use CGMs, these data underscore the importance of understanding geographic barriers to adoption of diabetes technology in order to improve outcomes for people with type 1 diabetes (36). Notably, while not the primary objective of this study, we also found significantly lower rates of CGM-billed visits among those from historically marginalized racial and ethnic groups as well as those with Medicaid as their primary insurance coverage, findings which are consistent with previous literature (5,8,9).

Taken together, these findings strongly suggest that along with other factors, such as socioeconomic status and racial and ethnic background, geographic place is a risk factor for encountering barriers to use of diabetes technology and receiving optimal diabetes care. For example, previous work has identified lack of communication infrastructure, such as broadband internet, transportation to appointments, and local social and medical supports as potential barriers to accessing care among rural populations. Furthermore, the plateau in the overall rise in CGM adoption during the height of COVID-19–related lockdowns suggests that patients living in rural areas may be particularly vulnerable to health system disruptions. Given the unique challenges faced by patients living in rural areas and the understudied nature of this population, more data are needed to understand the specific barriers these patients face in engaging with care and how to best address the needs of this population (37,38). In light of the findings of our previous work, which demonstrated wider disparities in care access among lower income and racial minorities during the early transition to telemedicine during COVID-19, these data suggest that health systems should proceed with caution in using technology-based solutions to address care gaps in care (27).

The current study has several advantages to previous work evaluating CGM-based outcomes. First, the diabetes program from which these data were drawn includes a clinical presence both in a large, urban academic medical center as well as in four clinical sites in larger rural towns. This expanded geographic presence resulted in a larger diversity of patient geography, improving the power of this study. In addition, our primary outcome—CGM-billing code—gives the current study several advantages. Previous work evaluating CGM use has relied on self-report, CGM prescription records, and/or review of provider clinic notes, none of which provide clarity on patient-level device use, how the data are driving care decisions, or for prescription data, whether the device is being used at all. Because providers are only able to bill with a CGM code if at least 72 h of CGM data have been reviewed during the clinic visit, using this as our outcome of interest ensures that those counted as "using" these devices have met these criteria. By using the billing code as our outcome, findings from the current study likely provide a more accurate reflection of patient-level barriers to CGM use, such as difficulty obtaining needed supplies and technological and connectivity challenges, which are key barriers especially relevant to rural populations.

Our study has several limitations. While basing our definition of CGM use on billing codes provides some advantages, we are not able to determine whether some visits may have included a CGM interpretation but were not appropriately coded. Given the large number of CGM prescriptions filled by durable medical equipment companies, we were not able to extract meaningful CGM prescription data from our electronic health record system to use this to help confirm our billing-based data. Despite this, given the financial incentives associated with these codes and administrative support for appropriate coding, the number of visits missing these codes is likely minimal and not correlated with patient geography, thus likely having a minimal impact on these results. It is also possible that active CGM users experienced technical difficulties at the time of their visit that did not allow for billing in the office, despite active home CGM use. One of the significant benefits of CGMs are facilitating in-office adjustments of insulin regimens among patients with type 1 diabetes, which these patient visits would not have provided.

Additionally, our data set includes demographic data from the end of the study period and thus does not account for potential movement of patients between RUCA regions. However, with overall migration in the U.S. out of rural areas, assigning location based on a home address at the end of the study period would be expected to result in our estimated ORs being an underestimate of the true odds (39).

A final limitation is that this study spans the COVID-19 pandemic, including both pre- and postpandemic data, which significantly impacted diabetes care during this period. This significant heterogeneity in the nature of diabetes visits may have created some additional barriers to engaging with care, which we are not able to completely account for. Reassuringly, the results from this study are consistent with previous data from our research group evaluating technology use in diabetes care as well as previous data demonstrating disparities in technology use among young adults with type 1 diabetes (5,27,40).

In summary, these data from medical record reviews of a pediatric endocrinology program that includes a large catchment area show that children with type 1 diabetes living in rural areas are significantly less likely to complete diabetes care visits where CGM data are used as a part of patient care. These data suggest that pediatric diabetes providers should be aware of the potential barriers to CGM use experienced by patients living in rural areas and attempt to work together with patients to identify and develop strategies to overcome these barriers to optimal diabetes care. Future work should explore the barriers experienced by rural families in effectively using CGMs to understand these barriers and develop interventions to address disparities in technology use to improve outcomes among children with type 1 diabetes living in rural areas.

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