A Learner-Centered Diabetes Management Curriculum

Reducing resident errors on an inpatient diabetes pathway

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OBJECTIVE—Diabetes errors, particularly insulin administration errors, can lead to complications and death in the pediatric inpatient setting. Despite a lecture-format curriculum on diabetes management at our children's hospital, resident diabetes-related errors persisted. We hypothesized that a multifaceted, learner-centered diabetes curriculum would help reduce pathway errors.

RESEARCH DESIGN AND METHODS—The 8-week curricular intervention consisted of *1*) an online tutorial addressing residents' baseline diabetes management knowledge, *2*) an interactive diabetes pathway discussion, *3*) a learner-initiated diabetes question and answer session, and *4*) a case presentation featuring embedded pathway errors for residents to recognize, resolve, and prevent. Errors in the 9 months before the intervention, as identified through an incident reporting system, were compared with those in the 10 months afterward, with errors classified as relating to insulin, communication, intravenous fluids, nutrition, and discharge delay.

RESULTS—Before the curricular intervention, resident errors occurred in 28 patients (19.4% of 144 diabetes admissions) over 9 months. After the intervention, resident errors occurred in 11 patients (6.6% of 166 diabetes admissions) over 10 months, representing a statistically significant ($P = 0.0007$) decrease in patients with errors from before intervention to after intervention. Throughout the study, the errors were distributed into the categories as follows: insulin, 43.8%; communication, 39.6%; intravenous fluids, 14.6%; nutrition, 0%; and discharge delay, 2.1%.

CONCLUSIONS—An interactive learner-centered diabetes curriculum for pediatric residents can be effective in reducing inpatient diabetes errors in a tertiary children's hospital. This educational model promoting proactive learning has implications for decreasing errors across other medical disciplines.

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Medical errors are a leading cause of death, with an estimated 98,000 deaths per year attributable to preventable errors (1). Annually, approximately 70,000 children hospitalized in the U.S. experience an adverse event, and 60% of these events may be preventable (2). Diabetes-related medical errors can lead to excessive morbidity, complications, and even death. Hellman (3) found that errors involving insulin therapy were responsible for 33% of deaths occurring within 48 h of a medical error in an inpatient setting. Insulin has been identified as a particularly dangerous medication, causing sudden, unexpected death in hospitalized children (4). In addition to medication errors involving insulin, other errors may also fall through the multidisciplinary "safety net" as a result of complex system failures. Errors may result when health care providers are overworked or sleep deprived (5), or when there are communication lapses.

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In 1997, the Endocrinology and Diabetes Division at the Children's National Medical Center (CNMC) implemented a clinical pathway on inpatient diabetes management that led to a decreased average length of stay (6). Despite the implementation of the diabetes pathway, data showed that pediatric residents were making frequent diabetes-related errors in the inpatient setting. The resident errors continued despite traditional lectures on diabetes management delivered by faculty members. The persistence of resident errors was the impetus for the development of a learner-centered diabetes curriculum designed to activate learners, empowering them to be participants in sessions, rather than relying on the passive learning in traditional lectures.

The overall goals of the curriculum were both to improve resident knowledge and performance in treating hospitalized children with diabetes and to decrease inpatient diabetes-related errors. The curriculum had three learning objectives: *1*) to develop a proactive understanding of diabetes management, *2*) to identify the errors and pitfalls upon application of the inpatient diabetes pathway, and *3*) to prevent and correct errors in the inpatient management of children with diabetes

We thus hypothesized that successful implementation of these learning objectives through a learner-centered curriculum, as opposed to previous traditional didactic sessions, would reduce pathway-related errors.

RESEARCH DESIGN AND METHODS

Setting

CNMC is a 303-bed, freestanding, university-affiliated, tertiary urban pediatric hospital with an average of 404 diabetes admissions to the general medical floor or intensive care unit per year. The diabetes pathway and order sets can be accessed through the CNMC intranet (Supplementary Appendix). At the time of our study, the pediatric residency program at CNMC consisted of 89 residents: 26 were first year,

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29 were second year, and 34 were third year. The CNMC institutional review board approved the study, and informed consent was obtained from the residents.

Educational intervention

The diabetes educational intervention targeted only CNMC pediatric residents; inpatient unit nurses received traditional diabetes in-service teaching in the same period from the diabetes team nursing staff but did not participate in the resident curricular intervention. The new resident diabetes curriculum occurred during an 8-week period in the fall of 2010 and consisted of four modules (7) (Table 1). The resident core lecture series is available for all pediatric residents who have daytime clinical responsibilities at CNMC, and attendance is recorded by an electronic badge swipe. As such, we calculated the percentage of onsite residents who participated in each module.

Module 1. In "Principles of Diabetes Management," we created an online interactive PowerPoint presentation, including a case of a hospitalized child with new-onset diabetes, followed by a discussion of diabetes pathophysiology and management. This self-directed learning module was made available as an e-mail attachment and by Blackboard (a web-based education software program) to all residents 1 month before the first face-to-face conference. All CNMC pediatric residents were required to complete this module. The Brookfield Critical Incident Questionnaire (CIQ) was administered after the presentation to document the resident learning experience and areas for improvement (8). The CIQ was developed for classroom teaching according to adult learning principles and consists of five narrative questions (Table 1). Brookfield suggests using the CIQ as a method to engage learners and then summarize students' answers to the questions from the previous learning experience.

Module 2. "Diabetes Pathway and Pitfalls," a 1-h discussion highlighting potential errors with the pathway, was presented at resident noon conference. In this module, the CNMC diabetes clinical pathway was discussed in detail with participating residents, soliciting their review and comments. Specific portions of the pathway spurring resident confusion and potential subsequent errors (e.g., administration of intermediate-acting insulin at 2:00 AM on admission and again at 7:00 AM with breakfast, resulting in midmorning hypoglycemia) were discussed in detail.

Module 3. "Diabetes Potpourri," a 1-h resident noon conference, consisted of a question and answer session about all inpatient diabetes-related topics. The chief pediatric residents collected questions anonymously from the residents for 1 week before the conference and collated them into themes. Questions were general or specific depending on residents' concerns. Each question was read aloud by the facilitator (F.R.C.), who first asked the residents for their responses, allowing identification of resident knowledge gaps and focusing further discussion on each topic related to learner gaps in knowledge.

Module 4. The "Diabetes Case Presentation" addressed the hospital course of the patient presented in Module 1. Two of the authors (F.R.C. and D.J.D.) embedded subtle errors into the case, reflecting the five main categories of documented pathway errors (insulin, communication, intravenous fluids, nutrition, and discharge delay). During this 1-h noon conference, residents were divided into four teams and were instructed to uncover and categorize each of the pathway errors, offer immediate solutions to the patient's current status, and project how they might prevent the same errors from occurring again. The investigators reviewed the

Table 1—*Curriculum modules and topics*

	Curriculum modules			
Topics	1. Interactive online diabetes toolkit: Case presentation*	2. Diabetes pathway and pitfalls	3. Diabetes potpourri	4. Diabetes case presentation embedded with errors
Diabetes diagnostic criteria	X[a]	X	X	
Signs and symptoms	X[a,c]	X	X	
Laboratory evaluation	X[a]		X	X
Assessment and action plan	X[a]			X
Initial fluid resuscitation; electrolytes	X[b,c,d]	X	X	X
Insulin drip	X	X	X	X
Nutrition (carbohydrate counting)	X			X
Insulin calculations (subcutaneous)	X[a,c,d,e]	X	X	X
Flow sheets	X[c]	X		X
Transition from split mixed insulin to basal/bolus therapy	X		X	X
Explanation of insulin-to-carbohydrate ratios and correction factors	X		X	
Pattern management	X[d]		X	
Appendix with additional topics:				
Permanent neonatal diabetes	X			
Type 2 medications	X			
Insulin pump therapy	X			
Research and future technology	X[b,e]			
Brookfield CIQ*	X			

*Table footnotes *a* to *e* represent answers to the questions on the Brookfield CIQ. [a]When were you most engaged? [b]When were you most distanced? [c]What did you find most affirming? [d]What was most puzzling? [e]What was most surprising? (Overall, residents were most surprised by the presentation clarity and simplification of diabetes management.)

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resident responses to identify the team most successful in the identification, resolution, and prevention of future errors in this simulated case. Residents from the winning team received a gift card.

Modules 2 to 4 were evaluated by residents on a Likert scale with the following values: 1, poor; 2, fair; 3, good; 4, excellent; and 5, outstanding. After Module 4 was completed in September 2010, there were no additional curricular interventions or booster sessions.

Information on patients and inpatient errors

Nearly all patients with new-onset diabetes are admitted to CNMC for treatment of diabetic ketoacidosis (DKA) or subsequent insulin initiation, stabilization, and diabetes education taught by our nurse educators. Other patients with hyperglycemia secondary to cystic fibrosis–related diabetes, steroid- or medication-induced diabetes, or known diabetes are either admitted for DKA secondary to nonadherence or secondary to non–diabetes-related illnesses.

After stabilization, all newly diagnosed patients were either initially begun on conventional split mixed insulin 2 or 3 injections per day or multiple daily injections with insulin glargine or detemir and rapid-acting insulin. Patients with previously diagnosed diabetes who were admitted with DKA or for other reasons were restarted on their home regimen after stabilization. No patients receiving insulin pump therapy were admitted to CNMC during the study period.

Patient demographic data were obtained, including number of diabetes admissions, age, sex, and diabetes type, for 9 months before the curricular intervention (January–September 2010) and 10 months after the intervention (October 2010–July 2011). For the same periods, data on diabetes-related errors were obtained from the CNMC Incident Report System, an online tool to document medical errors. Diabetes-related errors are reported through this system by nurses, diabetes educators, and endocrinology faculty. The information from the incident reports was documented in an Access database and stripped of identifiers after collection for purposes of this study. Recognizing that inpatient nurses were neither a part of the curricular intervention nor aware of our study, we also reviewed nursing diabetes-related errors so that resident and nurse data could be compared in the pre- and postintervention periods.

On the basis of previously occurring pathway errors, we hypothesized that nearly all errors would fall into one of five areas: insulin, communication, intravenous fluids, nutrition, and discharge delay. Insulin errors were related to dosage, timing, and omission. Communication errors were based on faulty communication among the multidisciplinary staff. Fluid errors were primarily concerned with intravenous fluid choice after transfer to the intensive care unit and the timing of discontinuation of intravenous fluids. Nutrition errors were related to meal carbohydrate counts. Finally, discharge errors were concerned with a delay in the time of discharge.

Method of evaluation and statistical analysis

We evaluated the impact of the curriculum by documenting the number of patients with resident errors per total number of diabetes admissions before and after the intervention to determine whether there was a decrease in total patient errors. We chose this particular metric because once an error occurs, there can be a cascade effect that causes subsequent errors. Thus any one patient may have had only one or as many as three different errors made by a nurse, a resident, or both. Patient admissions were categorized in a 2×2 table according to whether they occurred before or after the intervention and whether there was an error committed by the resident, nurse, or both. A χ^2 analysis with SAS software compared the number of patients with errors before and after intervention. Significance was defined as $P < 0.05$.

RESULTS

Educational intervention

Module 1. "Principles and Management of Diabetes" remained online throughout the study; however, logistical difficulties with the Blackboard website rendered us unable to track the number of times it was accessed by the residents. The resident responses to the Brookfield CIQ are summarized in Table 1.

Modules 2–4. "Diabetes Pathway and Pitfalls" (Module 2) was attended by 97.7% of residents onsite, including 100% of first years, 92.3% of second years, and 100% of third years. The mean Likert scale rating for this session was 4.63 out of 5. The attendance for "Diabetes Potpourri" (Module 3) was 89.5% overall, including 93.8% of first years, 81.8% of second years, and 90.9% of third years. This session received a mean rating of 4.71. For the final session, "Diabetes Case Presentation" (Module 4), the overall attendance was 91.7%, including 93.8% of first years, 88.9% of second years, and 90.9% of third years. The mean rating for Module 4 was 4.85.

Demographics of the diabetes patient population

In the 9 months before the educational intervention, there were 144 diabetes admissions, averaging 16 per month. In the 10 months after the intervention, there were 166 diabetes admissions, averaging 16.6 per month. The 66 patients affected by a diabetes-related error were demographically similar to the full group of patients with diabetes (Table 2).

Pathway errors before and after intervention

A total of 66 patients were affected by a pathway error through the 19-month duration of the study. Because errors could involve both residents and nurses, overall, 39 patients were affected by a resident error and 40 patients were affected by a nursing error. In the 9 months before the curricular intervention (144 total admissions), there were 28 patients with resident-related errors and 20 patients with nursing-related errors. In the 10 months after the intervention (166 total admissions), there were only 11 patients with resident-related errors and 20 patients with nursing-related errors. Thus the percentage of patients with resident errors significantly decreased after the intervention (from 19.4 to 6.6%; $P < 0.01$), whereas the percentage of patients with nursing errors did not change significantly (from 13.9 to 12.1%; $P = 0.63$) (Fig. 1).

Resident pathway error types

For the entire study period, the error types were as follows: insulin, 43.8%; communication, 39.6%; intravenous fluids, 14.6%; nutrition, 0%; and discharge delay, 2.1%. In the 9-month preintervention period, residents committed errors in the care of 28 patients in the categories of insulin (40%), communication (42.9%), and intravenous fluids (17.1%). In the 10 months after the intervention, residents committed errors in the care of 11 patients in the categories of insulin (53.9%), communication (30.8%), intravenous fluids (7.7%), and discharge delay (7.7%). The authors noted four major types of insulin errors: incorrect type, dose, timing, or failure to order.

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Table 2—*Patient demographics*

	Preintervention	Postintervention	Total
All diabetes-related admissions, *n*	144	166	310
Patient age, years (mean ± SD)	11.55 ± 1.04	11.02 ± 0.7	11.27 ± 0.61
Patients with diabetes-related errors*, *n* (%)	40 (27.8)	26 (15.7)	66 (21.3)
Patient age, years (mean ± SD)	11.4 ± 3.08	10.9 ± 1.5	11.2 ± 1.95
Sex, *n* (%)			
Male	19 (47.5)	10 (38.5)	29 (43.9)
Female	21 (52.5)	16 (61.5)	37 (56.1)
Diabetes type, *n* (%)			
Type 1	35 (81.5)	21 (80.8)	56 (84.8)
Type 2	2 (5)	4 (15.4)	6 (9.1)
Other†	3 (7.5)	1 (3.8)	4 (6.1)
Reason for admission, *n* (%)			
New-onset type 1 diabetes	23 (57.5)	18 (69.2)	41 (62.1)
Established patient with type 1 diabetes in DKA	12 (30)	5 (19.2)	17 (25.8)
New-onset type 2 diabetes	1 (2.5)	1 (3.8)	2 (3)
Other§	4 (10)	2 (7.7)	6 (9.1)

*Resident or nurse errors. †Other diabetes type includes patients with hyperglycemia secondary to other diagnoses (cystic fibrosis–related diabetes, steroid- or medication-induced hyperglycemia, stress-induced hyperglycemia). §Other reasons for admission include patients with known diabetes who were admitted for other illnesses, such as gastroenteritis, bronchiolitis, fever, and pancreatitis.

For three of the five categories of pathway errors, there was a decrease in total number of resident errors. Of the 144 admissions before the intervention, 9.7%, 10.4%, and 4.2% of the patients had insulin, communication, and intravenous fluid errors, respectively. After the intervention (166 admissions), only 4.2%, 2.4%, and 0.6% of patients had insulin, communication, and intravenous fluid errors, respectively. For discharge delay, the number of errors increased from 0 to 1, and no errors during the study period were related to nutrition.

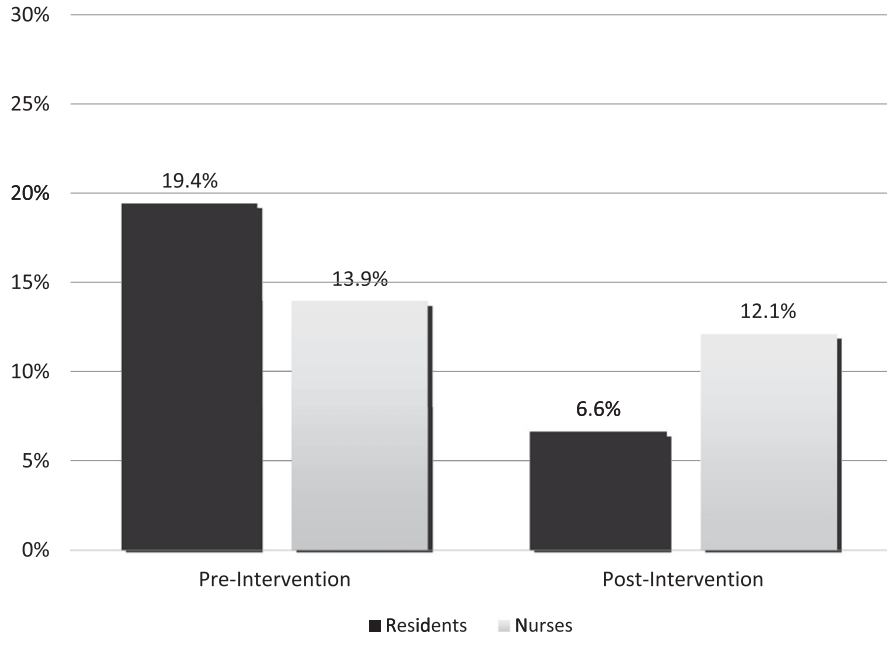

Figure 1—*Percentages of patients with errors for residents and nurses. Pre- versus postintervention analysis for residents:* $\chi^2 = 11.52$; P = *0.0007. Pre- versus postintervention analysis for nurses:* $\chi^2 = 0.23$; P = *0.63.*

Statistical significance was thus noted in reduction of resident errors in the categories of communication ($P = 0.0034$) and fluids ($P = 0.04$), with near statistical significance in the insulin category ($P = 0.05$) (Fig. 2).

CONCLUSIONS—To our knowledge, our study is the first to examine the impact of a multidisciplinary diabetes educational curriculum targeting residents at a children's hospital and to demonstrate an improvement in patient care as a result of the intervention. Our curriculum was effective in reducing the percentage of patients with resident-related diabetes errors from 19.4 to 6.6%, thus contributing to safer and more efficient patient care.

Evidence is accumulating that with increased clinical supervision, along with educational curricula promoting active learning, the frequency of medical errors can be reduced (9,10). For example, a recent diabetes educational curriculum—including order sets, pocket cards, lectures, and rounds—targeting first-year internal medicine residents at one institution led to modest gains in resident knowledge of diabetes management (11). In another study, Cook et al. (12) developed seven web-based inpatient diabetes management training modules for residents. Most of the 29 participating residents (>90%) considered the modules valuable to their inpatient experience; however, knowledge gains were not assessed, and it's unknown whether there was an actual impact on patient care. Tamler et al. (13) studied whether an educational intervention with internal medicine residents could improve blood glucose in hospitalized patients. They assigned 116 medicine residents to either online or classroom training on inpatient "dysglycemia" in the fall of 2008 and offered both groups refresher classes in the spring of 2009. Although 93.1% of the residents completed the training and the patients' mean blood glucose decreased, the clinical significance was uncertain. Finally, a performance improvement study by Sullivan et al. (14) demonstrated that a nursing online educational module was effective in reducing the incidence of insulin administration errors in a pediatric hospital. The insulin error rates before and after the intervention were 14.8% and 1.7%, respectively ($P < 0.001$).

Clearly, the overarching goal of resident education should be application of knowledge toward improved patient care

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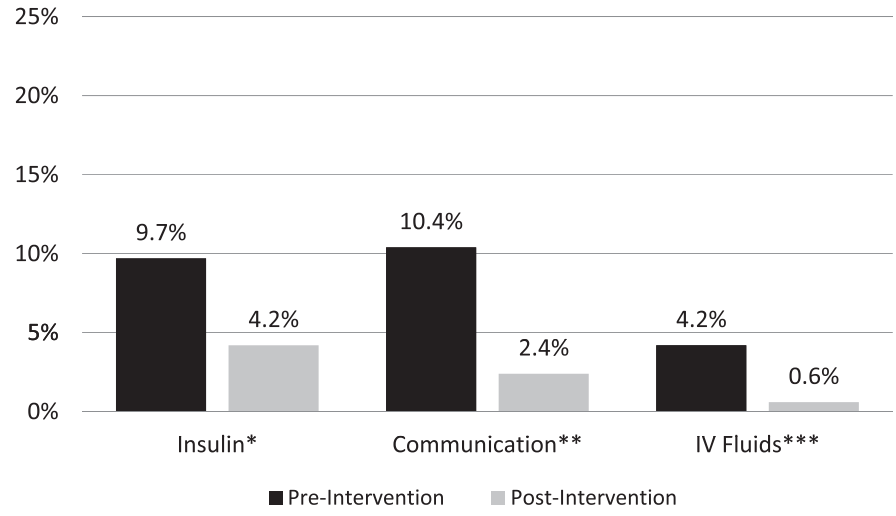

Figure 2—*Percentages of patients with resident errors by category. Pre- versus postintervention analysis by category:* $*\chi^2 = 3.7$, P = 0.05; $**\chi^2 = 8.59$, P = 0.003; $***\chi^2 = 4.44$, P = 0.04. *No nutrition errors were committed by residents either before or after the intervention. For the category of discharge delay, there was no reduction in patients with resident errors (0 resident errors before and 1 resident error after the intervention).*

and safety. Thus, the first aim is to avoid committing the "initial" patient error, thereby avoiding a cascade effect that could cause subsequent errors. Because insulin is one of the most common medications resulting in significant medical errors (15), resident education on diabetes management, especially insulin dosing, is paramount. Despite the decreased number of patients with insulin errors postintervention, insulin dosage and timing continued to be the most common error in diabetes management relative to other categories. In fact, we noted a slight increase in insulin errors about 6 months after the curricular intervention. Strategies to reduce these errors will be a focus for the next iteration of the study, which will include an educational booster 6 months after the initial training (16,17).

The resident response to the CIQ from Module 1 encouraged us to enhance the self-directed learning module as a venue to convey information, as opposed to traditional lectures. Thus future iterations of the study will also include a more sophisticated online self-instructional diabetes module with the SoftChalk e-Learning program. Additionally, we expect Modules 2 to 4 to be accessible for offsite residents through telemedicine capabilities. Finally, a tool to track errors made by individual residents is being developed. Because of the success of these modules, and acknowledging that errors arise from prescribing, dispensing, and administering by physicians, pharmacists, and nurses, we are developing a similar multifaceted curricular intervention that will focus on insulin delivery and communication with all members of the multidisciplinary team. Our first step will target inpatient nurses.

Our study has several limitations. First, we do not know how many residents completed the online module, and only onsite residents attended Modules 2 to 4. We hypothesized that this learner-based curriculum would spur discussions with residents not in attendance, thus possibly favoring error reduction even if residents were directly exposed to only some of the information. In addition, we were unable to identify which residents committed patient errors, either individually or by resident level of training, or to link errors with session attendance. Second, information on diabetes-related errors was obtained from the web-based incident reports. Although such databases have been shown to be an effective tool in tracking medical errors (15), additional errors may have been unreported. Third, we were unable to conduct a randomized controlled trial, comparing one cohort of residents who received all four modules of the curricular intervention (treatment group) with residents who continued to receive the traditional lectures (control group). Several factors prevented a randomized design, including resident work-hour limitations and residents not physically present at the study site. Finally, although it could be postulated that resident errors decreased as the result of a Hawthorne effect (18)—behavior change resulting from study awareness—we believe this to be unlikely because second- and third-year residents had previously participated in a traditional lecture format discussion of diabetes without any significant change in errors and because the decrease in resident errors persisted 10 months after the intervention.

In summary, through use of an established inpatient diabetes pathway, we developed and implemented an interactive learner-centered curriculum for pediatric residents in a tertiary children's hospital that resulted in a statistically significant decrease in the number of patients with diabetes-related errors. This performance improvement study represents a model that positively impacted patient safety and has implications for decreasing errors across other medical disciplines.

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D.J.D. participated in modular design, reviewed and analyzed data, and wrote and edited the manuscript. L.W.G. assisted with study design and reviewed and edited the manuscript. C.L.H. collected and analyzed the data. F.R.C. designed the study and modules, collected and analyzed data, and wrote and edited the manuscript. F.R.C. is the guarantor of this work and, as such, had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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