


BMJ Open Quality Improving inpatient hyperglycaemia in non-critically ill adults in resident wards through audit and feedback

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ABSTRACT

Inpatient hyperglycaemia is associated with an increase in morbidity and mortality, number of rehospitalisations and length of hospitalisation. Although the advantages of proper glycaemic control in hospitalised patients with diabetes are well established, a variety of barriers limit accomplishment of blood glucose targets. Our primary aim was to decrease the number of glucose values above 180 mg/dL in non-critical care hospitalised patients using an audit and feedback intervention with pharmacy and internal medicine residents. A resident-led multidisciplinary team implemented the quality improvement (QI) project including conception, literature review, educating residents, iterative development of audit and feedback tools and data analysis. The multidisciplinary team met every 5 weeks and undertook three 'plan-do-study-act' cycles over an 8-month intervention period (August 2022 to March 2023) to educate residents on inpatient hyperglycaemia management, develop and implement an audit and feedback process and assess areas for improvement. We performed 1045 audits analysing 16 095 accu-checks on 395 non-duplicated patients. Most audits showed compliance with guidelines. The monthly run-on chart shows per cent of glucose values above 180 mg/dL in our non-ICU hospitalised patients and an overall pre-to-post comparison of 25.1%–23.0% (p value<0.05). The intervention was well accepted by residents evidenced by survey results. We did not meet our primary aim to reduce hyperglycaemia by 30% and this combined with the audits showing mostly compliance with guidelines suggests that prescribing behaviour was not a key driver of inpatient hyperglycaemia in our population. This internal medicine resident and pharmacy interprofessional collaboration with audit and feedback for inpatient hyperglycaemia was feasible, well accepted and had a statistically significant yet small improvement in inpatient hyperglycaemia. The project may be helpful to others wishing to explore inpatient hyperglycaemia, interprofessional QI with pharmacists, resident-led QI and audit and feedback.

PROBLEM

Inpatient hyperglycaemia is associated with an increase in morbidity and mortality, number of rehospitalisations and length of hospitalisation.¹ Although the advantages of proper glycaemic control in hospitalised

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The advantage of proper glycaemic control in hospitalised patients is well known. Audit and feedback has been a successful intervention to change physician behaviour in other settings.

WHAT THIS STUDY ADDS

⇒ This study shares lessons learnt from an internal medicine resident and pharmacy team that developed and implemented an audit and feedback tool to improve inpatient hyperglycaemia on internal medicine resident wards teams.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Lessons learnt from this quality improvement (QI) project can be used to help those looking to improve inpatient hyperglycaemia, implement interprofessional QI projects with medical residents and pharmacists or implement audit and feedback.

patients with diabetes are well established, a variety of barriers limit accomplishment of blood glucose targets.²

Our multidisciplinary quality improvement (QI) project was conducted as part of the University of Texas Rio Grande Valley Internal Medicine residency programme's required QI projects each academic year. Our hospital was Doctors Hospital at Renaissance, a 530-bed community hospital, serving a region of approximately 1.4 million individuals on the southern border of Texas. The region is predominantly Hispanic (92%) and suffers from high rates of diabetes at 27% of adults with diabetes, more than double the national prevalence rate of 11.3%.^{3 4} Given these factors and new Endocrine Society's Practice Guidelines published in 2022, the internal medicine residents had a strong interest in evaluating the inpatient hyperglycaemia management practices.

Our primary aim was to reduce the per cent of glucose accu-checks above 180 mg/dL by 30% in non-critical care internal medicine



resident hospitalised patients using an audit and feedback intervention with pharmacy from August 2022 to March 2023.

BACKGROUND

The Endocrine Society and American Diabetes Association (ADA)/American Association of Clinical Endocrinologists (AAACE) Practice Guidelines in 2022 were published to update the previous 2012 guidelines for the management of hyperglycaemia in hospitalised non-critical care settings. They recommend that most non-critically ill patients receiving insulin treatment maintain a premeal glucose level below 140 mg/dL and a random glucose level below 180 mg/dL.^{5 6} Per recommendation 7.1, ‘in most adult patients with hyperglycaemia hospitalised for a non-critical illness, we suggest that scheduled insulin therapy be used instead of non-insulin therapies for glycaemic management’.⁷ Scheduled insulin is defined as basal or basal/bolus insulin. Moreover, scheduled insulin therapy should be initiated if persistent hyperglycaemia is observed, defined as two or more glucose measurements ≥ 180 mg/dL in a 24-hour period on correctional insulin alone (recommendations 10.1 and 10.2).⁷ Once insulin therapy is initiated, a target glucose range of 140–180 mg/dL (7.8–10.0 mmol/L) is recommended for the majority of patients.

Approximately 25% of hospitalised non-critical care adults have diabetes and another 12%–25% of hospitalised patients develop hyperglycaemia.^{8–11} Hyperglycaemia in people with and without diabetes is associated with increased morbidity and mortality, higher rates of rehospitalisation, extended hospital stays and increased costs.^{1 12 13} Subcutaneous sliding scale insulin, also called correctional insulin, has been the mainstay for non-critically ill hospitalised adults despite clinical guidelines and randomised trials showing superior outcomes with scheduled insulin use.^{7 13}

Resident physicians have a large role in the treatment of hospitalised adults in the USA. The number of residents have increased by about 5000 each year since 2019 with the latest 2022 report showing 149 296 active resident physicians in the USA.¹⁴ The Accreditation Council for Graduate Medical Education (ACGME) requires resident physicians ‘demonstrate competence in working in interprofessional teams to enhance patient safety and improve patient care quality’.¹⁵ It also requires that residents participate in interprofessional clinical patient safety activities.¹⁵ Resident-led QI projects help prepare physicians to lead in healthcare but programmes face various challenges engaging residents in meaningful QI.¹⁶

Despite these ACGME requirements and benefits, there is limited literature describing interprofessional QI projects with residents and even less literature where residents take a leadership role in an interprofessional team.^{17–20} Furthermore regarding diabetes, there are published reports describing resident QI projects for

diabetes management, yet they are solely in the outpatient setting.^{21–23}

A call to action from the American Diabetes Association states studies are needed to promote inpatient scheduled insulin, educate providers and change prescribing behaviour.²⁴ Healthcare organisations employ various methods to enhance adherence to medical practice guidelines, and one such approach is the utilisation of audit and feedback. This method involves assessing the performance of individuals or groups, comparing it to established practice standards and providing actionable feedback. Studies show by delivering timely, individualised and actionable feedback, professionals are motivated to enhance their performance.^{25 26} There are multihospital settings in which inpatient hyperglycaemia was improved in both critical care and non-critical care patients with multiple interventions one of which being ‘feedback of metrics’.^{27 28}

MEASUREMENT

The primary outcome in this study is the per cent of glucose value > 180 mg/dL in non-critical care resident ward patients. Internal medicine residents partnered with pharmacy and the hospital diabetes quality committee to obtain the accu-checks in non-critical care internal medicine resident hospitalised patients on a monthly basis. The following inclusion criteria apply: age 18–65 years old, non-critical care, and resident team. Exclusion criteria are pregnancy and critical care. All data was anonymised, confidential and secure. The data collected was processed and filtered using Python, a computational tool, to analyse and summarise the glycaemia values.

We planned to assess the monthly percentage in a run-on chart from June 2022 to March 2023 as well as a pre–post z test to analyse for statistical significance.

Our secondary outcome was feedback from the residents on their perception of the intervention on improving inpatient glucose management. As audit and feedback can be considered a training method, we structured the survey using the Kirkpatrick model, a globally recognised method of evaluating training and learning programmes. We assessed resident perception of level 1 reaction, level 2 learning, level 3 impact (behaviour) and level 4 results (performance). We used the 5-point Likert agreement scale for the 7-question anonymous survey.

DESIGN

Our team had eight internal medicine residents, one internal medicine faculty and four pharmacists. We met every 5 weeks when the group of residents was together in continuity clinic, in addition to phone calls and e-mails in between. We planned to develop a lecture based on the guidelines and then develop and implement an audit and feedback process with the pharmacists. We planned to implement three plan–do–study–act (PDSA) cycles during the 8-month intervention based on the results of

the audits, the monthly hyperglycaemia rates and feedback from team members.

We were uncertain how long it would take pharmacy to perform the audit and feedback and uncertain how accepting residents would be of the feedback. By striving to make the audit and feedback form streamlined and by seeking and acting on resident feedback, we hoped to address these concerns and increase sustainability.

Four pharmacists drafted the first audit form by reflecting the goals and therapy management recommendations provided in the 2022 Endocrine Society Clinical Practice Guidelines for the management of hyperglycaemia

in hospitalised adult patient in non-critical care settings. They brought this form to our monthly meeting with residents for feedback from the prescriber standpoint. The pharmacists also found some areas for streamlining once they started the audits and the last version of the form developed in January 2023 is shown [figure 1](#). It brought to the attention of the prescriber the indications for scheduled insulin use in hyperglycaemia.

During the intervention period, one pharmacist physically rounded with an internal medicine team Monday through Friday and provided in-person recommendations in real time. The second pharmacist reviewed the charts

Exclusion criteria

- Critical Care (e.g. CCU, NSICU, SICU)
- Age < 18 years
- Pregnancy

Hypoglycemia risk factors

- Age > 65 years old
- ESRD

Review HBA1C

*Ensure HBA1c in the past 90 days; HBA1c:

Review diet status

- NPO
- Enteral Nutrition
- Parenteral Nutrition

Review active inpatient medications that may affect blood glucose level.

- Glucocorticoids

Review medication history snapshot for noninsulin diabetes medications and/or insulin

- Noninsulin diabetes medications prior to admission
- Insulin prior to admission

Review problems & diagnosis

- History of type 1 diabetes
- History of type 2 diabetes
- No history of diabetes

Review active continuous infusions.

- Dextrose

*Recommend discontinuation of continuous infusions if appropriate

Review inpatient medication management of hyperglycemia.

Please select the option that applies to your patient:

Adults with no prior history of diabetes with:

- Hyperglycemia (serum BG > 140) during hospitalization (*take fasting state into account*)
 - Was correctional insulin initiated within 24 hours of initial serum BG > 140?
 - Yes
 - No
 - Persistent hyperglycemia (> 2 POC-BG \geq 180 in a 24-hour period on correctional insulin alone)
 - Was scheduled insulin initiated within 24 hours of second POC-BG \geq 180?
 - Yes
 - No
- Adults with diabetes treated with diet or non-insulin diabetes medications prior to admission:**
 - *Was scheduled OR correctional insulin initiated within 24 hours of admission date & time?
 - Yes
 - No → Recommend correctional OR scheduled insulin if it is currently not active
 - Hyperglycemia (serum BG > 180) within 24 hours of admission date & time
 - *Was scheduled insulin initiated within 24 hours of initial serum BG > 180?
 - Yes
 - No → Recommend scheduled insulin if it is currently not active
 - Persistent hyperglycemia (> 2 POC-BG \geq 180 in a 24-hour period on correctional insulin alone)
 - *Was scheduled insulin initiated within 24 hours of second POC-BG > 180?
 - Yes
 - No → Recommend scheduled insulin if it is currently not active
 - Adults with insulin-treated diabetes prior to admission:**
 - *Was scheduled insulin regimen continued from home (with appropriate modifications for inpatient nutrition & clinical status) within 24 hours of admission date & time?
 - Yes
 - No

Analyze insulin regimen & assess for opportunities.

*How many units of correctional scale insulin have been utilized in last 24 hours? _____

*Recommend modification of regimen based on insulin utilization if appropriate

Recommendations

 - Order lab (HBA1c)
 - Modify continuous infusions
 - Initiate correctional insulin
 - Initiate scheduled insulin
 - Modify insulin regimen based on correctional scale usage
 - Management of hyperglycemia consistent with Endocrine Society Clinical Practice Guidelines

Figure 1 Hyperglycaemia audit form. CCU: Critical Care Unit; NSICU: NeuroSurgical Intensive Care Unit; SICU: Surgical Intensive Care Unit; HBA1C: Hemoglobin A1C; NPO: Nothing by mouth; BG: Blood Glucose; POC: Point of Care.

of the other two internal medicine teams and provided written recommendations.

PATIENT AND PUBLIC INVOLVEMENT

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our QI programme.

STRATEGY

Our primary aim was to decrease by 30% the number of glucose values above 180 mg/dL in non-critical care hospitalised patients from August 2022 to March 2023. We have summarised our changes in the three PDSA test cycles over the 8-month intervention period.

PDSA cycle 1: August to September 2022

Our initial intervention was to educate internal medicine residents on inpatient hyperglycaemia management and develop our first audit and feedback form and process with pharmacy. We submitted to the institutional review board (IRB) which determined that the project was not a human subjects research and did not require IRB oversight. We delivered an educational lecture to the residents and attendings about the 'New Endocrine Society Guidelines for the Management of Hyperglycemia in Hospitalized Patients in Non-critically Ill Settings from 2022'.⁷ We used cases to emphasise the recommendations on the use of scheduled insulin.

We developed inclusion and exclusion criteria and a 10-step process for pharmacy to perform the chart audit. As adults regardless of diabetes status were included, we designed three sections that contained the guidelines for each population: adults with no prior history of diabetes, adults with diabetes treated with diet or non-insulin prior to admission or adults with insulin-treated diabetes prior to admission (figure 1).

The written feedback resulting from the audit was provided to the attending physicians via a secure e-mail.

We saw a reduction of the hyperglycaemia percentage from 25.24% in June and 24.98% in July, our pre-intervention, to 15.08% in August, our nadir, and 20.92% in September.

PDSA cycle 2: October to December 2022

Feedback indicated that the e-mails with the feedback from the audit were difficult to open, due to the extra security as they contained patient information, and often did not reach the target audience of the resident who inputs the orders. We polled the residents for how they would like to receive the information and implemented a message within the Electronic Medical Record (EMR) linked to the patient's chart which went to the entire team (resident, intern, attending).

The audit and feedback tool went through an iterative process to simplify the chart review and ensure that feedback was actionable, emphasising the need for it to be timely, individualised and non-punitive. We also

employed small changes in our messaging with hopes to incentivise and reward good practices, for example, changing from 'no changes recommended' to 'great job team!' Full examples of EMR messages include:

1. "Patient has a history of Type 2 Diabetes Mellitus. She is currently controlling it with diet. There is no Hemoglobin A1C (HbA1C) documented.
Recommendation: HBA1C ordered for 3/9/23."
2. "Internal Medicine teams A and B have been reviewed for hyperglycaemia management and there are no recommendations. Great job team!"

The pharmacy and resident review of the new guidelines led to an unexpected opportunity to update the EMR order sets to improve adherence to the new evidence-based guidelines. Pharmacy also invited the internal medicine residents to the diabetes committee of the hospital which further helped the team get involved in system-based care, align themselves with hospital goals and access data more efficiently.

PDSA cycle 3: January to March 2023

While we first decided to include only patients younger than 65 years, pharmacy alerted us that many patients were being excluded and wanted the group to consider including patients aged 65–76 years. We decided to modify the form to include this group and mark it as a hypoglycaemia risk factor beginning January 2023 (see figure 1, version B audit).

To preserve analysis in our pre-post and run-on charts, we only included patients aged less than 65 years but we were able to perform the audit and feedback on patients aged 65–75 years as well.

During our last cycle, we formally sought resident feedback on the intervention modelling questions to assess the educational programme model Kirkpatrick level 1 reaction, level 2 learning, level 3 impact (behaviour) and level 4 results (performance).²⁹

RESULTS

The primary outcome in this study was the change in per cent of glucose value >180 mg/dL before and after the QI intervention. The monthly hyperglycaemia rates from June 2022 to March 2023 are shown in the run chart (figure 2 and table 1). The overall pre-to-post comparison was 25.0% of glucose values >180 mg/dL in the pre and 23.0% of glucose values >180 mg/dL in the post, with a statistically significant difference and p value <0.05.

During the first PDSA cycle involving an educational lecture for residents and attendings, we saw a reduction of the hyperglycaemia percentage from 25.24% in June and 24.98% in July, our pre-intervention, to 15.08% in August, our nadir, and 20.92% in September.

During the second and third PDSA cycles in which the audit and feedback was implemented and improved in an iterative fashion, the monthly percentages are shown in table 1 and run chart in figure 2. We had a peak in January 2023 at 32.7%. The last 2-month hyperglycaemia

Monthly percentage of Glucose level > 180 mg/dl

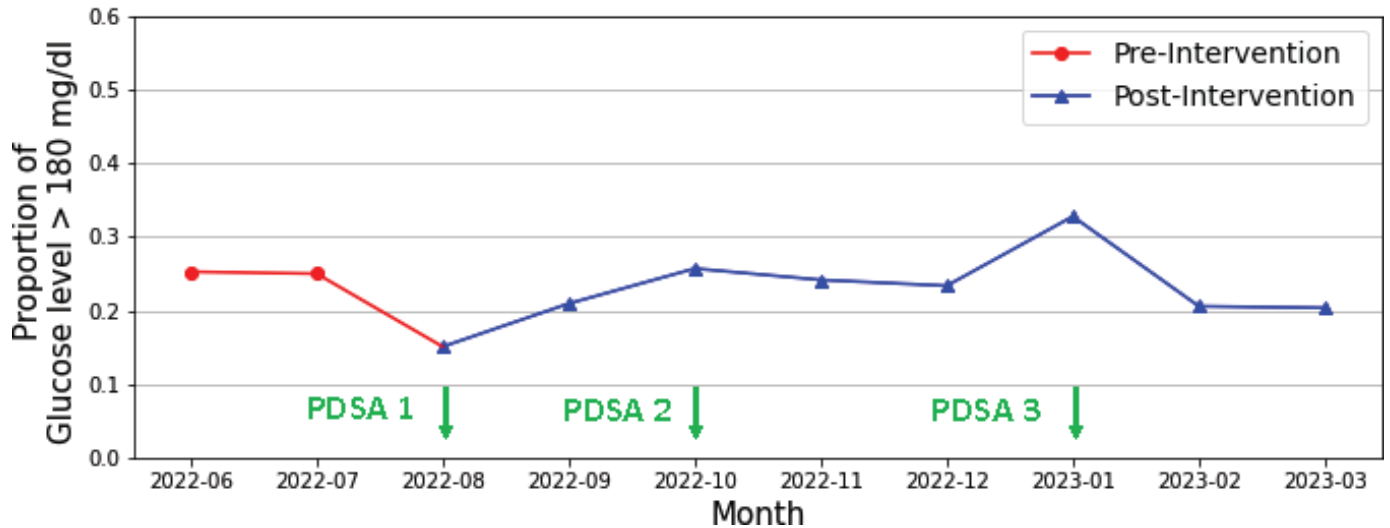


Figure 2 Run chart.

rates are 20.5% and 20.3%, which is 20% lower than the pre-intervention rate of 25.0%.

We performed 1045 audits analysing 16 095 accu-checks on 395 non-duplicated patients. The majority of audits showed compliance with guidelines.

Our secondary outcome was the resident evaluation of the intervention using the Kirkpatrick model. The survey yielded 11 responses from 47 surveyed residents, a 23% response rate (online supplemental table 1). Overall, 81% of the residents expressed agreement or strong agreement that they “would like to continue receiving feedback by pharmacy about my inpatient management of hyperglycemia while rotating in wards”. Overall, 81% agreed or strongly agreed that they would recommend this model of audit and feedback for other areas of

training. Overall, 100% agreed that the lecture and feedback sessions enhanced their knowledge, corresponding to level 2 (learning). Regarding level 3 (behaviour), 90% agreed that their management of hyperglycaemia had improved as a result of the feedback received. Overall, 72% agreed that the lecture had a positive effect on their hyperglycaemia management. In terms of level 4 (results), 90% agreed that the feedback they received helped them achieve adequate glucose control. Overall, 100% agreed that the QI project had a positive effect on the health of the patients involved.

Table 1 Results of inpatient hyperglycaemia on resident wards teams

Month and year	Number of patients	Number of accu-checks	% of glucose values > 180 mg/dL
June 2022	97	1448	25.24
July 2022	98	2063	24.98
Overall, pre intervention	195	3511	25.0
August 2022	103	1787	15.08
September 2022	97	1690	20.92
October 2022	89	1639	25.67
November 2022	81	1189	24.14
December 2022	86	1296	23.34
January 2023	89	1982	32.74
February 2023	85	1457	20.57
March 2023	87	1544	20.34
Overall, post intervention	717	12 584	23.0

The fluctuations in number of patients, the number of accu-checks performed and the percentage of glucose values exceeding 180 mg/dL are demonstrated. The overall pre-to-post comparison was 25.0% in the pre and 23.0% in the post with a statistically significant difference and p value < 0.05.

DISCUSSION

While we did not meet our primary aim to reduce hyperglycaemia by 30%, we did achieve an overall pre-to-post statistically significant change from 25.1% to 23.0% (p value <0.05). When analysing the run-on chart, our last 2 months of intervention remain better than pre-intervention.

Project strengths include successful implementation of a resident-led interprofessional QI project and implementing continuous improvement. It was innovative taking an effective mechanism to change practice behaviour, audit and feedback and implementing it in a new environment—inpatient hyperglycaemia with internal medicine residents.

Our “SMART” (Specific Measurable Achievable Relevant Time-bound) aim had perhaps too high a goal at 30% reduction. January 2023 stands out as higher rate of hyperglycaemia at 32.7% raising the question of seasonal variation, impact from infections or other winter acuity impact.^{30 31} Our intervention focused primarily on prescribing behaviour which possibly was not enough of a driver of inpatient hyperglycaemia in our population.

The audit and feedback was well accepted by residents, evidenced by survey results. Our project serves as an example for other residency programmes looking to implement interprofessional QI activities, a requirement from the ACGME. We found the IPE Core Competencies helpful as guiding principles.³² While we did not find a published pharmacy and internal medicine resident QI project on inpatient hyperglycaemia, there are published examples of this partnership for other goals such as statin prescribing³³ and improving sepsis outcomes.³⁴

Resident-led QI projects not only satisfy ACGME requirements but also, more importantly, are critical to building the future leaders of healthcare. Physicians with experience in leading QI will have more tools to address the Institute for Healthcare Improvement ‘Triple Aim’—improving the experience of care; improving the health of populations; and reducing the per capita cost of healthcare.³⁵ Residents became more engaged in QI through the resident-led project and subsequent publication, consistent with other resident-led QI projects.²¹

We faced and overcame three common challenges of resident-led QI projects: acquiring data, sustaining projects and resident schedules.³⁶ We restructured our aim statement multiple times to ensure specificity. It would have been ideal to align our aim with a hospital system-wide goal such as the CMS Hospital Inpatient Quality Reporting on Inpatient Diabetes Mellitus. Having the interprofessional team eased our access to data.

Regarding sustaining the project, we ensured our aim statement was realistic and time based. We also had clear roles outlined for residents including principal investigator, co-principle investigator, information technology manager, IRB lead, literature searcher, stakeholder manager, data collector and a quality improvement tools expert. To overcome the challenge of conflicting resident schedules, our team was composed of residents who were

in clinic together every 5th week. We also had monthly deadlines due at the end of that 5th week.

LIMITATIONS

There were several limitations to our study. Our study focused primarily on physician behaviour which may have been affected by observer (Hawthorne) effect and is only one of the many variables that impact inpatient glucose.²

We used total accu-checks as our denominator which could skew the per cent hyperglycaemia in either direction depending on whether the patient got fewer or more accu-checks. A continuous glucose monitor would provide a more holistic assessment and add the value of assessing severity and frequency of hyperglycaemia. It would also be valuable to assess hypoglycaemia, patient acuity and comorbidities, insulin ordered but not administered and a cost analysis.

While our survey on acceptability was positive, it had a lower response rate at 23% and a subjective assessment.

CONCLUSION

While the harms and challenges of inpatient hyperglycaemia are known, the feasibility and impact of using audit and feedback was not well known in this population. While our intervention did not achieve our primary aim of 30% reduction in hyperglycaemia, there was a statistically significant improvement in hyperglycaemia and it was well accepted by residents.

We found the project useful because we gained understanding of drivers of inpatient hyperglycaemia and we trained internal medicine resident physicians to be leaders of improvement in the interprofessional and complex setting of healthcare.

Further work is being considered to use audit and feedback with residents and pharmacy to address other hospital-wide goals. Our project would be helpful to others wishing to explore inpatient hyperglycaemia, interprofessional QI with pharmacists and resident-led QI.

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Patient consent for publication Not applicable.

Ethics approval Ethical approval for the project was provided by the institutional review board (IRB) of the University of Texas Rio Grande Valley which determined that the project was not a human subjects research and did not require IRB oversight.

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Supplemental Table 1 Post-Intervention Survey

The post-intervention survey utilized the Kirkpatrick model to assess the impact of the lecture, audits and feedback on the management of hyperglycemia. The survey table presents the responses to each question with the corresponding percentages and Kirkpatrick level assessed.

Post-intervention survey						
Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Kirkpatrick level
I would like to continue receiving feedback by pharmacy about my inpatient management of hyperglycemia while rotating in wards	0% (0)	0% (0)	18% (2)	36% (4)	46% (5)	1 (Reaction)
Based on my experience with this QI project using pharmacy and an audit and feedback on inpatient hyperglycemia management, I would recommend this model for other areas of training	0% (0)	0% (0)	18% (2)	46% (5)	36% (4)	1 (Reaction)
The interventions of the QI project including the lecture audits and feedback improved my knowledge on inpatient hyperglycemia management	0% (0)	0% (0)	0% (0)	55% (6)	46% (5)	2 (Learning)
I changed my hyperglycemia management based on the audits and feedback provided by pharmacy	0% (0)	0% (0)	9% (1)	63% (7)	27% (3)	3 (Impact)
The “New endocrine society guidelines for the management of hyperglycemia in hospitalized patients in non-critically ill settings” changed my management of hospitalized patients with hyperglycemia	0% (0)	0% (0)	20% (2)	40% (4)	40% (4)	3 (Impact)
The audit and feedback provided by pharmacy helped me achieve adequate glycemic control in my patients with hyperglycemia	0% (0)	0% (0)	9% (1)	63% (7)	27% (3)	4 (Results)
The interventions of the QI project including the lecture, audits and feedback had a positive impact on our patient’s health	0% (0)	0% (0)	0% (0)	73% (8)	27% (3)	4 (Results)