GLYCEMIC MANAGEMENT SYSTEM OF TCVGH
Taichung Veterans General Hospital

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Executive Summary

Inadequate glycemic control in hospitalized patients with diabetes is associated with increased healthcare costs, higher complication rates, and worsened clinical outcomes. Improved glycemic management for hospitalized diabetic patients has been shown to significantly reduce healthcare expenditures and enhance clinical outcomes. In response to this challenge, we developed a dynamic dashboard integrated with a remote management system and assessed its impact on inpatient glycemic control.

This program tackled the issue by leveraging technological innovations and process improvements to optimize glycemic management. A dynamic, electronic medical record (EMR)-based dashboard and a virtual glucose management service were implemented to provide real-time analysis and continuous monitoring of glucose levels across the patient population. Key process enhancements included the integration of point-of-care (POC) testing data directly into the EMR, facilitating automated daily updates on patient glucose levels. Furthermore, endocrinologists delivered virtual glycemic management recommendations to ensure timely and effective interventions.

Implementing of these tools and process improvements resulted in substantial improvements in glycemic control. There was a 43% reduction in the proportion of patients with poor glycemic control, a 43% reduction in hyperglycemia (glucose > 300 mg/dL), a 50% reduction in hypoglycemia (glucose < 70 mg/dL), and a 57% reduction in severe hypoglycemia (glucose < 50 mg/dL). Additionally, the mean length of hospital stay (LOS) decreased by 40.4%, from 13.6 days to 8.1 days.

The adoption of a hospital-wide electronic remote glycemic management system led to significant improvements in glycemic control, reducing both hyperglycemia and hypoglycemia incidences, as well as shortening the length of hospital stay. These findings suggest that this approach may also reduce the cost of avoidable hospitalizations, underscoring the potential of integrating technology to enhance diabetes care in the hospital setting.

Define the Clinical Problem and Pre-Implementation Performance

- **Define the Clinical Problem**

    Clinical Issue: Poor glycemic control among hospitalized adults, specifically hyperglycemia and hypoglycemia.

Obstacles for Glycemic Control in Hospitals

Numerous obstacles hinder glycemic control in hospitals, including unanticipated changes in nutrition, medication changes, physiologic stress responses, and comorbid events like acute renal insufficiency. System and organizational barriers also exist, such as lack of communication and diabetes management knowledge among providers. Coordinating insulin dosing with meals is often problematic. Hospital staff may have varying degrees of knowledge about proper hyper- and hypoglycemia management.

1	Develop Provider Education Tools	2	Implement Clinical Decision Aids	3	Enhance Provider Communication
	Create tools to improve knowledge and address barriers to achieving glycemic control		Develop point-of-care aids to guide prescribers in implementing evidence-based guidelines		Create inpatient glucose management sign-out tools to improve communication between providers

Reference: Diabetes Care. 2013 Jul;36(7):1807-14. doi: 10.2337/dc12-2508

- **Reason for Prioritization:**

    The significant impact of poor glycemic control on patient outcomes, including higher rates of complications, longer hospital stays, and increased healthcare costs.

- **Pre-Implementation Performance**

    Performance Metrics before Implementation:

    Adherence to Care Quality Measure: Before the implementation of the dashboard system, the proportion of patients with poor glycemic control was high. **Hyperglycemia and hypoglycemia rates were 10.2 and 7.0 per day per 100 patients with glucose monitoring, respectively.**

- **Poor Glycemic Control Definition:**

    Hyperglycemia: Blood glucose levels ≥300 mg/dL on two or more occasions.

    Hypoglycemia: Blood glucose levels <70 mg/dL.

    Severe hypoglycemia: Blood glucose levels <50 mg/dL.

- **Numerator and Denominator:**

    Numerator: Number of patients experiencing hyperglycemia or hypoglycemia.

    Denominator: Total number of patients with glucose monitoring per day.

- **Clinical Exemption Criteria:**

    Patients in pediatrics were excluded from the measurement cohort due to their specific conditions and management protocols.

- **Targeted Performance Goals:**

  Aimed to reduce the rates of poor glycemic control among hospitalized patients, including the incidence of hyperglycemia and hypoglycemia.

  Specific targets were set for reducing poor glycemic control by 43%, hyperglycemia (>300mg/dl) by 43%, hypoglycemia (<70mg/dl) by 50%, and Severe hypoglycemia (<50mg/dl) by 57%.

- **Impact on Health Equity**

  The system is implemented in whole interstitial-wide to ensure equitable health outcomes.

Design and Implementation Model Practices and Governance

Clinical Leaders and Subject Matter Experts:
Involve endocrinologists, diabetologists, certified diabetes educators, and nurse practitioners knowledgeable in glycemic control. C-Suite Executives: Engage Chief Medical Officer (CMO) and Chief Information Officer (CIO) for strategic alignment and resource allocation. IT Champions: Collaborate with IT specialists to adapt electronic health record (EHR) systems to new workflows and ensure data integration.

Workflow Design and Solution Selection
Needs Assessment: Review current workflows to identify gaps in glycemic control processes.
Technology Solutions: Select IT solutions like electronic dashboards for real-time blood glucose monitoring.
Testing and Field Testing: Pilot solutions in select departments to address potential issues and refine the system.
Implementation and Training
Training Programs: Develop and conduct training on new systems and workflows, emphasizing both practical and theoretical aspects.
Go-Live Support: Provide comprehensive support during system go-live, including IT support and superuser assistance.
Governance and Continuous Improvement
Governance Structure: Establish a committee with clinical, IT, and administrative members to oversee project implementation.
Regular Reviews and Updates: Conduct regular meetings to evaluate the impact and make necessary adjustments based on feedback.
Change Management: Implement a structured process for system and workflow updates to minimize disruptions.

Performance and Impact Evaluation
Metrics and Analytics: Utilize collected data to measure performance against clinical targets and outcomes.
Health Equity Considerations: Ensure the new technologies equitably improve health outcomes across different patient populations.
**Management of Indicators:** Monthly reviews by clinical units of the poor glycemic control rate, discussing and planning improvements.
Documentation and Reporting
Documentation Practices: Maintain detailed records of all decisions and changes for compliance and tracking.
Outcome Reporting: Regularly share results of IT interventions with stakeholders to support further investment in technology-enhanced solutions.

Organizational Structure for Inpatient Glycemic Management
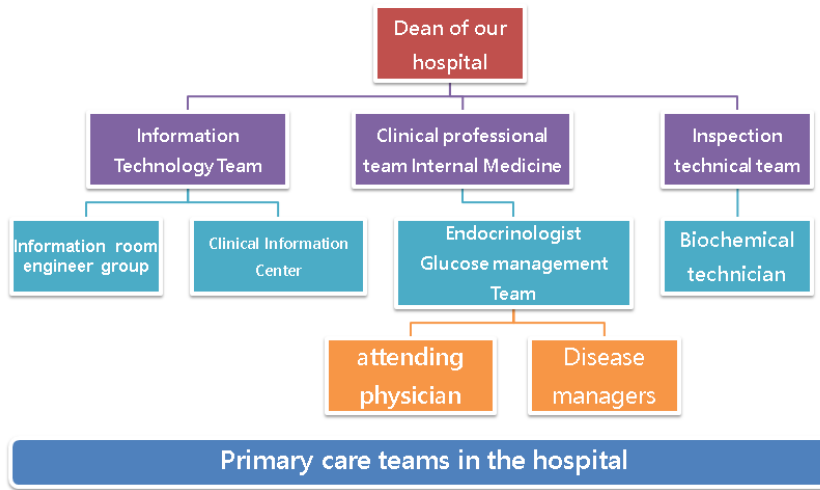
Clinical Transformation enabled through Information and Technology

- Workflow:
  Includes a detailed flow chart that outlines the entire clinical workflow for a specified disease state or clinical problem, capturing all the critical phases of patient care and decision points.

Proactively provide hospital-wide glycose care service
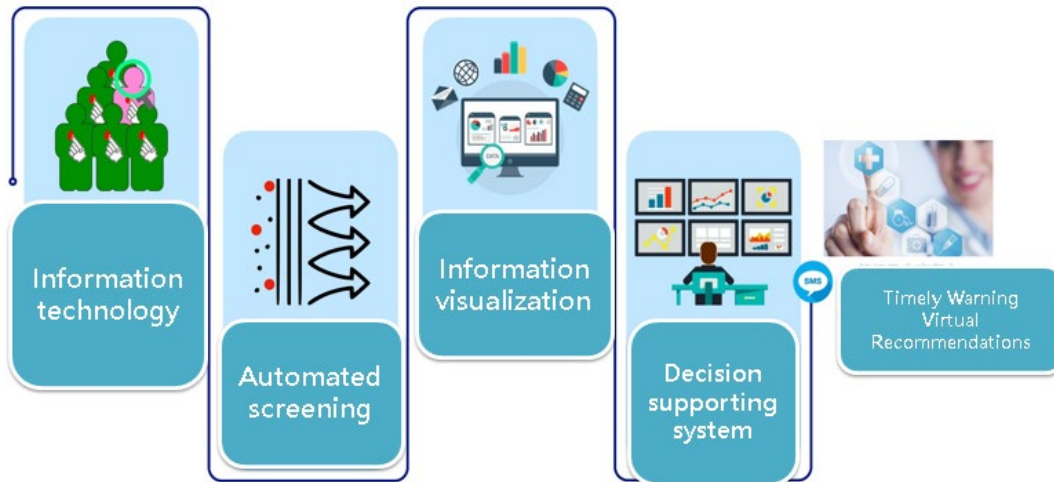
- Use of Artificial Intelligence:
  AI tools utilize clinical and lab data to categorize patients into specific cohorts relevant to the quality measure denominator, enhancing targeted care approaches.
- Risk Adjustment Algorithms:
  Algorithms incorporate patient history, clinical data, behavioral health data, and social determinants of health to adjust the risk profiles of individual patients.
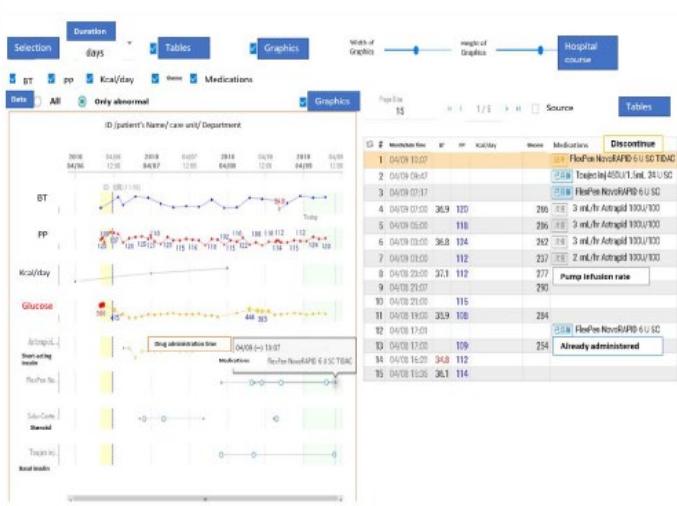
Clinical and lab data are leveraged to enrich decision support systems with precise, actionable insights.

- Clinical Decision Support Systems:
  Deployment of best practice advisories, standardized orders, and customized templates that interrupt usual workflows to guide clinicians towards optimal care standards.
  Includes screenshots and detailed descriptions of interfaces, with training protocols for clinicians on how to effectively use these tools.

Electronic glycemic management system for hospitalized patients.
A, The glycemic management system showing a list of all inpatients with poor glycemic control (hyperglycemia events shown in blue; hypoglycemia events shown in red).
B. The electronic glycemic management system showing the link to dynamic electronic medical records (EMRs) with vital signs and medication lists; users can select and summarize all messages related to glycemic control.

- Adaptation to Changes in Standard of Care:
  Identification of changes in care standards over time and the corresponding updates made to the information and technology frameworks supporting clinical care.

- Enhancement of Patient Safety Tools:
  Describes tools that support medication management and infection control, aimed at bolstering patient safety.
  Based on information from this dashboard, the glycemic management team could post virtual glycemic management recommendations to the message board via the EMR system, for use by the primary care team each morning. Examples of warning messages and virtual glycemic management recommendations are shown in Table 1. We informed the primary care team members that these recommendations were only a part of the clinical decision support system and were not equivalent to a formal note provided during an endocrinology consultation. As such, they should use their own best clinical judgment based on each patient's condition, with formal endocrinology consultation services available if needed.

Blood Glucose Adjustment Recommendations

The glycemic management team will receive a list of patients whose blood glucose monitoring values are ≥300 mg/dL more than twice, or <70 mg/dL at least once in the previous 24 hours. The following data are on the list: Bed No.: _____ Patient Name: _____.

Based on these data, we propose the following suggestions:

☐ Administration of glucose-lowering drugs: _____ Dose and administration method: _____.

☐ Baseline insulin: _____ units

    Preprandial insulin:

        Before breakfast: _____ units

        Before lunch: _____ units

        Before dinner: _____ units

☐ Premix insulin: Dose and administration method: _____

☐ GIK (glucose, RI, KCl) infusion: _____

☐ Insulin pump: _____

The above recommendations were proposed based on the patient's recent blood glucose status and clinical data. No onsite patient interview was conducted, and these are not official recommendations from a consultation meeting. When there are changes in the patient's diet, adjustments should be made to the preprandial insulin dose or glucose-controlling drugs. Your consideration of the patient's clinical status is highly important.

If you require assistance from the endocrinologist, please issue a consultation meeting form to officially inform the endocrinologist. Thank you.

Abbreviations: GIK = insulin infusion; KC = potassium chloride; RI = regular insulin.

Hypoglycemia Notification

The glycemic management team will receive a list of patients with blood glucose values <70 mg/dL.

The following information is on this list: Bed No.: _____ Patient Name: _____. Please manage his/her hypoglycemia and closely follow-up with the patient until his/her blood glucose levels recover to normal levels. In addition, we recommend an inspection of blood glucose control drugs and dietary status.

This patient is currently on___ to control blood glucose. We recommend suspension/reduction/adjustment of this high-risk drug be carried out when blood glucose levels are low.

The above recommendations were proposed based on the patient's recent blood glucose status and clinical data. No onsite patient interview was conducted, and these are not official recommendations from a consultation meeting. When there are changes in the patient's diet, adjustments should be made to the preprandial insulin dose or glucose-controlling drugs. Your consideration of the patient's clinical status is highly important.

If you require assistance from the endocrinologist, please issue a consultation meeting form to officially inform the endocrinologist. Thank you.

- Alerts and Monitoring Interfaces:
  Systems that alert clinical staff when a patient shows signs of deterioration, complete with visual interface screenshots and protocols detailing the appropriate responses.

Improving Adherence to the Standard of Care

- We analyzed the percentage of patients (per day per 100 patients with glucose monitoring) with poor glycemic control and those within the two target ranges for adults who received glucose tests.
- The glucometer data were uploaded directly to the EMR system automatically via wireless connection. In late 2016, a glycemic management team was formed, which integrated physicians from various medical services departments with information technology experts in order to develop and implement a hospital-wide glycemic management program.
- We designed an electronic glucose dashboard that analyzed and monitored all hospitalized inpatients using POC glucose systems as well as plasma glucose data obtained from the hospital's biochemistry laboratory
- Information from the dashboard was automatically updated every night at 23:59 pm. The dashboard could be used to discriminate inpatients who had poor glycemic control from those who had been within range of their targets.

- Two targets for glycemic control were predetermined. Target 1 was defined as overall glycemic values of 110-180 mg/dL, while Target 2 was defined as glycemic values of 140-180 mg/dL in the previous 24 hours.
- There was a 30% improvement in the 'treat to target' outcomes during this period

Treat to Target
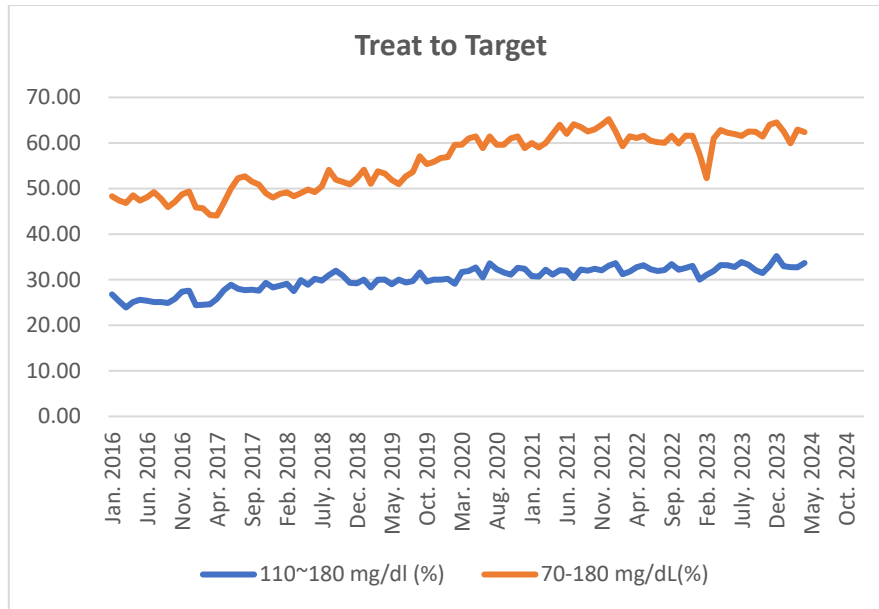
Improving Patient Outcomes

- The number of diabetic patients receiving outpatient and inpatient care at Taichung Veterans General Hospital has increased year by year,
- The results showed that after the implementation of a hospital-wide glycemic management program, the health of adults improved during the 7-year observation period.
- Poor glycemic control included hyperglycemia, defined as two or more glucose values of ≥300 mg/dL, and hypoglycemia, defined as a glucose level <70 mg/dL during the previous 24 hours.
- During the study period from January 2016 to April 2024, the total number of hospitalized adults receiving glucose monitoring increased from 426 per day to 651 per day, an increase of 53%.
- We observed significant reductions in poor glycemic control by 43%, hyperglycemia (>300 mg/dL) by 43%, hypoglycemia (<70 mg/dL) by 50%, and severe hypoglycemia (<50 mg/dL) by 57%.
- From 2016 to 2023, we observed a 40.4% reduction in the mean length of stay (LOS), decreasing from 13.6 to 8.1 days. Findings observed in this study might be associated with the reduction in the cost of avoidable hospitalizations.

Hospitalized patient under glycemic control

Values: 16271 (2016), 17049 (2017), 18321 (2018), 22724 (2019), 29920 (2020), 32533 (2021), 36424 (2022), 40615 (2023)

OPD DM patient numbers

Values: 16788 (2019), 17520 (2020), 18127 (2021), 18768 (2022), 19854 (2023)
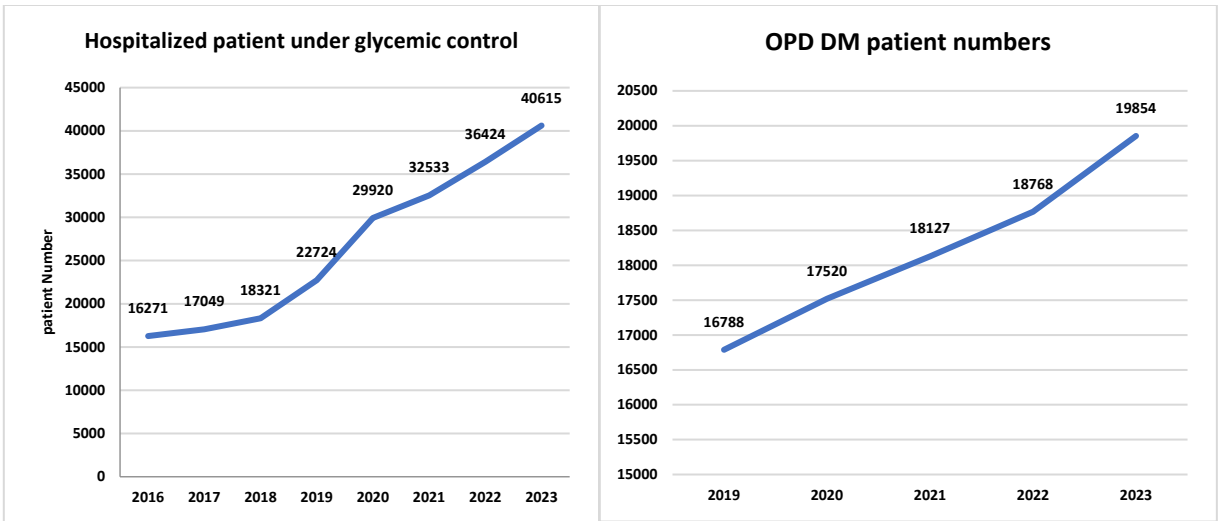
Increasing annual number of diabetic patients receiving outpatient and inpatient care at TCVGH

Poor glycemic control

Legend: Poor glycemic control (%) — Hypoglycemia (%) — Hyperglycemia (%) — Less than 50 mg/dL (%)
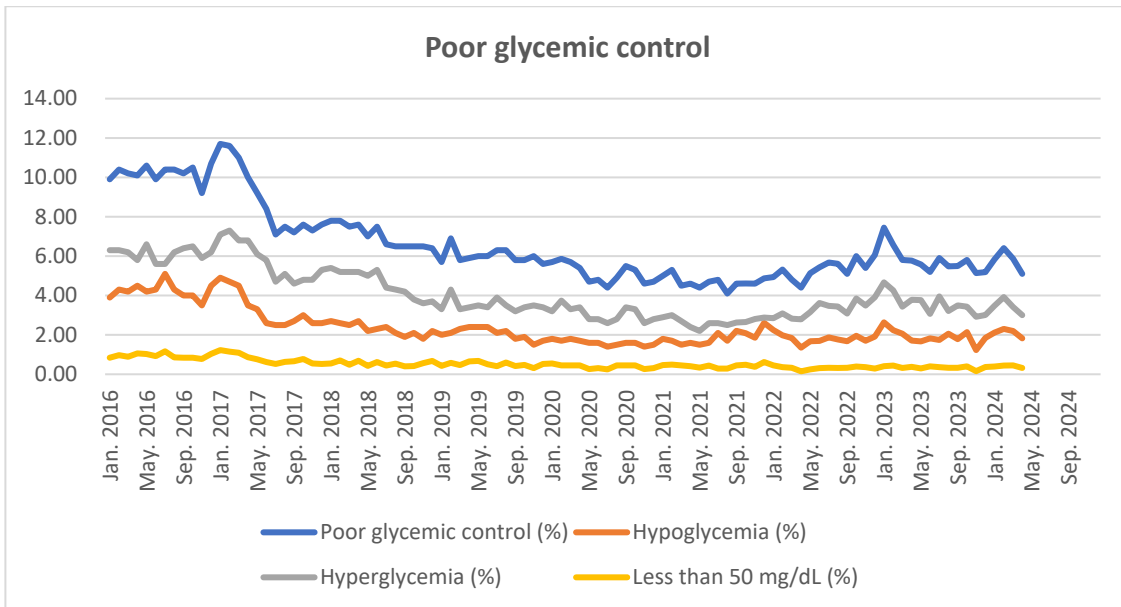
Train of both hyperglycemia and hypoglycemia rates improved after the implementation of EMR-based virtual glycemic control

Poor glycemic control rate of hospitalized adults

	2016	2017	2018	2019	2020	2021	2022	2023	2024
Poor glycemic control (%)	10.21	8.85	7.02	6.01	5.13	4.67	5.32	5.78	5.81
Hypoglycemia (%)	4.23	3.28	2.29	2.07	1.60	1.86	1.81	1.91	2.11
Hyperglycemia (%)	6.13	5.77	4.61	3.51	3.06	2.66	3.30	3.58	3.46
Less than 50 mg/dL (%)	0.94	0.78	0.54	0.51	0.39	0.43	0.32	0.35	0.40
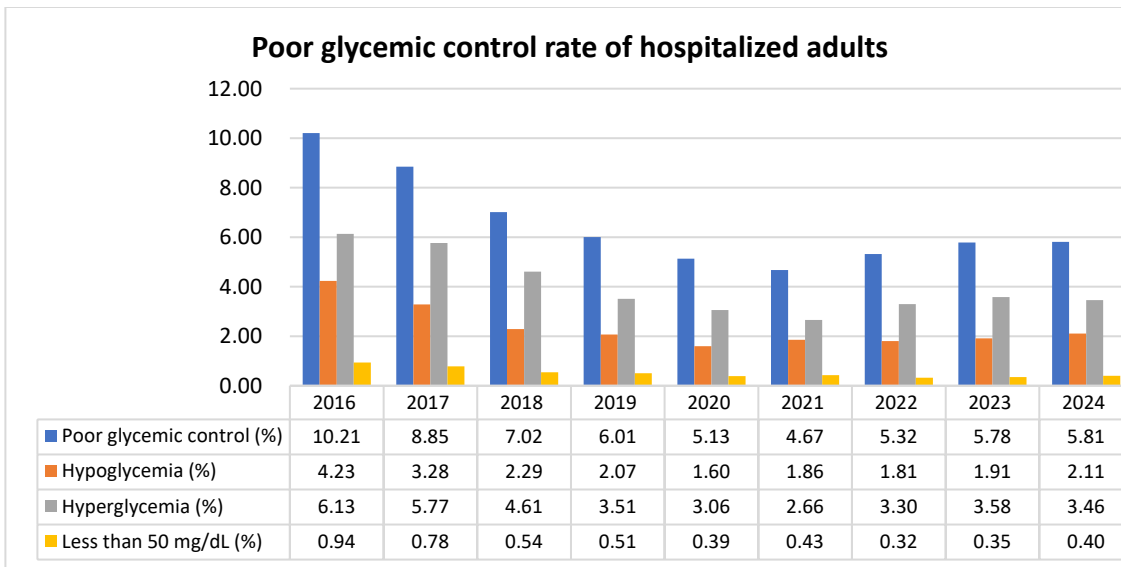
The mean proportions of hyperglycemia and hypoglycemia among hospitalized patients improved between January 2016 and May 2024
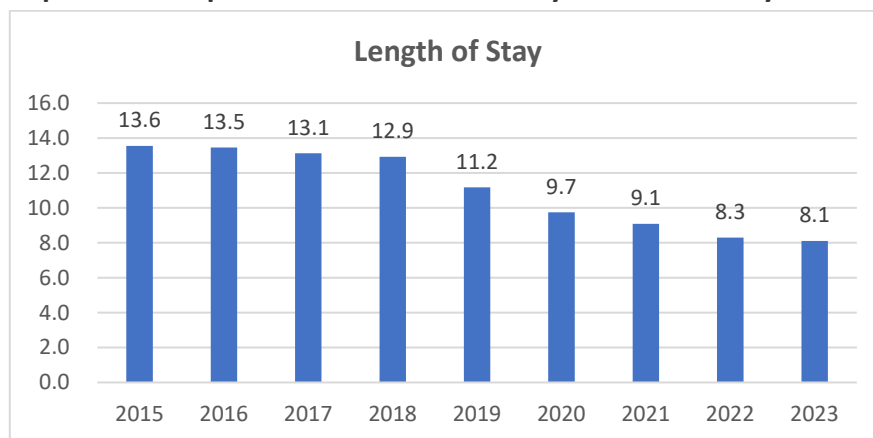
Reduce length of hospital stay
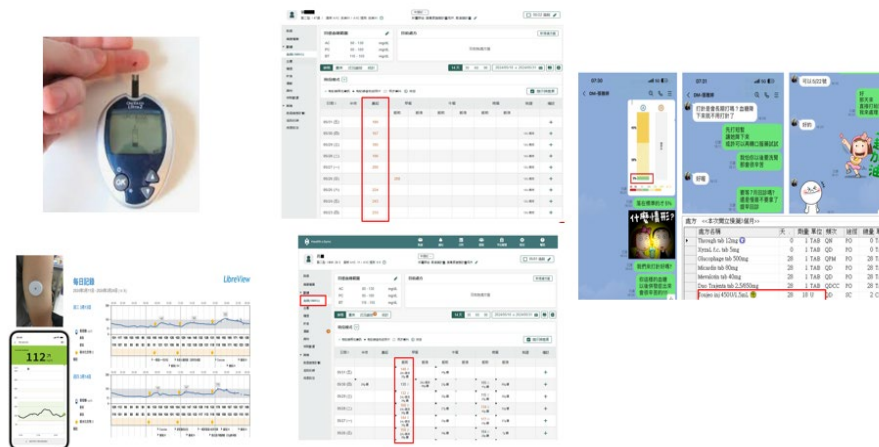
Remote monitoring tools to help aid in preventing rehospitalizations

Accountability and Driving Resilient Care Redesign

- Institution-wide dynamic EMR-based dashboard monitoring system and glycemic management program implementation The study hospital has a comprehensive EMR system that integrates health information systems, nursing systems, laboratory systems, pharmacy systems, and physician dictation systems.

- The glucometer data were uploaded directly to the EMR system automatically via wireless connection. We designed an electronic glucose dashboard that analyzed and monitored all hospitalized inpatients using POC glucose systems as well as plasma glucose data obtained from the hospital's biochemistry laboratory.

- Information from the dashboard was automatically updated every night at 23:59. Bar charts were generated showing the proportion of patients with poor glycemic control, and those within the treat-to-target range, allowing for simple visualization and comparison of glycemic goal attainment among different care units or departments.

- Glycemic management program
Glycemic management system- daily warning message; virtual glycemic management recommendation; timely warning and recommendations for hypoglycemia: The electronic glycemic management system was specially designed to automatically integrate with the hospital's dynamic EMR system, displaying all data, including the identification of patients with hyperglycemia or hypoglycemia. A hospital-wide summary of glycemic control among different care units was also available through the pull-down menu embedded in the dynamic EMR system. The tables and graphs menu includes trends in glucose values obtained from the POC system, vital signs, current diet orders, body weight, and information on all medications that might influence glucose levels, such as insulin, steroids, oral anti-diabetic drugs, etc., along with the time they are administered.

Award, Publications, and Patent certificates
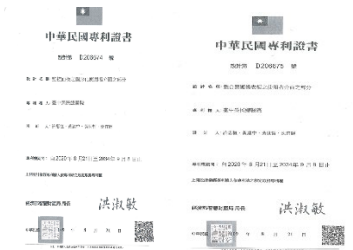
- Our hospital-wide glycemic care is effective, clinically operational, and yields sustained results that are internationally recognized and acclaimed.

Comparison of Institutional Achievements with National and International Standards

National Hospital		TCVGH (1,500-bed)	Taiwan Medical Center [1] (1,500-bed)	Israel Wolfson Medical Center [2] (700-bed)	Australia Royal Melbourne Hospital[3] (571-bed)	China Southern Region Hospitals[4] (>700-bed)	USA- UCSF Medical Center Three Emergency Hospitals[5] (>700-bed)
Quantity		213857 patients 8 years	35889 patient days Keep 8 weeks	150,000 times blood glucose measurements/ 2 years	1002 patients/ 20 weeks	886 patients/ 12 weeks	1,3371 patients/ 3 years
Quality	Hyperglycemia	≥300 mg/dL 6.1%→3.46% (P<0.001) Reduced 43%	BG>250mg/dL Reduce 21.3%	BG>300 mg/dL 16.2%→10.2% (P<.0001)	BG> 270 mg/dL 7.3%→3.3% (P=0.010)	BG>180mg/dL 31.1%	> 225 mg/dL 6.6%→4.0% (P=0.010) Reduced 39%
	Hypoglycemia	<70 mg/dL 4.2%→1.91% (P<0.001) Reduced 50% <50mg/dl 0.94%→0.35% Reduce 57%	BG<70 mg/dL Reduce 2.1%	BG<60 mg/dL 1.55%→1.48%, (P<.0001)	BG<72 mg / dL 3.8%→4.0% (P=0.69)	Hypoglycemia 7.8%	Hypoglycemia Recused 36%

References
1. Lin SD et. al. The Changhua Journal of Medicine 2016;14:49-56
2. Boaz M, et.al. J Journal of diabetes science and technology 2009, 3(5):1168-1174.
3. Kyi M, et al.A Cluster Randomized Trial. Diabetes care 2019, 42(5):832-840.
4. Hao S, et.al., Current medical research and opinion 2017, 33(8):1371-1377.
5. Rushakoff RJ, et.al. Annals of internal medicine 2017, 166(9):621-627

UK 2023 published hypoglycemia events 2.5%; severe hypoglycemia 1.7%*

TCVGH mean hypoglycemia event rate in 2023 were 1.91 %; severe hypoglycemia was 0.35 %.

*Reference:

Ruan, Y., et al., Increase in hypoglycaemia and hyperglycaemia in people with diabetes admitted to hospital during COVID-19 pandemic. J Diabetes Complications, 2023. 37(7): p. 108474.

Publications related to system development: meet the model for pathways to quality management of hyperglycemia and diabetes

- Sheen, Y.J., et al., IMPLEMENTATION OF AN ELECTRONIC DASHBOARD WITH A REMOTE MANAGEMENT SYSTEM TO IMPROVE GLYCEMIC MANAGEMENT AMONG HOSPITALIZED ADULTS. Endocr Pract, 2020. 26(2): p. 179-191.
- Sheen, Y.J., et al., Electronic dashboard-based remote glycemic management program reduces length of stay and readmission rate among hospitalized adults. J Diabetes Investig, 2021. 12(9): p. 1697-1707.
- Sheen, Y.J., et al., Accuracy of Point-of-Care Blood Glucometers in Neonates and Critically Ill Adults. Clin Ther, 2023. 45(7): p. 643-648.
- Shi, Z.Y., et al., Sustaining Improvements of Surgical Site Infections by Six Sigma DMAIC Approach. Healthcare (Basel), 2022. 10(11).

Intervention ➡ **Improved patient care** ➡ **Improved Outcomes**

System-level interventions[3]
- Hospital-wide Hypo and Hyperglycemia Policies and Order sets through centralized glucose management programs
- Education tools to improve provider knowledge (nursing, physicians, mid-level care providers, pharmacists)
- Clinical decision aids at point of care

Patient-level interventions—treatment
- Insulin and/or incretin-based therapies for special patient populations—enteral and parenteral nutrition, organ transplantation, dialysis, labor & delivery, insulin pump

Patient-level interventions—discharge planning
- Appropriate discharge to home processes

Improved Processes of Care
- Initiating appropriate components of insulin therapy (scheduled instead of sliding scale insulin use)
- Appropriate daily adjustments to insulin
- Appropriate nutritional insulin administration practices
- Protocol-driven response to hypoglycemia
- Protocol adherence

Improved Intermediary Glucose Outcomes [1] ⭐
- % of readings within hypoglycemic, euglycemic, or hyperglycemic range.
- % of patient hospital days with an episode of hypoglycemia (e.g., <40 mg/dL) or hyperglycemia.
- % of patient hospital days with day-weighted mean BG in euglycemic & hyperglycemic range
- Overall mean patient-day or patient-stay blood glucose

Improved clinical and Economic Outcomes ⭐
- Decreased LOS [2]
- Decreased cost of admission [2]
- Decreased incidence of readmission for hyperglycemia, or DKA
- Decreased rates of inpatient mortality, nosocomial infections [4]

Pathways to quality inpatient management of hyperglycemia and diabetes

Adapted from Diabetes Care. 2013 Jul;36(7):1807-14. doi: 10.2337/dc12-2508.

1. Sheen, Y.J., et al., IMPLEMENTATION OF AN ELECTRONIC DASHBOARD WITH A REMOTE MANAGEMENT SYSTEM TO IMPROVE GLYCEMIC MANAGEMENT AMONG HOSPITALIZED ADULTS. Endocr Pract, 2020. 26(2): p. 179-191.

2. Sheen, Y.J., et al., Electronic dashboard-based remote glycemic management program reduces length of stay and readmission rate among hospitalized adults. J Diabetes Investig, 2021. 12(9): p. 1697-1707.

3. Sheen, Y.J., et al., Accuracy of Point-of-Care Blood Glucometers in Neonates and Critically Ill Adults. Clin Ther, 2023. 45(7): p. 643-648.

4. Shi, Z.Y., et al., Sustaining Improvements of Surgical Site Infections by Six Sigma DMAIC Approach. Healthcare (Basel), 2022. 10(11).

HIMSS Global Conference Audience Guidance

Topic Guidance: Check three which apply to this case study

✓ Clinical Informatics and Clinician Engagement

Clinically Integrated Supply Chain

Consumer/Patient Engagement and Digital/Connected Health

Consumerization of Health

Culture of Care and Care Coordination

Data Science/Analytics/Clinical and Business Intelligence

Disruptive Care Models

Grand Societal Challenges

Health Informatics Education

Health Information Exchange

Interoperability

Integration, and Standards

✓ Healthcare Applications and Technologies Enabling Care Deliver y

Healthy Aging and Technology

✓ Improving Quality Outcomes

Innovation, Entrepreneurship, and Venture Investment

Leadership, Governance, and Strategic Planning

Population Health Management and Public Health

Precision Medicine and Genomics

Process Improvement, Workflow, and Change Management

Social, and Behavioral Determinants of Health

Telehealth

User Experience (UX)

Usability

User-Centered Design