**Name of journal:** ***World Journal of Diabetes***

**Manuscript NO: 50050**

**Manuscript type: EDITORIAL**

**Future technology-enabled care for diabetes and hyperglycemia in the hospital setting**

Montero AR *et al*. Future inpatient tech-enabled diabetes care

Alex Renato Montero, Jeffrey S Dubin, Paul Sack, Michelle F Magee

**Alex Renato Montero,** **Paul Sack, Michelle F Magee,** MedStar Diabetes Institute, Washington, DC 20010, United States

**Alex Renato Montero,** Department of Medicine, MedStar Georgetown University Hospital, Washington, DC 20007, United States

**Jeffrey S Dubin,** MedStar Washington Hospital Center, Washington, DC 20010, United States

**Paul Sack,** MedStar Union Memorial Hospital, Baltimore, MD 21218, United States

**Michelle F Magee,** MedStar Health Research Institute, Washington, DC 20010, United States

# ORCID number: Alex Renato Montero (0000-0003-3475-6239); Jeffrey S Dubin (0000-0002-8765-591X); Paul Sack (0000-0003-0734-1564); Michelle F Magee (0000-0002-4692-3201).

# Author contributions: Montero AR and Magee MF conceived the study, reviewed the literature and drafted the manuscript; Dubin JS and Sack P reviewed the literature and revised the manuscript; all authors approved the final version of the article.

# Conflict-of-interest statement: Montero AR, Dubin JS and Sack P have no financial conflicts of interest to declare relevant to any of the content of this editorial. Magee M received funding on behalf of MedStar Health Research Institute during the study period from Eli Lilly for the REWIND Study, From Sanofi for the AMPLITUDE Study, from the Patient-Centered Outcomes Research Institute (NCT-02093234), from the National Institutes of Health (NIH DK-109503) and from Mytonomy. She served as a speaker for the American Diabetes Association and for PRIMED® and on an Advisory Focus Group for Merck.

**Open-Access:** This is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

**Manuscript source:** Invited manuscript

**Corresponding author: Alex Renato Montero, MD, Assistant Professor,** MedStar Diabetes Institute, 100 Irving Street NW (Suite 4114), Washington, DC 20010, United States. arm243@georgetown.edu

**Telephone:** +1-202-8772383

**Fax:** +1-202-8776775

**Received:** June 28, 2019

**Peer-review started:** June 29, 2019

**First decision:** August 2, 2019

**Revised:** August 13, 2019

**Accepted:** August 27, 2019

**Article in press:** August 27, 2019

**Published online:** September 15, 2019

# Abstract

Patients with diabetes are increasingly common in hospital settings where optimal glycemic control remains challenging. Inpatient technology-enabled support systems are being designed, adapted and evaluated to meet this challenge. Insulin pump use, increasingly common in outpatients, has been shown to be safe among select inpatients. Dedicated pump protocols and provider training are needed to optimize pump use in the hospital. Continuous glucose monitoring (CGM) has been shown to be comparable to usual care for blood glucose surveillance in intensive care unit (ICU) settings but data on cost effectiveness is lacking. CGM use in non-ICU settings remains investigational and patient use of home CGM in inpatient settings is not recommended due to safety concerns. Compared to unstructured insulin prescription, a continuum of effective electronic medical record-based support for insulin prescription exists from passive order sets to clinical decision support to fully automated electronic Glycemic Management Systems. Relative efficacy and cost among these systems remains unanswered. An array of novel platforms are being evaluated to engage patients in technology-enabled diabetes education in the hospital. These hold tremendous promise in affording universal access to hospitalized patients with diabetes to effective self-management education and its attendant short/long term clinical benefits.

# Key words: Diabetes; Inpatients; Continuous subcutaneous insulin infusion; Continuous glucose monitoring; Clinical decision support; Patient education; Self-management

**© The Author(s) 2019.** Published by Baishideng Publishing Group Inc. All rights reserved.

# Core tip: Achieving optimal glycemic control in inpatients with diabetes and hyperglycemia remains a challenge for hospital providers. An array of technology-supported systems are evolving to assist providers and patients in meeting this challenge. Next generation, robust clinical decision support systems embedded in the electronic medical record are well positioned to replace structured order sets in the near term. If demonstrated to be cost effective, fully automated electronic glycemic management systems may become commonplace, in particular in intensive care unit settings. Novel media platforms hold tremendous potential for expanding access to crucial, effective self-management education for all patients with diabetes in hospital settings.

Montero AR, Dubin JS, Sack P, Magee MF. Future technology-enabled care for diabetes and hyperglycemia in the hospital setting. *World J Diabetes* 2019; 10(9):473-480

URL: https://www.wjgnet.com/1948-9358/full/v10/i9/473.htm

DOI: https://dx.doi.org/10.4239/wjd.v10.i9.473

**INTRODUCTION**

Adults with diabetes mellitus in the United States account for 7.2 million hospital discharges and 40.3 million hospital days annually[1,2]. Inpatient glycemic control remains suboptimal both in the United States[3] and abroad[4]. Numerous variables impact inpatient glycemic control, including: the pre-admission level of glycemic control[5]; medications prescribed for acute conditions (*e.g.*, steroids)[6]; comorbidities such as acute or worsened renal failure; and nutritional status[7]. Throughout the stay, providers need to identify glycemic trends in the context of multiple dynamic factors to safely and effectively optimize the insulin regimen.

In response to these challenges, technology-enabled systems are being evaluated and adapted for inpatient use. There is significant outpatient experience with diabetes technologies such as continuous subcutaneous insulin infusion (CSII) and continuous glucose monitoring (CGM) systems. Experience with emerging technology systems such as electronic medical record (EMR) based clinical decision support (CDS) for insulin prescription remains limited. Finally, inpatient engagement technology for diabetes education holds the potential to allow access to survival skills education for all inpatients with diabetes.

This editorial will focus on future directions evolving as technology-enabled supports for inpatient diabetes care delivery. For purposes of this discussion, we have grouped these endeavors into three broad categories shown on Table 1.

**OUTPATIENT TECHNOLOGIES *ADAPTED FOR INPATIENT USE***

# *CSII*

In 2016 five million persons with diabetes were utilizing CSII pumps[8-10]. Inpatient CSII use is not well characterized, but is likely to grow. CSII for hospital diabetes self-management is considered by the American Diabetes Association (ADA) to be appropriate for select patients[11].

CSII pumps deliver basal insulin (units per hour) to meet insulin requirements in the fasting state and between meals. The pump delivers bolus insulin doses (units) to match nutritional intake and as correction doses when blood glucose (BG) levels are high. Hospital providers need to be cognizant of these basics to safely supervise glycemic management when these patients are under their care. Patient ability to continue pump use in the hospital can be assessed by asking patients to describe essential pump skills such as how to adjust the basal rate, administer a bolus dose, and problem solve correction of an out of target BG[12]. A dedicated insulin pump protocol should address hospital use of CSII, including its use during procedures and in the operating room[13]. Training in pump basics should be provided to nurses and non- endocrinologist inpatient providers, including hospitalists and anesthesiologists, who may be called upon to write CSII orders and oversee glycemic management[14].

Potential CSII safety issues in the hospital include insertion site infections; mechanical pump failure; the need for frequent pump interruptions (*e.g.*, radiology tests involving ionizing radiation); and handoffs for procedures and diagnostic testing. Expert consensus recommends that appropriate patient selection is essential to safe hospital CSII use. Limited retrospective case series suggest a good safety record. The largest series (*n* = 164 admissions) found no surgical site infections, mechanical failures, or hospital-acquired diabetic ketoacidosis[15,16]. Both retrospective studies and a single, small randomized trial suggest that when compared to usual care, inpatient CSII use is equivalent for hyperglycemia events and possibly superior in hypoglycemia prevention[17,18].

# *CGM*

CGM systems measure and report BG every 5-15 min. CGM technology is estimated to be used by 4%-26% of Americans with type I diabetes[19]. CGM systems use subcutaneously placed sensors that measure BG in interstitial fluids and typically require changing every 10-14 d. Intensive care unit (ICU) CGM use has been studied for over ten years in both observational and prospective randomized studies of varying size. CGM systems accuracy compared to venous/arterial BG performed in the hospital laboratory and efficacy compared to usual care glycemic outcomes have been examined. The accuracy studies have found data generated by CGM systems to be acceptable. With regards to efficacy, a recent systematic review identified five randomized clinical trials. Most reported no significant difference in glycemic control (*i.e.*, mean glucose or time in range) while two found significant reduction in severe hypoglycemia favoring CGM[20,21]. Concerns regarding appropriateness of CGM use when factors which may impact subcutaneous circulation such as hypotension have been raised[22]. Larger randomized studies are needed to confirm benefits in hypoglycemia prevention for CGM in ICU settings and its cost effectiveness when compared to usual care.

Studies assessing routine CGM use in non-ICU settings are limited to small, uncontrolled prospective studies[23-26]. These studies report no difference in mean daily glucose, and CGM identified more hypoglycemic events compared to traditional point of care testing. However, for patients wishing to use their home CGM devices in the hospital, expert consensus has articulated several important potential safety concerns including the accuracy of CGM data when acute physiologic disturbances are present (*i.e.*, hypoxemia, vasoconstriction, and rapidly changing glucose levels in diabetic ketoacidosis) as well as concerns over correct CGM data interpretation by non- Endocrine inpatient care providers[18], and as a result, routine use of patient-generated CGM readings to guide inpatient insulin prescribing is not currently recommended.

Several insulin pumps now utilize CGM data to auto-modify insulin dosing via computerized algorithms. While there have been studies looking at use of “closed loop” insulin delivery systems for inpatients[27-29], to our knowledge, none have used the commercially available pump devices to date.

# INPATIENT SPECIFIC TECHNOLOGIES CDS SYSTEMS

Structured insulin order sets are now widely used in hospitals for subcutaneous insulin ordering and have been shown to improve daily average glucose, reduce glycemic extremes, and reduce prevalence of sliding scale only regimens[30-32]. Based on this evidence, current guidelines recommend the use of structured, electronic order sets that include advice for optimal insulin prescription[8].

CDS refers to electronic systems which assist in clinical decision making via provision of recommendations based on processing and presenting patient specific data at an appropriate time. This contrasts with passive order sets that provide advice that is not patient specific. The ubiquity of inpatient EMRs combined with guidelines for the use of insulin to manage most cases with hyperglycemia make inpatient insulin prescribing ideal for incorporation of CDS into workflow. Controlled evidence of the impact of CDS for inpatient insulin prescribing are lacking. However, the safety and acceptability of the Gluco Tab® mobile insulin prescription CDS system[33] has been reported and recently, the creation and implementation of an inpatient insulin prescription CDS module for the Epic EMR system has been described. This utilizes interactive computerized physician order entry elements which prompt the provider to input relevant factors (*e.g.*, indication for insulin - acute hyperglycemia without prior DM *vs* established DM not on insulin *vs* established DM on insulin) while also extracting other relevant factors (*e.g.*, insulin received in last 24 h) in order to process each element into formulating insulin prescription recommendations; the provider then selects one of the provided options[34].Studies on the efficacy and safety of this CDS module are in progress.

# ELECTRONIC GLYCEMIC MANAGEMENT SYSTEMS

While CDS systems rely on user input and chart extraction of key information, more automated CDS systems require minimal provider input and are termed electronic glycemic management systems (eGMS). Several proprietary eGMS systems have been developed for intravenous insulin infusion and subcutaneous administration. Examples include Glytec’s GlucommanderTM system[35], GlucoStabilizer®[36] by Medical Decision Networks, and Monarch’s EndoTool®[37]. These software systems use multivariate algorithms to continuously recalculate the appropriate insulin dose, adjusting to patient specific variables. Generally, the initial insulin dose is set by the provider based on a weight-based calculation or custom order and the algorithm makes subsequent insulin dosing adjustments. There are several potential advantages to such a system, including reduction in hypoglycemia and hyperglycemia, reduction in the cost of care, improvements in patient safety and provider satisfaction.

Reduction in hypoglycemia rates has been shown in several eGMS studies. Rabinovich *et al*[38] used the Glucommander eGMS to show reduction in BG < 3.9 mmol/L from 21.5% to 1.3% (*P* < 0.0001) and severe hypoglycemia reduction from 5.4% to 0.01% (*P* < 0.0001) in a retrospective review of critically ill patients on insulin infusions. A comparison between the eGMS and a computerized basal-bolus order set for non-critically ill patients on subcutaneous insulin also found a difference in glucose < 3.9 mmol/L (1.9% *vs* 2.8%, *P* = 0.001)[39]. These results may be magnified when an eGMS is implemented where basal-bolus insulin therapy is not prevalent. Newsom *et al*[40] found the rates of use of sliding scale insulin go from 95% to 4% after eGMS implementation, moderate and severe hypoglycemia rates drop by 21% and 50% respectively, reduced length of stay and fewer point of care tests per patient. Although there is limited data demonstrating potential cost savings[41], convincing hospital leadership to invest in them may present a challenge. It remains to be determined where they will fit in the big picture of technology supported inpatient glycemic management as CDS tools evolve and data to support each model accumulates.

# TECHNOLOGY-ENABLED DIABETES EDUCATION IN THE HOSPITAL

Deficits in diabetes knowledge and self-care management skills contribute to hospitalizations among persons with diabetes. Hospitalization presents an opportunity to provide education to this population, many of whom may not otherwise have access to this service. An accumulating body of evidence suggests that inpatient diabetes education, improving communication of discharge instructions and involving patients in medication reconciliation may reduce risk for early readmissions[42] and improve outcomes, including hemoglobin A1C and risk of readmission to the Emergency Department[43-46].

The ADA recommends that education be provided during an admission when a need is identified[8]. Content focused on “survival skills” to enable safe self-management until further outpatient instruction, as needed, is recommended. Inpatient diabetes education should also include a discharge plan for continuity of diabetes care as the transition from hospital to home is especially challenging and is associated with a high risk of negative outcomes, including readmissions[8]. Inpatient diabetes education delivery may be supported by both “low-tech” and increasingly by “high-tech” patient engagement strategies as shown on Table 2.

While patient engagement technologies offer the potential to expand the reach of education, in the hospital setting research in this field is emergent and outcomes data is lacking. It is crucial to patient engagement that technology tools are user friendly from a human factors perspective and that support is available to assure patient access and movement through the education content. Finally, if education is to be individualized, data security and privacy need to be assured[47].

Patient education systems are evolving from basic methods to high-tech-enabled systems. Low-tech methods include generic diabetes education sourced from providers such as KRAMES and Healthwise® and delivered *via* “SMART” TVs. These systems offer the advantage availability at every bed in the hospital and delivery through a familiar platform. Reports assessing the impact this type of education are lacking. In addition, whether hospitalized patients would choose to watch health information videos in large numbers remains in question. The Diabetes To Go study explored the effectiveness of video-based inpatient diabetes education in a large urban teaching hospital. Adults with diabetes participated in survival skills education delivered at the bedside *via* DVD player. Significant improvements in diabetes knowledge and medication adherence, as well as a trend towards reduction in hospital admissions in the 3 mo post- intervention were observed[37].

High-tech support for individualized diabetes education can potentially be delivered from the internet via tablet computer or smartphone using a web-interface from an education platform or embedded directly onto a tablet computer. Such platforms have ability to administer surveys and subsequently auto-direct the user to content tailored to responses. Staff must deliver the devices to the bedside, if they are not included with each bed, and staff time is often required to familiarize the patient with the platform.

Education delivery *via* personal-use devices also requires attention to infection control, physical device management and ergonomics. While web-based patient education technologies are being studied in the outpatient setting, inpatient studies are needed.

Finally, there are over 5000 technology applications and a wide variety of telehealth coaching programs available for diabetes education support. Among these technologies, very few have reported data or conducted clinical trials to assess impact on outcomes and none to-date has targeted education for inpatients with diabetes[48].

# CONCLUSION

Despite the current challenges in achieving optimal glycemic control in the hospitalized patient, there are an array of technology-based systems that have the potential to impact the future of inpatient glycemic management. Of the systems reviewed to-date, EMR-based CDS systems which facilitate insulin management and technology-enabled education would appear to hold the greatest potential for widespread dissemination and impact in a cost-effective fashion. Inpatient use of personal CSII pumps and CGM systems will likely continue to grow making it necessary for hospitals to develop policies and familiarize providers with their use. Electronic Glucose Management systems, whether EMR-based or provided by third parties, will also likely play a role in inpatient glycemic management, particularly in intensive care units. Long after an admission, it is reasonable to believe that technology-enabled diabetes education delivered in the hospital could afford the patient clinical benefit, such as has been documented with traditional outpatient diabetes education approaches. Ongoing research to compare and contrast the potential for impact of each of these technologies in hospital diabetes care management and to develop the business case for their use is needed to help enlighten future use strategies.

# REFERENCES

1 **American Diabetes Association.**. Economic Costs of Diabetes in the U.S. in 2017. *Diabetes Care* 2018; **41**: 917-928 [PMID: 29567642 DOI: 10.2337/dci18-0007]

2 **Centers for Disease Control and Prevention**.National Diabetes Statistics Report, 2017. Atlanta, GA, Centers for Disease Control and Prevention, U.S. Available from: https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf

3 **Swanson CM**, Potter DJ, Kongable GL, Cook CB. Update on inpatient glycemic control in hospitals in the United States. *Endocr Pract* 2011; **17**: 853-861 [PMID: 21550947 DOI: 10.4158/EP11042.OR]

4 **National Health Service**. National Diabetes Inpatient Audit England and Wales, 2017. Available from: https://files.digital.nhs.uk/pdf/s/7/nadia-17-rep.pdf

5 **Pasquel FJ**, Gomez-Huelgas R, Anzola I, Oyedokun F, Haw JS, Vellanki P, Peng L, Umpierrez GE. Predictive Value of Admission Hemoglobin A1c on Inpatient Glycemic Control and Response to Insulin Therapy in Medicine and Surgery Patients With Type 2 Diabetes. *Diabetes Care* 2015; **38**: e202-e203 [PMID: 26519335 DOI: 10.2337/dc15-1835]

6 **Donihi AC**, Raval D, Saul M, Korytkowski MT, DeVita MA. Prevalence and predictors of corticosteroid-related hyperglycemia in hospitalized patients. *Endocr Pract* 2006; **12**: 358-362 [PMID: 16901792 DOI: 10.4158/EP.12.4.358]

7 **Mathioudakis NN**, Everett E, Routh S, Pronovost PJ, Yeh HC, Golden SH, Saria S. Development and validation of a prediction model for insulin-associated hypoglycemia in non-critically ill hospitalized adults. *BMJ Open Diabetes Res Care* 2018; **6**: e000499 [PMID: 29527311 DOI: 10.1136/bmjdrc-2017-000499]

8 **Beck RW**, Tamborlane WV, Bergenstal RM, Miller KM, DuBose SN, Hall CA; T1D Exchange Clinic Network. The T1D Exchange clinic registry. *J Clin Endocrinol Metab* 2012; **97**: 4383-4389 [PMID: 22996145 DOI: 10.1210/jc.2012-1561]

9 **Lynch PM**, Riedel AA, Samant N, Fan Y, Peoples T, Levinson J, Lee SW. Resource utilization with insulin pump therapy for type 2 diabetes mellitus. *Am J Manag Care* 2010; **16**: 892-896 [PMID: 21348559]

10 North America insulin pump market prospect, share, development, growth, and demand forecast to 2022. Research and Markets. 2017. Available from: https://www.researchandmarkets.com/research/qnp7d9/north\_america

11 **American Diabetes Association.**. 15. Diabetes Care in the Hospital: *Standards of Medical Care in Diabetes-2019*. *Diabetes Care* 2019; **42**: S173-S181 [PMID: 30559241 DOI: 10.2337/dc19-S015]

12 **Houlden RL**, Moore S. In-hospital management of adults using insulin pump therapy. *Can J Diabetes* 2014; **38**: 126-133 [PMID: 24690507 DOI: 10.1016/j.jcjd.2014.01.011]

13 **Noschese ML**, DiNardo MM, Donihi AC, Gibson JM, Koerbel GL, Saul M, Stefanovic-Racic M, Korytkowski MT. Patient outcomes after implementation of a protocol for inpatient insulin pump therapy. *Endocr Pract* 2009; **15**: 415-424 [PMID: 19491071 DOI: 10.4158/EP09063.ORR]

14 **Lansang MC**, Modic MB, Sauvey R, Lock P, Ross D, Combs P, Kennedy L. Approach to the adult hospitalized patient on an insulin pump. *J Hosp Med* 2013; **8**: 721-727 [PMID: 24227761 DOI: 10.1002/jhm.2109]

15 **Thompson B**, Leighton M, Korytkowski M, Cook CB. An Overview of Safety Issues on Use of Insulin Pumps and Continuous Glucose Monitoring Systems in the Hospital. *Curr Diab Rep* 2018; **18**: 81 [PMID: 30120619 DOI: 10.1007/s11892-018-1056-7]

16 **Cook CB**, Beer KA, Seifert KM, Boyle ME, Mackey PA, Castro JC. Transitioning insulin pump therapy from the outpatient to the inpatient setting: a review of 6 years' experience with 253 cases. *J Diabetes Sci Technol* 2012; **6**: 995-1002 [PMID: 23063024 DOI: 10.1177/193229681200600502]

17 **Kannan S**, Satra A, Calogeras E, Lock P, Lansang MC. Insulin pump patient characteristics and glucose control in the hospitalized setting. *J Diabetes Sci Technol* 2014; **8**: 473-478 [PMID: 24876608 DOI: 10.1177/1932296814522809]

18 **Lee IT**, Liau YJ, Lee WJ, Huang CN, Sheu WH. Continuous subcutaneous insulin infusion providing better glycemic control and quality of life in Type 2 diabetic subjects hospitalized for marked hyperglycemia. *J Eval Clin Pract* 2010; **16**: 202-205 [PMID: 20367835 DOI: 10.1111/j.1365-2753.2009.01134.x]

19 **Wong JC**, Foster NC, Maahs DM, Raghinaru D, Bergenstal RM, Ahmann AJ, Peters AL, Bode BW, Aleppo G, Hirsch IB, Kleis L, Chase HP, DuBose SN, Miller KM, Beck RW, Adi S; T1D Exchange Clinic Network. Real-time continuous glucose monitoring among participants in the T1D Exchange clinic registry. *Diabetes Care* 2014; **37**: 2702-2709 [PMID: 25011947 DOI: 10.2337/dc14-0303]

20 **van Steen SC**, Rijkenberg S, Limpens J, van der Voort PH, Hermanides J, DeVries JH. The Clinical Benefits and Accuracy of Continuous Glucose Monitoring Systems in Critically Ill Patients-A Systematic Scoping Review. *Sensors* (Basel) 2017; **17**: [PMID: 28098809 DOI: 10.3390/s17010146]

21 **Wallia A**, Umpierrez GE, Rushakoff RJ, Klonoff DC, Rubin DJ, Hill Golden S, Cook CB, Thompson B; DTS Continuous Glucose Monitoring in the Hospital Panel. Consensus Statement on Inpatient Use of Continuous Glucose Monitoring. *J Diabetes Sci Technol* 2017; **11**: 1036-1044 [PMID: 28429611 DOI: 10.1177/1932296817706151]

22 **Umpierrez GE**, Klonoff DC. Diabetes Technology Update: Use of Insulin Pumps and Continuous Glucose Monitoring in the Hospital. *Diabetes Care* 2018; **41**: 1579-1589 [PMID: 29936424 DOI: 10.2337/dci18-0002]

23 **Burt MG**, Roberts GW, Aguilar-Loza NR, Stranks SN. Brief report: Comparison of continuous glucose monitoring and finger-prick blood glucose levels in hospitalized patients administered basal-bolus insulin. *Diabetes Technol Ther* 2013; **15**: 241-245 [PMID: 23360391 DOI: 10.1089/dia.2012.0282]

24 **Rodríguez LM**, Knight RJ, Heptulla RA. Continuous glucose monitoring in subjects after simultaneous pancreas-kidney and kidney-alone transplantation. *Diabetes Technol Ther* 2010; **12**: 347-351 [PMID: 20388044 DOI: 10.1089/dia.2009.0157]

25 **Gómez AM**, Umpierrez GE, Muñoz OM, Herrera F, Rubio C, Aschner P, Buendia R. Continuous Glucose Monitoring Versus Capillary Point-of-Care Testing for Inpatient Glycemic Control in Type 2 Diabetes Patients Hospitalized in the General Ward and Treated With a Basal Bolus Insulin Regimen. *J Diabetes Sci Technol* 2015; **10**: 325-329 [PMID: 26330394 DOI: 10.1177/1932296815602905]

26 **Levitt DL**, Silver KD, Spanakis EK. Inpatient Continuous Glucose Monitoring and Glycemic Outcomes. *J Diabetes Sci Technol* 2017; **11**: 1028-1035 [PMID: 28290224 DOI: 10.1177/1932296817698499]

27 **Boughton CK**, Bally L, Martignoni F, Hartnell S, Herzig D, Vogt A, Wertli MM, Wilinska ME, Evans ML, Coll AP, Stettler C, Hovorka R. Fully closed-loop insulin delivery in inpatients receiving nutritional support: a two-centre, open-label, randomised controlled trial. *Lancet Diabetes Endocrinol* 2019; **7**: 368-377 [PMID: 30935872 DOI: 10.1016/S2213-8587(19)30061-0]

28 **Bally L**, Gubler P, Thabit H, Hartnell S, Ruan Y, Wilinska ME, Evans ML, Semmo M, Vogt B, Coll AP, Stettler C, Hovorka R. Fully closed-loop insulin delivery improves glucose control of inpatients with type 2 diabetes receiving hemodialysis. *Kidney Int* 2019 [PMID: 31133457 DOI: 10.1016/j.kint.2019.03.006]

29 **Bally L**, Thabit H, Hartnell S, Andereggen E, Ruan Y, Wilinska ME, Evans ML, Wertli MM, Coll AP, Stettler C, Hovorka R. Closed-Loop Insulin Delivery for Glycemic Control in Noncritical Care. *N Engl J Med* 2018; **379**: 547-556 [PMID: 29940126 DOI: 10.1056/NEJMoa1805233]

30 **Guerra YS**, Das K, Antonopoulos P, Borkowsky S, Fogelfeld L, Gordon MJ, Palal BM, Witsil JC, Lacuesta EA. Computerized physician order entry- based hyperglycemia inpatient protocol and glycemic outcomes: The CPOE-HIP study. *Endocr Pract* 2010; **16**: 389-397 [PMID: 20061296 DOI: 10.4158/EP09223.OR]

31 **Schnipper JL**, Liang CL, Ndumele CD, Pendergrass ML. Effects of a computerized order set on the inpatient management of hyperglycemia: a cluster-randomized controlled trial. *Endocr Pract* 2010; **16**: 209-218 [PMID: 20061280 DOI: 10.4158/EP09262.OR]

32 **Wexler DJ**, Shrader P, Burns SM, Cagliero E. Effectiveness of a computerized insulin order template in general medical inpatients with type 2 diabetes: a cluster randomized trial. *Diabetes Care* 2010; **33**: 2181-2183 [PMID: 20664017 DOI: 10.2337/dc10-0964]

33 **Neubauer KM**, Mader JK, Höll B, Aberer F, Donsa K, Augustin T, Schaupp L, Spat S, Beck P, Fruhwald FM, Schnedl C, Rosenkranz AR, Lumenta DB, Kamolz LP, Plank J, Pieber TR. Standardized Glycemic Management with a Computerized Workflow and Decision Support System for Hospitalized Patients with Type 2 Diabetes on Different Wards. *Diabetes Technol Ther* 2015; **17**: 685-692 [PMID: 26355756 DOI: 10.1089/dia.2015.0027]

34 **Mathioudakis N**, Jeun R, Godwin G, Perschke A, Yalamanchi S, Everett E, Greene P, Knight A, Yuan C, Hill Golden S. Development and Implementation of a Subcutaneous Insulin Clinical Decision Support Tool for Hospitalized Patients. *J Diabetes Sci Technol* 2019; **13**: 522-532 [PMID: 30198324 DOI: 10.1177/1932296818798036]

35 Glytec Glucommander TM. Available from: https://www.glytecsystems.com/News/glytec-s-glucommander-and-eglycemic-management-system-featured-in-five-studies-presented-at-the-american-diabetes-association-s-76th-scientific-sessions.html

36 Glucostabilizer®. Available from: https://glucostabilizer.net/News.htm

37 Endotool®. Available from: https://monarchmedtech.com/endotool-glucose-management

38 **Rabinovich M**, Grahl J, Durr E, Gayed R, Chester K, McFarland R, McLean B. Risk of Hypoglycemia During Insulin Infusion Directed by Paper Protocol Versus Electronic Glycemic Management System in Critically Ill Patients at a Large Academic Medical Center. *J Diabetes Sci Technol* 2018; **12**: 47-52 [PMID: 29251064 DOI: 10.1177/1932296817747617]

39 **Aloi J**, Bode BW, Ullal J, Chidester P, McFarland RS, Bedingfield AE, Mabrey M, Booth R, Mumpower A, Wallia A. Comparison of an Electronic Glycemic Management System Versus Provider-Managed Subcutaneous Basal Bolus Insulin Therapy in the Hospital Setting. *J Diabetes Sci Technol* 2017; **11**: 12-16 [PMID: 27555601 DOI: 10.1177/1932296816664746]

40 **Newsom R**, Patty C, Camarena E, Sawyer R, McFarland R, Gray T, Mabrey M. Safely Converting an Entire Academic Medical Center From Sliding Scale to Basal Bolus Insulin via Implementation of the eGlycemic Management System. *J Diabetes Sci Technol* 2018; **12**: 53-59 [PMID: 29237289 DOI: 10.1177/1932296817747619]

41 **Ullal J**, McFarland R, Bachand M, Aloi J. Use of a Computer-Based Insulin Infusion Algorithm to Treat Diabetic Ketoacidosis in the Emergency Department. *Diabetes Technol Ther* 2016; **18**: 100-103 [PMID: 26783996 DOI: 10.1089/dia.2015.0215]

42 **Rubin DJ**, Donnell-Jackson K, Jhingan R, Golden SH, Paranjape A. Early readmission among patients with diabetes: a qualitative assessment of contributing factors. *J Diabetes Complications* 2014; **28**: 869-873 [PMID: 25087192 DOI: 10.1016/j.jdiacomp.2014.06.013]

43 **Magee MF**, Khan NH, Desale S, Nassar CM. Diabetes to Go: Knowledge- and Competency-Based Hospital Survival Skills Diabetes Education Program Improves Postdischarge Medication Adherence. *Diabetes Educ* 2014; **40**: 344-350 [PMID: 24557596 DOI: 10.1177/0145721714523684]

44 **Healy SJ**, Black D, Harris C, Lorenz A, Dungan KM. Inpatient diabetes education is associated with less frequent hospital readmission among patients with poor glycemic control. *Diabetes Care* 2013; **36**: 2960-2967 [PMID: 23835695 DOI: 10.2337/dc13-0108]

45 **Dungan K**, Lyons S, Manu K, Kulkarni M, Ebrahim K, Grantier C, Harris C, Black D, Schuster D. An individualized inpatient diabetes education and hospital transition program for poorly controlled hospitalized patients with diabetes. *Endocr Pract* 2014; **20**: 1265-1273 [PMID: 25100371 DOI: 10.4158/EP14061.OR]

46 **Donihi AC**. Practical Recommendations for Transitioning Patients with Type 2 Diabetes from Hospital to Home. *Curr Diab Rep* 2017; **17**: 52 [PMID: 28573408 DOI: 10.1007/s11892-017-0876-1]

47 **Prey JE**, Woollen J, Wilcox L, Sackeim AD, Hripcsak G, Bakken S, Restaino S, Feiner S, Vawdrey DK. Patient engagement in the inpatient setting: a systematic review. *J Am Med Inform Assoc* 2014; **21**: 742-750 [PMID: 24272163 DOI: 10.1136/amiajnl-2013-002141]

48 **Veazie S**, Winchell K, Gilbert J, Paynter R, Ivlev I, Eden K, Nussbaum K, Weiskopf N, Guise JM, Helfand M. Mobile Applications for Self-Management of Diabetes [Internet]. Rockville: Agency for Healthcare Research and Quality (US), 2018 [PMID: 30088878]

49 BlueStar Diabetes. Apple App Store, 2018. Available from: https://itunes.apple.com/us/app/bluestar-diabetes/id700329056?mt=8

**P-Reviewer:** Stavroulopoulos A, Zhao J

**S-Editor:** Ma RY **L-Editor:** A **E-Editor:** Xing YX

**Specialty type:** Endocrinology and metabolism

**Country of origin:** United States

**Peer-review report classification**

Grade A (Excellent): 0

Grade B (Very good): B, B

Grade C (Good): 0

Grade D (Fair): 0

Grade E (Poor): 0

**Table 1 Technology-enabled strategies for inpatient glycemic management and diabetes care**

|  |  |  |
| --- | --- | --- |
| **Technology category** | **Purpose** | **Technologies** |
| Outpatient technologies adapted for inpatient use | Support insulin management  | Personal continuous subcutaneous insulin infusion pumpsContinuous glucose monitoring sensor systems |
| Technologies developed for inpatient use | Diabetes and glycemic care management, including care transitions | Electronic medical record based clinical decision supportElectronic glycemic management systems |
| Technology-enabled diabetes education | Engagement in diabetes survival skills education | Electronic medical record-generated, printed education content“SMART” TVsWeb-based education platform |

**Table 2 Inpatient diabetes education delivery - current and future states**

|  |  |  |
| --- | --- | --- |
| **Modality** | **Current state** | **Future state** |
| 1:1 at the bedside | Unit nurse/Physician/educator provides basic education- often skills based, *e.g.*, insulin instruction, and/orprinted generic content | Supplemented by printed individualized electronic medical record clinical decision support generated content based on diagnoses, procedures, medications |
| Low-tech | Generic education content delivered *via* SMART TV or video | Video-based survival skills education content individualized for diabetes medications prescribed at dischargeProvider and/or electronic medical record clinical decision support prescribes targeted generic education content |
| High-Tech | Generic education content prescribed for delivery at bedside on TV or tablet computer from web-based platform | Individualized education delivered via an interactive patient engagement platform.Content auto-directed to learner based on embedded survey responses.“App” for telehealth coaching prescribed, *e.g.*, BlueStar[49] |