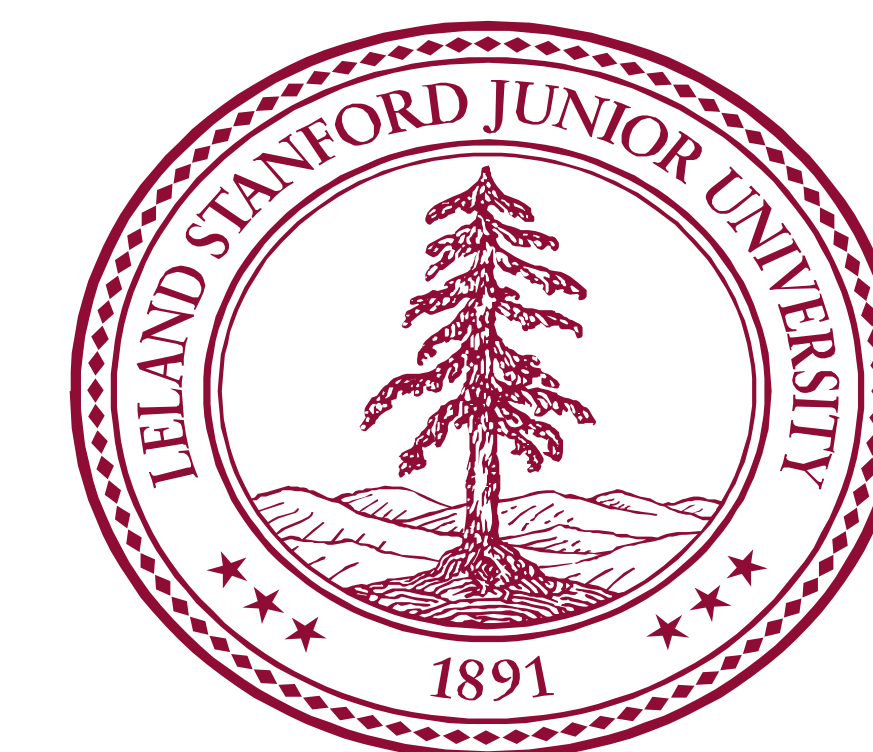


Implementing an Automated Electronic Calculator for Management of DKA/HHS

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Introduction

- **Diabetic ketoacidosis (DKA)** and **hyperosmolar hyperglycemic state (HHS)** are dangerous hyperglycemic complications of diabetes mellitus that require urgent intravenous (IV) insulin and correction of fluid and electrolyte abnormalities
- Current protocol at Stanford Healthcare (SHC) is a complex paper-based manual algorithm (Figure 1)

ALGORITHM #1		ALGORITHM #2		ALGORITHM #3		ALGORITHM #4	
BG	Units/hr	BG	Units/hr	BG	Units/hr	BG	Units/hr
<i>Less than 70 = Hypoglycemia (follow protocol below)</i>							
<i>BG 70-79 turn off infusion, check BG every 30 minutes until BG 80, re-start at lower Algorithm</i>							
80-109	0.2	80-109	0.5	80-109	1	80-109	1.5
110-119	0.5	110-119	1	110-119	2	110-119	3
120-149	1	120-149	1.5	120-149	3	120-149	5
150-179	1.5	150-179	2	150-179	4	150-179	7
180-209	2	180-209	3	180-209	5	180-209	9
210-239	2	210-239	4	210-239	6	210-239	12
240-269	3	240-269	5	240-269	8	240-269	16
270-299	3	270-299	6	270-299	10	270-299	20
300-329	4	300-329	7	300-329	12	300-329	24
330-359	4	330-359	8	330-359	14	330-359	28
>360	6	>360	12	>360	16	>360	32

Step 1: Regular IV insulin bolus of 0.10 units/kg (max recommended 10 units) may be ordered by MD.

Step 2: Initiate insulin infusion at Algorithm 1 (select dose based on BG result). Check blood glucose (BG) every hour.

Step 3: Adjust insulin infusion rate per BG results and rules (titration instructions and algorithm switching below). The goal is to decrease BG level by 50-70 mg/dL per hour until target range met. Validate POCT glucose > 500 mg/dL with plasma glucose. Obtain order from MD (see Reference #6, page 3).

Step 4: Notify MD when BG falls under 250 mg/dL to prompt ordering of dextrose-containing IV fluid (DKA and HHS)

Step 5: Notify MD when anion gap is closed (≤ 12), patient is awake, nausea/vomiting under control, insulin infusion rate is stable (+/- 1 unit), and blood sugars have been in target range x 3-4 hours (within 50 points mg/dL) to facilitate transition to SC insulin and change in diet order.

Figure 1. Excerpt of current DKA/HHS management protocol

- Prior research shows that a computer-based insulin infusion algorithm for emergency dept DKA treatment can decrease hospital admissions by 45%^{1,2}
- An automated Epic flowsheet was successfully implemented at SHC in 2013 for management of hyperglycemia with IV insulin and is used daily in the intensive care setting

Problem: The current DKA/HHS paper protocol is bulky, complex, and susceptible to human error

Aims:

1. Assess need and desire among SHC staff for a computerized DKA/HHS calculator in Epic
2. Translate the paper protocol into an automated flowsheet for implementation in Epic

Survey

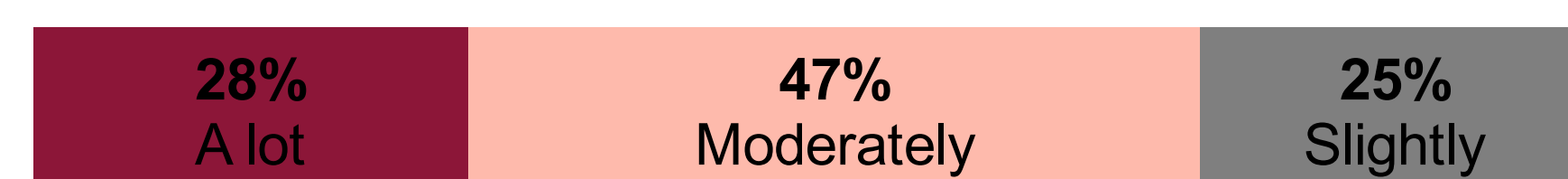
- Cross-sectional Qualtrics survey distributed to relevant SHC staff from March 3 – 17, 2017
- Likert scale question (n = 73)
- Work experience: Avg 11 yrs (Std 9, Med 8, Max 35)

Is DKA management by the current paper protocol **susceptible to human error**?



Perceived rate of error: Avg 36% (Std 25.5)

To what extent do errors **impact patient safety**?

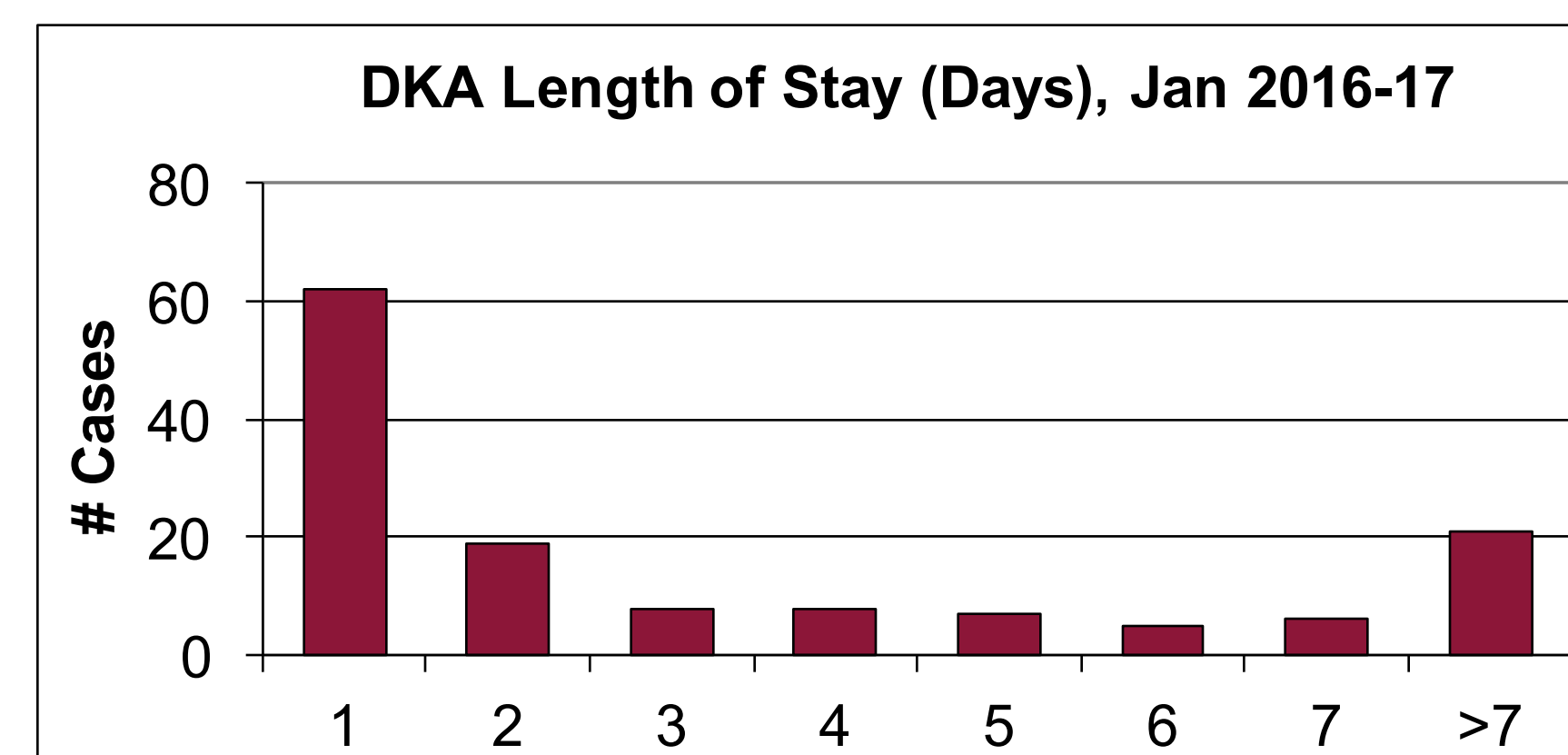


Would you find an automated Epic calculator **helpful for DKA management**?



Retrospective Review

- January 2016 – January 2017 (n = 136 DKA cases)
- **Cost: \$27 million** (Avg \$198.7k per case)
- **LOS: Avg 5 days** (Std 7.8, Med 2, Max 50)



- Only 46% of DKA cases were discharged within 1 day, 15% of cases stayed longer than 1 week
- Most common documented "complications of care": hypokalemia (n=6), acute renal failure (5), pneumonitis secondary to aspiration (5), acute respiratory failure (4), hypomagnesemia (3), hypoglycemia (3), delirium (3), sepsis (2)

Discussion

- An electronic calculator in Epic is **highly desired** among SHC diabetes staff due to the complexity of protocol and its susceptibility to errors. We report the strong need for an automated electronic insulin calculator for management of DKA/HHS patients.
- The annual cost of DKA stays sum to \$27 million dollars, and represents a **high potential for cost savings** if LOS is reduced through this tool.
- Initial findings are consistent with literature showing that mean blood glucose is lowered and time within target range is increased when a computerized insulin dosing method of managing continuous IV insulin infusions is implemented.

Strengths:

- A similar calculator (continuous IV insulin for hyperglycemia) has previously been successfully implemented in Epic
- Electronic insulin calculator will reduce errors, reduce healthcare costs, and aid with the implementation of a complex protocol

Limitations:

- Calculator only applicable to SHC, as other institutions utilize different DKA/HHS protocols

Electronic DKA/HHS Management Tool

- Model was developed in Excel to automate the DKA/HHS algorithm, systematically tested with a variety of use cases, and designed for ease of implementation as Epic flowsheet. *Note: Insulin IV protocol requires DKA target of 150-200 mg/dL, and HHS target of 250-300 mg/dL.*

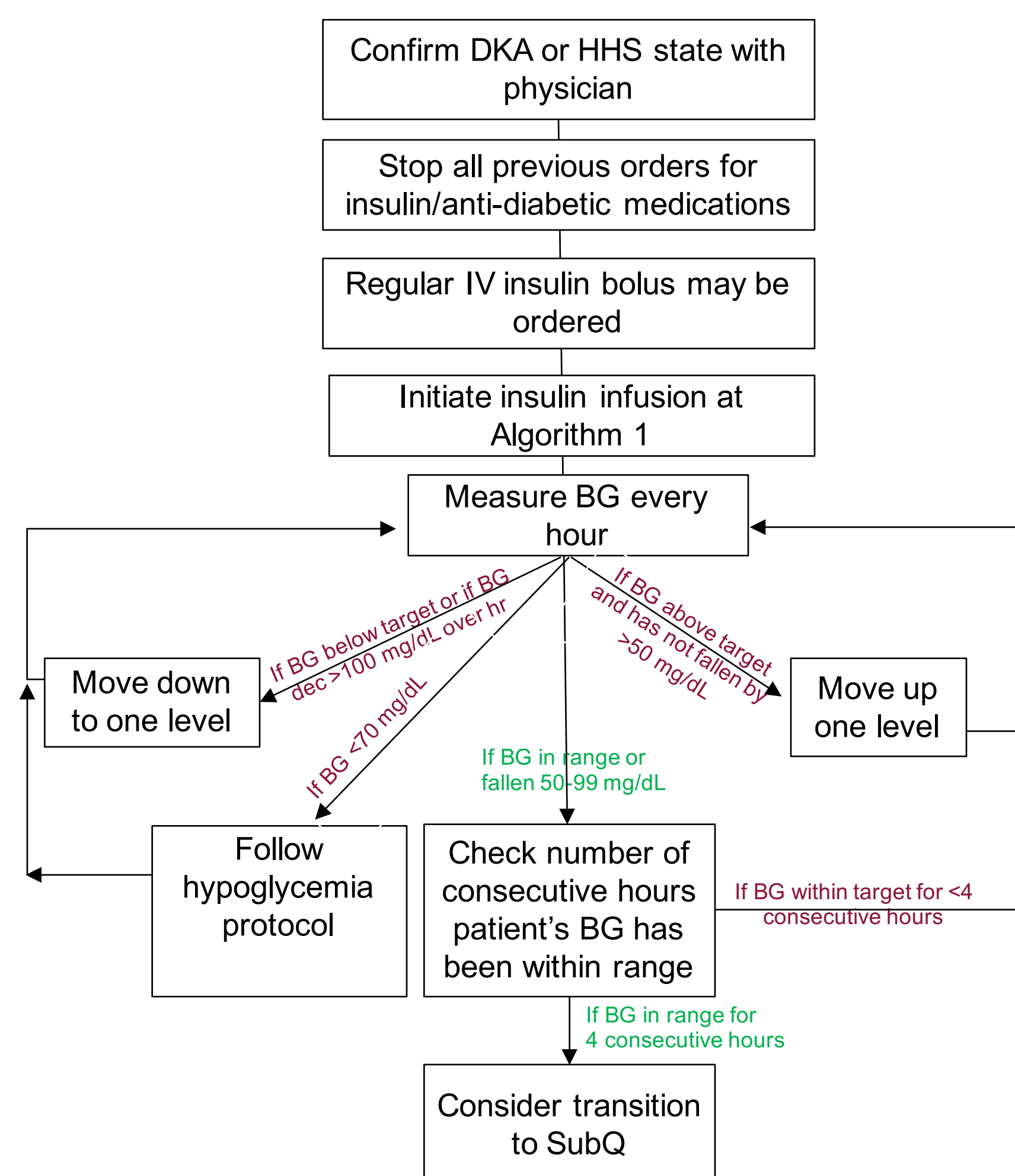


Figure 2. DKA/HHS Insulin Infusion Process Map

Time	BG Level	K+ Level	Insulin Units	Algorithm	BG in Target	Dextrose IV	Transition SQ	Push D50W	Replace K+	Notify MD
9:00 AM	350	4.1	4	1	No	No	No	No	No	No
9:58 AM	325	4.1	7	2	No	No	No	No	No	No
10:59 AM	300	4.1	12	3	No	No	No	No	No	No
12:03 PM	150	4.1	2	2	Yes	Yes	No	No	No	Notify MD
1:05 PM	90	4.1	0.2	1	No	Yes	No	No	No	No
2:00 PM	40	3.2	STOP	1	No	Yes	No	Yes	Yes	Notify MD
3:00 PM	150	4.1	0.75	1	Yes	Yes	No	No	No	No
4:05 PM	160	4.1	1.5	1	Yes	Yes	No	No	No	No
5:00 PM	150	4	1.5	1	Yes	Yes	No	No	No	No
	150	4	1.5	1	Yes	Yes	No	No	No	No

Figure 3. Example screenshot of DKA/HHS Model

- **Inputs:** serum glucose, potassium, anion gap
- **Outputs:**
 - IV insulin rate
 - In target vs not
 - Prompt for next glucose recheck
 - Alert/instructions for hypoglycemia, potassium repletion, dextrose IV, D50W, transition to subcutaneous insulin

Next Steps

- Work with SHC Epic team to conduct rigorous quality testing of electronic tool
- Train hospital personnel, particularly nursing staff in ICU and ED, on how to use new calculator
- Conduct post-implementation quality evaluation on relevant outcomes to establish true efficacy of tool (e.g. length of stay, number of protocol errors)

Acknowledgements & References

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