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Glycemic Control Through Computerized Subcutaneous Insulin Calculators

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Abstract. Sliding scale insulin (SSI) is a reactive therapy and does not maintain euglycemia in hospitalized patients. A combination of basal insulin, prandial insulin, and correction factor dosing provides a more consistent insulin state encouraging improved glycemic control. Intermountain Healthcare developed an application consisting of four calculators incorporating scheduled (basal and prandial) and correction-factor insulin. The result is a patient-specific order set with calculated insulin orders, a correction factor dosing table, and a carbohydrate dosing table. This paper describes the SQIC, access, usage monitoring, and challenges and solutions to the computerized decision support application created to replace SSI.

Keywords: Decision Support System, Personalized Care, Glucose Management

1. Introduction

The professional literature presents compelling studies and anecdotal details showing sliding scale insulin (SSI) dosing alone does not maintain euglycemia in hospitalized patients [1-8]. Sliding scale insulin is a reactive therapy treating short term future glycemic levels based only upon a current glycemic reading. Winterstein reported a small-scale hospital-based study showed over one hundred unique SSI orders were active simultaneously over a one month period resulting in misunderstandings by the nurses responsible for administering the correct insulin dose [8]. This variability makes it impossible to effectively measure and track outcomes based on a consistent process.

Euglycemia is better achieved using a combined basal-bolus treatment to obtain a more consistent insulin state [1-3],[9]. Basal (glargine) insulin is relatively peakless providing consistent insulin control regardless of caloric intake. Prandial, or nutritional, (aspart) insulin is short-acting to address caloric intake (oral, enteral, parenteral). In addition, correction-dose factor insulin will address hyperglycemia occurring before or between meals resulting from enteral or parenteral caloric intake.

For over a decade Intermountain Healthcare (Intermountain), a nonprofit, multi-state healthcare network in the United States, has progressed on an initiative to standardize clinical practice throughout the enterprise based upon current published research, national standards and regulatory guidelines [10]. Historically, glycemic control mechanisms were governed largely by preference and experience specific to units, care teams, and individual physicians. A few of Intermountain's critical care units were practicing highly-specific, time-based protocols limited to patients designated as NPO, being fed by parenteral or enteral routes. These highly successful, patient-specific delivery efforts involved tailored software solutions collecting automated glucometer data involving time-based prompts directed to the attending personnel for updating the treatment regimens. Anecdotal evidence suggested many internal care teams adhered to the traditional SSI dosing regimens common to current clinical practice patterns in the United States.

2. Objectives

In early 2005, Intermountain developed a series of spreadsheet-based calculations (based on an extensive literature review) using patient-specific input variables, including a patient's weight and glucose values, and a correction factor to generate a carbohydrate ratio and a series of associated orders. Trial usage orders at two local hospitals proved successful in controlling glycemic levels within national guideline parameters when transitioning from intravenous to subcutaneous insulin. This prompted leadership to expand the use of the spreadsheet calculations throughout the enterprise. Limitations in spreadsheet application access, high cost, and the need for training on the spreadsheet software prompted the creation of a web-based alternative for the spreadsheet, named Subcutaneous Insulin Calculators (SQIC). This paper describes the SQIC, monitoring, access, and challenges and solutions to the computerized decision support application created to replace SSI.

3. Materials and Methods

Development of the web-based SQIC began in early 2005. The SQIC contains five ordered sections: Demographic Info, Rate Estimation, Treatment Values, Dosing Tables, and Order Set. Choices made in a preceding section determine the options in the following section. Each field in a section contains content validation ensuring the entries fall within a predetermined range. Each field is followed by an Infobutton, containing field specific information and, when appropriate, a link to an adjustment calculator popup window to assist in identifying an appropriate dose.

Demographic Info contains a choice of three calculators (Currently on insulin, Initial dosage, Transition IV to SQ insulin), the current weight (kilograms), and personally identifiable information. Rate Estimation contains the Stable Insulin Infusion Rate and Caloric Intake options. The 24 hour insulin requirement, estimated treatment rate, estimated basal insulin (units insulin glargine), estimated correction factor, and estimated carbohydrate ratio are auto calculated and auto populated. Treatment Values contains the goal glucose, basal insulin, correction factor (decrease in mg/dL), correction factor (decrease per x units), carbohydrate ratio (grams carbohydrate/unit), and carbohydrate ratio (units insulin per gram carbohydrate) which are auto calculated and auto populated. However, all fields in this section may be revised by the ordering provider.

Dosing Tables contains up to two tables based upon selections and calculations in the previous sections. They are "Correction Factor Dosing Table" showing the aspart (units) per blood glucose (mg/dL) and, if receiving caloric intake, the "Carbohydrate (CHO) Dosing Table" showing aspart (units) per CHO (grams). Order Set contains several preselected and unselected orders resulting from selections in previous sections. All order selections may be altered by the ordering provider. The "Diet" section of the order set contains an embedded calculated insulin order based upon the enteral formula selected, associated auto calculated dosage (g/L) based on the formula's carbohydrate count, enteral rate (mL/hr), and auto calculated carbohydrate ratio.

Several assets were developed to support the SQIC functionality and are stored in the Knowledge Repository (KR) database. JavaScript libraries provide data validation, screen effects, and all calculations. Style sheet assets define fonts, colors, and other display attributes. An XSLT (Extensible Stylesheet Language Transformation) asset transforms the SQIC and order set XML into user-friendly HTML forms. The printing task uses a KR printing service receiving the order set input in XML format and, with a second XSLT, translates all the XML information into a PDF human readable format. The KR web services structure displays the SQIC enterprise-wide from a local electronic resources portal.

The first version of the web-based SQIC was released for internal testing in late 2005, and implemented in selected pilot Intensive Care Units (ICU) from early 2006 through 2007. Initially the SQIC was available through an e-resources page available from several points within the Intranet. Due to overwhelming demand, the SQIC pilot was made available as a protocol in Intermountain's web-based clinical electronic health record (HELP2), while expanding access to specific users in five facilities and additional non-ICU care settings.

In January 2008, the business owners ended all pilots and limited access to the SQIC only through HELP2. When in HELP2, a patient is enrolled in the SQIC protocol requesting the SQIC from the KR database via a service and passes the required patient demographic information using data derived from the patient's electronic health record as parameters through an HTTP request. When the KR service receives this HTTP request an HTML form is generated using an XSLT. The demographic parameters in the URL are used by the XSLT to pre-populate fields in the SQIC.

4. Results

All KR assets are monitored based on a call to retrieve the asset. SQIC monitoring data is based upon a call to retrieve the Subcutaneous Insulin Orders order set. A hit is recorded whether the asset is retrieved by a logged user, an application, or a URL. Only monitoring data containing a unique facility identification number was used to ensure the results display only data requested by HELP2.

Figure 1 shows the growth and decline of unique users per month. SQIC business owners report the decline is related to user dissatisfaction with the size and complexity of the order set form and printout, not with the actual calculator.

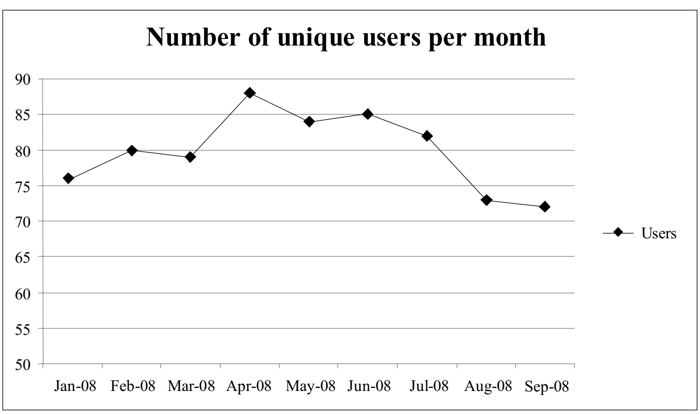

Figure 1. The number of unique users per month since access was restricted to HELP2 initially saw an increase but has steadily declined since May 2008.

Figure 2 compares SQIC usage between the 13 facilities currently allowed access within HELP2. Our flagship hospital, Intermountain Medical Center (IMED), is the most frequent user of the SQIC. The number of IMED hits declined in September 2008 due to fewer infrequent users accessing the SQIC.

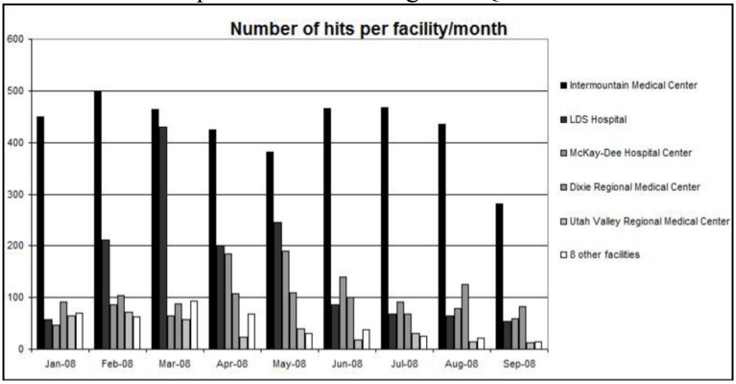

Figure 2. User access was expanded to include 12 facilities between January and September 2008.

5. Discussion

As more users accessed the SQIC, it was realized that the HTML form as it then appeared could potentially generate calculation errors due to errors of commission. This problem was resolved once access was limited to within HELP2. The SQIC has much more power when coupled tightly with the electronic medical record as opposed to a standalone resource, be it web-based or spreadsheet-based. In a future release, all demographic information will be removed from the SQIC form, except the current weight, as this information is already available within the HELP2 frame.

Several process changes were initiated so nurses could provide correct data to ordering providers. Nursing education materials were created and mandatory training was held on carbohydrate counting. Modifications were incorporated into the foodservice software to clearly identify the carbohydrate count on each patient food tray. Several changes were made to relevant forms in our clinical information systems.

The whole SQIC project is a composition of 18 XML and JavaScript libraries. The knowledge content, display styles, and functionality code are maintained as separate assets. The knowledge content and display styles can be quickly and easily updated as necessary without requiring a lengthy release process. It has been proposed that the supporting JavaScript libraries should be consolidated.

The dosing table printouts are used extensively by nurses. The printouts are placed on the patient's chart clipboard stored at the bedside so the content if readily available. When the order set and dosing tables are updated electronically, the unit clerk places the current dosing table printout on the bedside clipboard. Early in development a tab was added allowing only the dosing tables to be printed. The latest iteration of the software added a new calculator called "Correction Factor Only".

6. Conclusion

Intermountain developed an application consisting of four subcutaneous insulin calculators incorporating scheduled (basal and prandial) and correction-factor insulin to improve glycemic control for inpatients. The result is a patient-specific order set with calculated insulin orders used by an interdisciplinary care team, and a correction factor dosing table and a carbohydrate dosing table used extensively by nurses.

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