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Transcription Errors of Blood Glucose Values and Insulin Errors in an Intensive Care Unit: Toward Electronic Medical Record-Glucometer Interoperability

Azizeh Khaled Sowan; Ana Vera; Ashwin Malshe; Charles Reed

ABSTRACT

Background:

Critically ill patients require constant point-of-care-testing (POCT) for blood glucose using glucometers to guide initiation and titration decisions of continuous insulin infusion. Transcribing blood glucose tests' values from the glucometers into a paper log and the electronic medical record (EMR) is a very common yet error-prone practice in intensive care units (ICUs) given the lack of connectivity between glucometers and the EMR in many U.S. hospitals.

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This study examined (1) transcription errors of blood glucose values obtained by a glucometer and documented in the paper log and in the EMR vital signs flowsheet in a surgical trauma ICU, (2) insulin errors resulted from transcription errors of blood glucose values, (3) lack of documenting blood glucose values in the paper log and the EMR vital signs flowsheet, and (4) the average time for docking the glucometer.

Methods:

This secondary data analysis study examined 5049 point of care blood glucose tests for transcription errors, insulin errors, lack of documenting blood glucose values in the paper log and the EMR, and the glucometer docking time in a surgical trauma ICU. Transcription errors include errors in the paper log, errors in the EMR vital signs flowsheet, and errors in both. The results of the 5049 blood glucose tests were obtained from RALS®-Plus V1.5.1, a bi-directional interface software for in-hospital glucometers that uploads meters data after docking the meters into the EMR lab flowsheet. Chart audit was conducted to obtain the transcribed values of blood glucose tests from the EMR vital signs flowsheet and the patient demographic and clinical-related information. The paper log was accessed to obtain the corresponding transcribed values of the blood glucose tests. Three nurse educators obtained the data.

Results:

The 5049 blood glucose tests were pertinent to 234 patients. The total number of undocumented or untranscribed tests was 608 (12% out of 5049) in the paper log, 2064 (41% out of 5049) in the EMR vital signs flowsheet, and 239 (5% out of 5049) in both (paper log and the EMR vital signs flowsheet). The number of transcription errors for the documented tests was as follow: 98 (2% out of 4441 documented tests) in the paper log, 242 (8% out of 2985 tests) in the EMR vital signs flowsheet, and 43 (2% out of 2616 tests) in both. The percentage of transcription errors per patient was 0.4 (98 errors/234 patients) in the paper log, 1 (242 errors/234 patients) in the EMR vital signs flowsheet, and 0.2 in both (43/234 patients). Transcription errors in the paper log, the EMR vital signs flowsheet, and in both resulted in 8, 24, and 2 insulin errors, respectively. As a consequence, patients were given a lower or a high insulin dose than the dose they should receive if there were no transcription errors. Discrepancies in insulin doses were as follow: 2 units to 8 units lower insulin doses in the case of paper log transcription errors, 10 units lower to 3 units higher insulin doses in the case of transcription errors in the EMR vital signs flowsheet, and 2 units lower in the case of transcription errors in both. Overall, there were 30 unique insulin errors that affected 25 patients (11% out of 234 patients). The average time from the POCT to the time meters were docked (readings were uploaded into the EMR lab flowsheet) was 8 hours with a median of 5.5 hours. Some of the readings took 56 hours (2.3 days) to be uploaded into the EMR lab flowsheet.

Conclusions:

Transcription errors of blood glucose values obtained by glucometers do exist and result in insulin errors. A time lag exists between obtaining the results of blood glucose using glucometers and docking the meters to transfer the results into the lab flowsheet in the EMR. Given the high dependence on glucometers for POCT of blood glucose in ICUs, full EMR-glucometer interoperability is required for complete, accurate, and timely documentation of blood glucose values and elimination of transcription errors and the subsequent insulin-related errors in ICUs.

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Research paper

Title: Transcription Errors of Blood Glucose Values and Insulin Errors in an Intensive Care Unit: Toward Electronic Medical Record-Glucometer Interoperability

Authors:

1. Azizeh K. Sowan, PhD, RN, MSDA: Associate Professor, School of Nursing, University of Texas Health at San Antonio, San Antonio, TX, USA. sowan@uthscsa.edu
2. Ana Vera, MSN, RN, CCRN: University Health System, San Antonio, TX, USA. Ana.Vera@uhs-sa.com
3. Ashwin Malshe, PhD; Assistant Professor, School of Business, University of Texas at San Antonio, San Antonio, TX, USA. ashwin.malshe@utsa.edu
4. Charles C. Reed, PhD, RN, CNRN: Vice President/Associate Chief Nursing Officer Clinical Excellence and Ancillary Services, University Health System; San Antonio, TX, USA. Charles.Reed@uhs-sa.com

Corresponding Author Information

Azizeh K. Sowan, PhD, RN, MSDA

Associate Professor

Mailing Address: School of Nursing, Suite 2.628

7703 Floyd Curl Dr. - MC 7975

University of Texas Health, San Antonio, TX 78229-3900

Office number: (210) 567-5799

FAX number: (210) 567-1719

E-mail Address: sowan@uthscsa.edu

Abstract

Background: Critically ill patients require constant point-of-care-testing (POCT) for blood glucose using glucometers to guide initiation and titration decisions of continuous insulin infusion. Transcribing blood glucose tests' values from glucometers into a paper log and the electronic medical record (EMR) is a very common yet error-prone practice in intensive care units (ICUs) given the lack of connectivity between glucometers and the EMR in many U.S. hospitals.

Objective: This study examined (1) transcription errors of blood glucose values obtained by a glucometer and documented in the paper log and in the EMR vital signs flowsheet in a surgical trauma ICU, (2) insulin errors resulted from transcription errors of blood glucose values, (3) lack of documenting blood glucose values in the paper log and the EMR vital signs flowsheet, and (4) the average time for docking the glucometer.

Methods: This secondary data analysis study examined 5049 point of care blood glucose tests for transcription errors, insulin errors, lack of documenting blood glucose values in the paper log and the EMR, and the glucometer docking time in a surgical trauma ICU. Transcription errors include errors in the paper log, errors in the EMR vital signs flowsheet, and errors in both. The results of the 5049 blood glucose tests were obtained from RALS®-Plus V1.5.1, a bi-directional interface

software for in-hospital glucometers that uploads meters data after docking the meters into the EMR lab flowsheet. Chart audit was conducted to obtain the transcribed values of blood glucose tests from the EMR vital signs flowsheet and the patient demographic and clinical-related information. The paper log was accessed to obtain the corresponding transcribed values of the blood glucose tests. Three nurse educators obtained the data.

Results: The 5049 blood glucose tests were pertinent to 234 patients. The total number of undocumented or untranscribed tests was 608 (12% out of 5049) in the paper log, 2064 (41% out of 5049) in the EMR vital signs flowsheet, and 239 (5% out of 5049) in both (paper log and the EMR vital signs flowsheet). The number of transcription errors for the documented tests was as follow: 98 (2% out of 4441 documented tests) in the paper log, 242 (8% out of 2985 tests) in the EMR vital signs flowsheet, and 43 (2% out of 2616 tests) in both. The percentage of transcription errors per patient was 0.4 (98 errors/234 patients) in the paper log, 1 (242 errors/234 patients) in the EMR vital signs flowsheet, and 0.2 in both (43/234 patients). Transcription errors in the paper log, the EMR vital signs flowsheet, and in both resulted in 8, 24, and 2 insulin errors, respectively. As a consequence, patients were given a lower or a high insulin dose than the dose they should receive if there were no transcription errors. Discrepancies in insulin doses were as follow: 2 units to 8 units lower insulin doses in the case of paper log transcription errors, 10 units lower to 3 units higher insulin doses in the case of

transcription errors in the EMR vital signs flowsheet, and 2 units lower in the case of transcription errors in both. Overall, there were 30 unique insulin errors that affected 25 patients (11% out of 234 patients). The average time from the POCT to the time meters were docked (readings were uploaded into the EMR lab flowsheet) was 8 hours with a median of 5.5 hours. Some of the readings took 56 hours (2.3 days) to be uploaded into the EMR lab flowsheet.

Conclusions: Transcription errors of blood glucose values obtained by glucometers do exist and result in insulin errors. A time lag exists between obtaining the results of blood glucose using glucometers and docking the meters to transfer the results into the lab flowsheet of the EMR. Given the high dependence on glucometers for POCT of blood glucose in ICUs, full EMR-glucometer interoperability is required for complete, accurate, and timely documentation of blood glucose values and elimination of transcription errors and the subsequent insulin-related errors in ICUs.

Keywords: Transcription errors, blood glucose, insulin error, interoperability, glucometer, electronic medical record, secondary data analysis, intensive care unit.

Introduction

Background

Glycemic control in critically ill patients is essential to improve clinical outcomes and decrease morbidity and mortality [1-8], specifically for patients admitted to intensive care units (ICUs) for more than 3 days [2] and for patients admitted to surgical trauma ICUs (STICU) compared to medical ICUs [7]. Critically ill patients require constant point-of-care-testing (POCT) for blood glucose to guide initiation and titration decisions of continuous insulin infusion following insulin management protocols. Handheld blood glucose monitoring devices or glucometers are widely used in ICUs for this purpose for convenience and portability [9-10].

Transcribing blood glucose readings from glucometers into a paper log and different flowsheets in the electronic medical record (EMR) by healthcare professionals is a very common yet error-prone practice in ICUs given the lack of interoperability or connectivity between glucometers and the EMR in many U.S. hospitals [11]. Interoperability allows wireless transfer of blood glucose values from glucometers to the EMR without the need for manual data entry. Despite the call for systems interoperability and the emerging research describing frameworks and prototypes for seamless integration of medical devices' data into the EMR using different connectivity standards [12-15], medical device-EMR connectivity is limited in the U.S. In a national survey of 825 U.S. hospitals, the Health Information Management Systems Society Analytics Team reported a lack of any interface between the EMRs and the medical devices in 70% of the hospitals. The remaining 30% of the hospitals reported an interface of an average of 2.6 device types (out of 11 devices) with their EMRs. Interestingly, none of the hospitals provided an interface between glucometers and the EMR [11].

Extensive literature exists on the use of glucometers in ICUs. However, the majority of the studies focused on glucometers' accuracy in comparison to other blood glucose analytical measures [16-24]. Research on transcription errors is also available [25-27], however, there is a paucity of research on transcription errors of blood glucose values obtained by glucometers into the EMRs and the subsequent insulin errors [28]. Although the use of glucometers with high specificity and sensitivity is essential in critical care settings to prevent harmful effects associated with erroneous blood glucose readings and the subsequent under or overdose of insulin therapy, accurate and instant documentation of blood glucose values obtained by glucometers into the EMR is equally important to inform glycemic control and insulin management decisions.

Objective

This study examined (1) transcription errors of blood glucose values obtained by a glucometer that were documented in the paper log by technicians and in the EMR vital signs flowsheet by nurses in the ICU, (2) insulin errors resulted from transcription errors of blood glucose values, (3) lack of documenting blood glucose values in the paper log and the EMR vital signs flowsheet, and (4) the meter docking time.

Methods

Design, Sample, and Setting

This secondary data analysis study examined 5049 blood glucose tests for transcription errors, insulin errors, lack of documenting blood glucose values in the paper log and the EMR, and meter docking time. The study took place in a 30-bed STICU located in a 705-bed university teaching hospital with a large referral base in the southwest of the U.S. The STICU has an annual admission rate of 1,600 patients, an approximate monthly admission rate of 133 patients. Currently, there are 46 full-time and 11 part-time nurses and 13 technicians working in the unit. The average number of blood glucose POCT performed on patients in the unit is 4,200 – 4,300 tests per month.

After obtaining the IRB approval, the audit of blood glucose tests and insulin data was performed to a 20% stratified sample of all blood glucose tests available in the meters for cases admitted during 4 months (July to October of 2016). Stratification was based on the working shift (day/night) as the only possible factor that may introduce transcription errors of blood glucose readings as a result of fatigue expected at the end of each working shift and on the night shift. Additionally, when a blood glucose test was selected, all blood glucose tests pertinent to the same patient within the same episode of admission were also included to evaluate errors per patient. This resulted in a total of 5049 blood glucose tests.

Description of the Current Point-of-Care-Testing of Blood Glucose

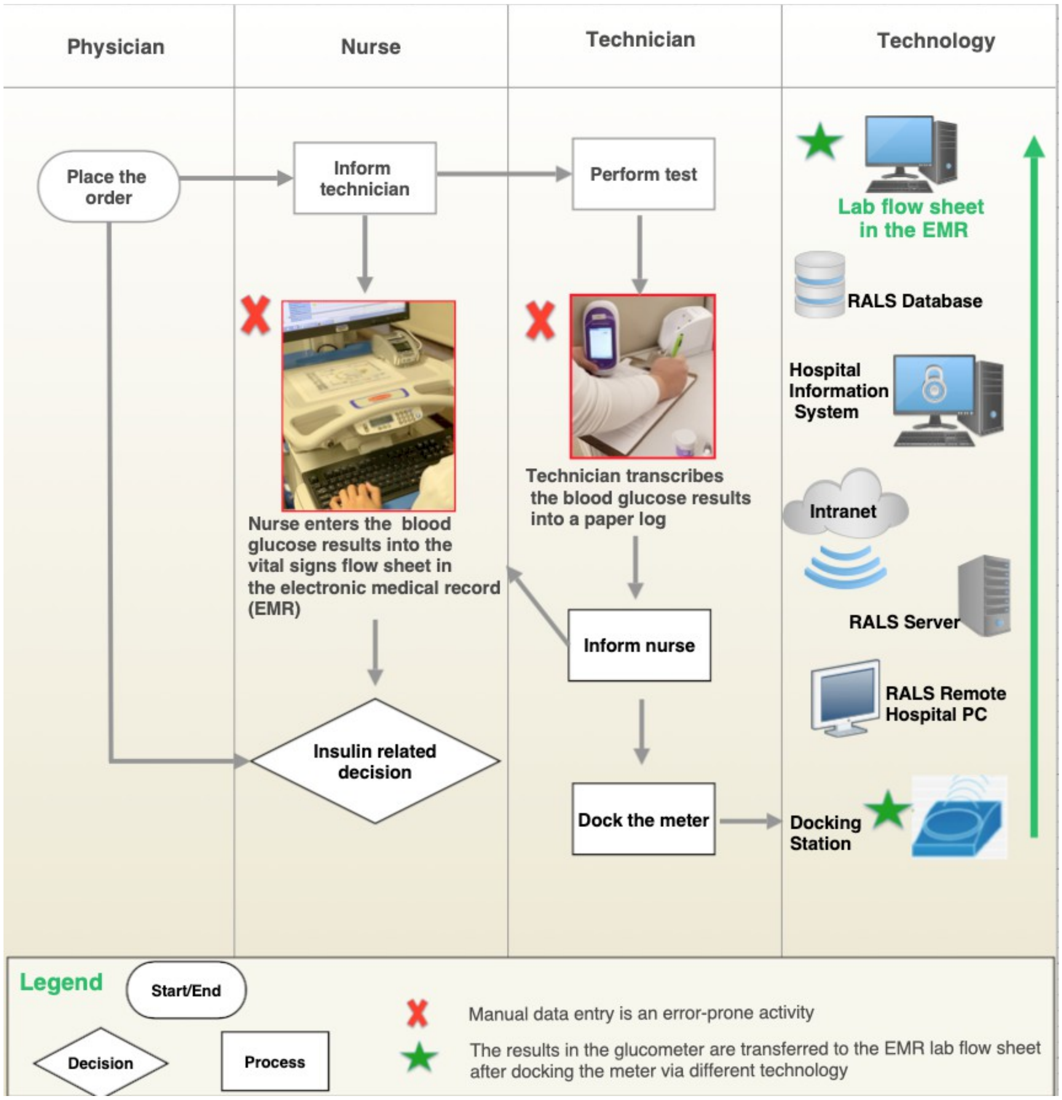
The STICU point of care glucose testing device is Accu-Chek-Inform® II (Roche Pharmaceuticals). Figure 1 depicts a functional workflow model for the current process of testing. The process starts by the physician ordering POCT. The nurse informs the technician about the order, who in turn performs the test using the glucometer and transcribes the result into a paper log- a grid that includes the patient name, visit identification number or VIN, room number, time and date of the test, and the result. VIN is a unique number for each patient episode of admission that is obtained by scanning the wristband of the patient at the time of performing the test.

Nurses then manually enter the readings for each patient into the EMR vital signs flowsheet and use this information to inform their insulin management decisions following physician orders and insulin-management protocols. Clinical decisions include continue to monitor, repeat the test to verify critical blood glucose values, inform the physician, give insulin, and titrate insulin drip based on the insulin management protocol. The blood glucose values entered by nurses into the EMR vital signs flowsheet can be obtained (a) from the glucometer itself by manually searching the readings using the time of the test and the patient VIN to locate the test value, (b) from the technician who verbally endorses the value to the nurse if he/she is available in the unit, or (c) by checking the value transcribed by the technician into the paper log.

The technician docks the meter by placing it into the meter-base-unit within 24 hours from the time of the first test for a given day. Meters maintain log data for up to 2000 readings. Since docking the meter can be performed after 24 hours of use, nurses usually base their insulin management decisions on the readings transcribed by the technicians into the paper log or the readings entered by the nurses into the vital signs flowsheet. By docking the meter, readings are automatically uploaded into RALS®-Plus database, which interfaces with the EMR lab flowsheet. These data include employee ID of the examiner, patient ID (name, VIN number), date and time of the test, time the meter was docked, and blood glucose values. It is worth noting that there is no *direct* link or seamless transfer of data in the EMR between the vital signs flowsheet and the EMR lab flowsheet.

RALS®-Plus V1.5.1 is a bi-directional interface software for in-hospital glucometers that uploads meters data into the EMR lab flowsheet only. The software also generates different types of reports for quality improvement. Data can be generated based on criteria such as the start and end date of the test, blood glucose values, patient VINs, sample type, and test location. Reports can be e-mailed, printed, saved or exported into an Excel, Rich text .rtf, or Pdf file format.

Fig 1. Workflow model of the point-of-care-testing of blood glucose



Main Outcome Variables

Transcription errors

Since the focus of this study is transcription errors, we assumed that technicians follow best practices in obtaining blood samples and in meters' use per the unit policies and procedures and the user manual of the glucometer. Blood glucose values uploaded into RALS®-Plus are those in the meters and they transfer to the EMR lab flowsheet. These values represent the accurate values. Transcribing blood glucose values from the meters to the paper log and the EMR vital signs flowsheet may result in 3 potential types of errors (Table 1). The "corresponding values" (Table 1) in the paper log and the EMR vital signs flowsheet are based on the same patient VIN, same date of the test, and within a one-hour timeframe window from the POCT (time in RALS) to the time the test was transcribed into the paper log or the EMR vital signs flowsheet.

Table 1. Types of transcription errors

	EMR vital signs flowsheet correct	EMR vital signs flowsheet wrong
Paper correct	*No error:* The blood glucose value in RALS database matches the corresponding value transcribed by technicians and nurses into the paper log and the EMR vital signs flowsheet for a given test in a given date and time	*Vital signs flowsheet error:* Any discrepancy regardless of the magnitude between blood glucose value in RALS database and the corresponding value transcribed by nurses into the EMR vital signs flowsheet
Paper wrong	*Paper log error:*	*Paper log and vital signs*

	Any discrepancy regardless of the magnitude between blood glucose value in RALS database and the corresponding value transcribed by the technician into the paper log	*flowsheet error:* The two blood glucose values transcribed by technicians and nurses into the paper log and the EMR vital signs flowsheet for a given test in a given date and time do not match the value in RALS database

Undocumented values of blood glucose tests

Untranscribed or undocumented blood glucose values are those available in RALS database but were not transcribed into the paper log or entered into the EMR vital signs flowsheet.

Insulin Errors related to erroneously transcribed blood glucose values

For each transcription error, we also examined if that error resulted in giving the wrong dose of insulin. The wrong insulin dose was evaluated based on administering a higher or lower insulin dose, regardless of the magnitude of the difference, than the one recommended by the protocol for the correct blood glucose value (the value in RALS system) or not giving insulin when it should be administered to the patient according to the insulin management protocol based on the correct blood glucose value.

Meter docking time

As mentioned before, we considered a one-hour timeframe window from the POCT (time in RALS/glucometer) to the time the test result was transcribed into the paper log or the EMR vital signs flowsheet when we retrieved the time for transcribing blood glucose values. Meter docking time was retrieved from RALS database and represents the time from the POCT to the time meters were docked (readings were uploaded into the EMR lab flowsheet).

In addition to these outcomes, we also collected patient demographics and clinical-related information such as, age, gender, diagnosis, diabetic status, admission and discharge dates, and total number of POCT performed to the patient during the ICU stay.

Data Collection Procedure

The following steps were followed in the sequence identified to collect the data. Three nurse educators collected the data from the paper log and the EMR vital signs flowsheet to enhance objectivity.

1. RALS database was accessed for the selected study months and the Excel file was downloaded. The file included the patient name, VIN, EMR number, test date and time, blood glucose value (meter value), and time of docking the meter.
2. A stratified sample of 20% blood glucose readings and the related information

from RALS were selected from the Excel file. In addition to the 20% sample of readings, we went back and selected all pertinent blood glucose tests within the episode of admission for all VINs included in the stratified sample.

3. For each test selected from RALS, the EMR was accessed and patient demographics and clinical related information were obtained based on the VIN, as well as the corresponding values of blood glucose transcribed into the vital signs flowsheet and time of documentation. We also accessed the lab flowsheet to make sure that the tests in RALS are pertinent to that patient.
4. For each test selected from RALS (step 2) for each patient and based on the VIN, the paper log was accessed using the patient name and the VIN as the identifiers. The corresponding blood glucose value was obtained for each test using the date and a one-hour timeframe window from the POCT (time in RALS) as the matching codes. The actual time of the test documented in the paper log was also obtained.

Data Analysis

R Statistical Computing Software was used to analyze the data. Patients' characteristics and all types of errors were presented using descriptive statistics. The difference in number of POCT between diabetic and non-diabetic patients was examined using t-test with < 0.05 significance value.

The analysis of transcription errors was limited to cases where the results of the blood glucose tests were transcribed by clinicians and nurses. For example, the denominator for the paper log transcription errors was the number of blood glucose readings transcribed into the paper log, excluding missing values, i.e., when the readings were not transcribed.

Results

The 5049 blood glucose tests analyzed for transcription errors, undocumented blood glucose readings, and meter docking time were pertinent to 234 unique patients, each with a unique VIN. Table 2 presents the patients' characteristics. The majority of the patients with known diabetes status were non-diabetic (N=93/234). Of the 234 patients, 97 were with unknown diabetic status. The average number of the POCT performed on diabetic patients (Table 3) was significantly higher than the one performed on non-diabetic patients (t test= -2.17, *P* = .03). One of the patients had 792 POCT during his length of stay (Table 2). The median POCT for diabetics was 12 tests.

Table 2. Patient characteristics (N= 234 patients)

Patient characteristic	**Mean (SD)**
Age in years	57.5 (17.4)
Length of stay in days	24.8 (48.3)
Average number of point-of-care-testing per patient	25.5 (67.9)
Patient characteristic	**Percentage (number)**
Gender	Male 56% (131)
Diabetic status	• Yes (N= 44, 32% out of 137) • No (N= 93, 68% out of 137)

	• Missing (N= 97)

Table 3. Comparison of the number of point-of-care-testing between diabetic (N=44) and non-diabetic (N= 93) patients

Diabetic status	**Min.**	**Median**	**Mean (SD)**	**Max.**
Diabetic	1	12	60 (126)	792
Non-diabetic	1	6	19 (40)	344

Missing Documentation and Transcription Errors

Table 4 describes the number of tests that were not transcribed into the paper log and/or the EMR vital signs flowsheet as well as the number of transcription errors. In the vital signs flowsheet, 41% of the tests (out of 5049 tests) were not transcribed. Five percent (239 out of 5049 tests, 5%) of the blood glucose tests were not transcribed in the paper log and in the EMR vital signs flowsheet at the same time.

As mentioned before, all types of transcription errors were analyzed when the blood glucose value was transcribed (Table 4, columns 3). Of the transcription errors, there were 98 paper log errors (2%, out of 4441 transcribed tests in the paper logs). These errors were related to 30 patients (13% of the patients). Out of the 2985 transcribed values in the vital signs flowsheet, there were 242 (8%) errors related to 63 patients (27% of the patients). The total number of paper log and vital signs flowsheet transcription errors was 43 (2%, out of 2616) related to 24 patients (10% of the patients). Overall, there were 68 (29% out of 234 patients) unique patients involved in all types of errors.

Errors in the paper log resulted in transcribing a blood glucose value that was up to 92 mg/dl (5.1 mmol/l) lower or 92 mg/dl higher than the correct value (the one in the EMR lab flowsheet or RALS). However, the majority of the errors, those between the 25th and 75th percentiles, were 12 mg/dl (0.7 mmol/l) lower to 7 mg/dl (0.4 mmol/l) higher than the accurate value. In the EMR vital signs flowsheet, the difference in blood glucose values between the correct blood glucose value and the erroneously transcribed value was 110 mg/dl (6.1 mmol/l) lower to 80 mg/dl (4.4 mmol/l) higher. The majority of the errors, those between the 25th and 75th percentiles, were 3 mg/dl (0.16 mmol/l) lower to 4 mg/dl (0.2 mmol/l) higher than the accurate values.

Table 4. Number of undocumented blood glucose tests and number of transcription errors

Type of transcription Error	**No. of Undocumented tests (out of 5049)**	**No. of tests analyzed (out of 5049)**	**No. of errors (% out of column 3)**	[a] **Range of error**	**Error rate per patient** (N= 234)
Paper log	608 (12%)	4441	98 (2% out of 4441)	-92 – 92 mg/dl (-5.1 – 5.1 mmol/l)	0.4 (98/234)
Vital signs flowsheet	2064 (41%)	2985	242 (8% out of 2985)	-110 – 80 mg/dl	1.0 (242/234)

				(-6.1 – 4.4 mmol/l)	
Both	239 (5%)	2616	43 (2% out of 2616)	NA	0.2 (43/234)

[a] Range of difference between the correct blood glucose value and the erroneously transcribed value

There were no significant differences in the number of transcription errors between the day and night shift (Table 5).

Table 4. Difference in transcription errors between the day and night shift

Error Type	Full sample N (%)	Day Shift N (%)	Night Shift N (%)	Chi-Square	P
Paper Log	98 (2%)	53 (2%)	45 (2%)	2.9	0.81
Vital signs Flowsheet	242 (8%)	163 (8%)	79 (7%)	3.1	0.07
Both	43 (2%)	24 (1%)	19 (2%)	0.6	0.41

Insulin Errors

The 242 transcription errors in the EMR vital signs flowsheet resulted in 24 insulin errors. These errors resulted in giving 10 units lower to 3 units higher insulin dose than the dose that should be given in case there were no transcription errors. The 98 transcription errors in the paper log resulted in 8 insulin errors and giving 2 to 8 units lower insulin dose than the dose that should be given in case there were no transcription errors. The 43 errors in the EMR vital signs flowsheet and paper logs resulted in 2 insulin errors both with 2 units lower than the correct insulin dose. Overall, there were 30 unique insulin errors that affected 25 patients

(11% of the patients).

Documentation Time

The average time from the POCT to the time meters were docked (readings were uploaded into the EMR lab flowsheet) was 8 hours with a median of 5.5 hours. The majority of the readings, between the 1st to the 3rd quartiles, took 1.3 to 12 hours to be uploaded into the EMR lab flowsheet. Some of the readings took 56 hours (2.3 days) to be uploaded into the EMR lab flowsheet.

In addition to these outcomes, we found 40 readings that were documented to some patients' EMRs and the paper log after the date of discharge.

Discussion

Principal Findings

This study examined transcription errors of blood glucose tests obtained by a glucometer and documented in the paper log by ICU technicians and in the EMR vital signs flowsheet by ICU nurses, insulin errors resulted from transcription errors of blood glucose values, the number of the undocumented blood glucose tests in the paper log and the EMR vital signs flowsheet, and the meters average docking time. Extensive research exists on glucometers in ICU and non-ICU settings. However, the majority of these studies focused on precision and accuracy of glucometers, sources of glucometers measurement errors, and the difference in sensitivity and specificity of glucometer devices from different vendors [16-29]. Nevertheless, glucometers are commonly used handheld devices to measure blood glucose at the point of care, specifically in ICUs to inform timely clinical decisions of insulin therapy. Up to our knowledge, this is the first study to examine transcription errors of blood glucose tests obtained by glucometers and to focus on the urgent need for EMR-glucometer interoperability.

Transcription errors ranged from 2% for paper log errors to 8% for vital signs flowsheet errors. These errors resulted in a total of 30 insulin errors and affected 11% of the patients. The higher percentage of transcription errors in the vital signs flowsheet in comparison to the paper log might by explained by a clinical workflow that has nurses obtain the results of blood glucose tests from three different sources, which are the paper log, the technicians, or the glucometers, while the technicians obtain the values only from the glucometers. Transcription errors in the vital signs flowsheet are clinically more significant than transcription errors in the paper log because they inform nurses' insulin management decisions. These errors affected 63 patients (27% of the patients).

It is important to note that our transcription errors and the associated insulin errors were examined only when the blood glucose test results were transcribed by technicians and nurses. The very high percentage of untranscribed values (i.e., up to 41% untranscribed into the vital signs flowsheet, n=2064) could mask the actual rate of transcription errors. Possible explanations for not transcribing blood glucose values might be workload issues and the assumption that all readings eventually will be available in the lab flowsheet in the EMR after docking the meter. In addition, finding 40 readings documented to some patients' EMRs and the paper log after the date of discharge is alarming. This means that technicians were not scanning the patient bracelet but probably a sticker that remained on the paper log or the patient monitor or bed. Although eliminating the use of a paper log via a full EMR-glucometer interoperability could decrease this error, adherence to the unit policies and procedures for safe testing is critical for complete elimination of this error.

Although a partial interface exists between glucometers and the EMR through RALS bi-directional interface software, this interface transfers the data only to the EMR central lab flowsheet. Additionally, based on the unit policies and procedures, the meters should be docked within 24 hours by technicians. This long time period hinders the availability of the tests' values at the point of care, making these data unusable for immediate clinical decisions. Furthermore, our results showed that in reality docking the meters might take for up to more than two days. Therefore, there is an urgent need for a full glucometer-EMR connectivity to allow seamless transfer of meters data into other fields of the EMR (i.e., vital signs flowsheet) in order to eliminate data transcription and the associated insulin errors.

The few available studies on medical devices-EMR connectivity have focused on vital signs monitors in ICUs and supported the improved efficiency and elimination of transcription errors when vital signs monitoring devices were connected to the EMR [14]. The results of our study supported the urgent need for a compressive and instant connectivity to transfer glucometers data to all fields of the EMR to better inform clinical decisions and eliminate insulin errors associated with transcription errors. On the other hand, from an engineering perspective, interoperability challenges do exist. These may include, lack of research describing success/challenges, complexity of data elements, and the difference in type of information and the formats in which information is stored and displayed. Most importantly, studies supported the potential for new types of errors in device connectivity such as transferring the data into the wrong patient EMR in addition to the slow speed of the interface attributed to the slow-speed of the old-fashioned medical devices and computers [12]. Therefore, the process of and errors associated with interoperability should be carefully examined.

Limitations

The results of this study should be interpreted in light of the following limitations. First, since workload/admission rate and the large number of monthly POCT are inherent factors that may affect transcription errors, our results can only be generalized to STICUs with similar workload and rate of POCT. Second, the errors examined in this study were limited to transcription errors, measurement errors of blood glucose values that may result from inappropriate testing or scanning the wrong patients were beyond the scope of this study. Finally, because we collected retrospective data, our risk assessment was limited to identifying the number of insulin errors resulted from transcription errors without identifying the clinical consequences or adverse events of insulin errors. On the other hand, insulin is a high alert medication and its errors may cause serious hypo and hyperglycemia, seizures, coma, ketoacidosis, and even death [30].

Conclusions

Transcription errors of blood glucose values obtained by glucometers do exist and result in insulin errors. Given the high dependence on glucometers for POCT of blood glucose in ICUs, full EMR-glucometer interoperability is required for complete and accurate documentation of blood glucose values, elimination of transcription error and the subsequent insulin-related errors in ICUs.

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Conflicts of Interest

None declared.

Abbreviations

Intensive care units: ICUs

Surgical trauma intensive care unit: STICU

Point-of-care-testing: POCT

Electronic medical record: EMR

Visit identification number: VIN

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