Original Article

Feasibility, efficacy, and safety of a simple insulin infusion protocol in a large volume cardiac surgery unit in India

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ABSTRACT

Aim: Inpatient hyperglycemia management is essential, but difficult to achieve especially in a large volume cardiac surgery setup, thus necessitating use of nurse-led insulin protocols. A rapid flux of nurses dealing with a huge workload has been a cause for traditionally not using nurse-led protocols in most Indian institutes. The challenges we faced were to have a simple protocol for the nurses to accept it without compromising on glycemic control. Therefore, this observational study was planned to measure the efficacy and safety of the insulin infusion protocol in cardiac surgery patients. **Materials and Methods:** Insulin protocol was implemented, using seven fixed columns of infusion with the nurse making decisions to initiate and titrate doses based on simple rules. Blood glucose (BG) data captured from blood gas analyzers (glucometrics) in the intervention group (i.e., after protocol implementation) were compared to control group (i.e., before the protocol implementation). **Results:** The mean BG for the first 48 h was lower in the intervention group as compared to control group, without an increase in the episodes of hypoglycemia. The nurses found the protocol easy to understand, less time-consuming and there was no protocol deviation over 8 months after implementation. **Conclusion:** A small change in the process, allowing nurses to titrate insulin doses based on some rules and having seven fixed columns of insulin infusion rates, improved glycemic control and efficiency.

Key words: Cardiac surgery, India, insulin protocol

Introduction

Hyperglycemia is commonly encountered in cardiac surgery patients because coronary artery disease, requiring coronary artery bypass is commonly associated with type 2 diabetes.[1] A subset of cardiac surgery patients who do not have preexisting diabetes, develop hyperglycemia after cardiac surgery due to stress-induced release in counter-regulatory hormones or use of vasopressors.[2]

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Hyperglycemia affects the clinical outcomes after cardiac surgery.[3-13] Therefore, it is desirable to control hyperglycemia to improve prognosis. However, the risk of hypoglycemia becomes a limiting factor.[14] It is also a resource intensive process involving intravenous insulin through infusion, 1-2 h blood glucose (BG) measurements, and titration of insulin doses.[14]

Medanta, the Medicity is a multispecialty tertiary care institute with a large number of cardiac surgery patients. The glycemic management in these patients is taken care of by the endocrinology team, who were using a column-based method of insulin infusion, with once a day dose titration. However, two important disadvantages of this system were individual doctor based variation in treatment and less frequent (usually once a day) adjustment in insulin doses. In June 2013, automation of glucose data collection from blood gas analyzers provided us an opportunity to improvise the

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glycemic management in cardiac surgery patients. Nurse led protocols are not commonly followed in India, in contrast to some other countries because the nurses traditionally have not been employed in decision-making. Furthermore, volume and turnover at our institute are high. We, therefore, planned to study the feasibility, efficacy and safety of implementing a simple nurse-led protocol in our system.

Based on the experience with the column method, seven fixed columns of insulin infusion were designed and implemented in September 2013. The nurses were instructed to adjust the infusion scales based on certain rules.

Materials and Methods

Study population

All patients who underwent cardiac surgery from June 1, 2013 to August 31, 2013 (i.e., prior to the insulin protocol) formed the control group. All patients who underwent cardiac surgery from February 1, 2014 to April 30, 2014 (i.e., after the protocol implementation) were analyzed in the intervention group.

Blood glucose data were analyzed in all cardiac surgery patients for first 48 h after surgery, although insulin was infused only in those who had hyperglycemia.

Hyperglycemia was defined as those with preexisting diabetes historically or those who had two consecutive readings more than 200 mg/dl after the surgery.

Insulin infusion

Regular insulin in normal saline (1:1) solution was given intravenously, the rate being decided by the ambient point of care-BG (POC-BG) value, which was measured 1-2 h.

Initiation and titration of insulin rates before the protocol

Endocrinologist wrote the rates in a column format with BG ranges on the left sided column and corresponding insulin rates to be given on the right-sided column [Appendi x 1]. The endocrinologist would modify the column after observing the glycemic response every day.

Initiation and titration of insulin rates after the protocol

In September 2013, seven fixed columns of insulin rates were designed based on the endocrinologist's judgment on commonly required insulin rates in these patients [Appendi x 2]. Nurses were instructed to initiate column 3 in all cardiac surgery patients with hyperglycemia, as soon as they reached the intensive care unit (ICU) after surgery. Column 6 was to be initiated in patients on vasopressor infusions.

The nurses were also asked to up titrate the column if two consecutive POC-BG values exceeded 200 mg/dl; or down titrate the column if two consecutive values were <100 mg/dl. A conservative BG target of 110–180 mg/dl was set [Appendix 2].

These instructions were delivered once to the nurses and the charts with these instructions and columns were availed for further reference.

The main differences in the processes before and after insulin protocol are tabulated in Table 1.

Rationale behind the column method of infusion

Although the algorithm being used at Medanta has organically developed and evolved without much influence of practices in other hospitals, it is similar to the Markowitz protocol.[15] Seven different columns of insulin infusion rates are as seen in the Appendix 2, with the insulin rates progressively increasing as we move from column 1 to 7. The change in insulin with change in BG (Δ I/Δ G) is higher for higher BG (curvilinear). In each column, insulin rates increase as BG rises; for example in column 3, the curvilinear nature results in an increase in "gain" from 0.025 to 0.05 IU/h/mg/dl change in BG, as BG rises from 120 to 250 mg/dl.[16] The provision to switch between columns in case of persistent hyperglycemia (two consecutive values more than 200 mg/dl) also leads to an increase in gain, if the patient's glucose level is still not controlled. For example, at a BG level of 160 mg/dl, gain increases from 0.025 to 0.05 IU/h/mg/dl change in BG as we move from column 3 to column 5. The protocol is detailed elsewhere.[17]

Nurses' acceptance and adherence to protocol

A questionnaire was given to a small sample of nurses surveying the acceptance to the protocol. Protocol adherence was confirmed during the daily endocrinologist's review of the glucose charts.

Point of care blood glucose monitoring

In ICU, arterial POC-BG was done 1-2 h using glucometers and blood gas analyzer (ABL800FLEX). Every 4th h, POC-BG was analyzed using blood gas analyzer. The blood gas analyzers were connected to a central computer, and these glucose data were available for analysis.

There is an in-hospital system quality control system for assessing the accuracy of glucometers and blood gas analyzers. Two controls, one for low BG and other for high BG, were run every day. Every week, plasma samples were sent to the laboratory.

Data collection

The blood gas analyzers in ICUs are connected to a central hospital database, and all glucose measurements are automatically recorded on this system. Other demographic data and laboratory test results were taken from the hospital information system for comparison of the population of patients being monitored.

Statistical analysis

Outcome measures

The following measures of glycemia (glucometrics),[18] were used for comparing the data before and after protocol modification:

- Mean BG for first 48 h after cardiac surgery
- Mean BG for first 24 and 2nd 24 h after surgery
- Percentage POC-BG readings exceeding 250 mg/dl
- Percentage POC-BG readings <60 mg/dl.

Statistical significance for mean values of POC-BG was compared between the two groups using *t*-test. Proportions were tested using the Pearsons Chi-square test.

Table 1: Comparison of elements of the protocol in the control (June-August 2013) and intervention groups (February-April 2014)

Protocol element	June-August 2013	February-April 2014
Insulin infusion initiation	Rates written by endocrinologist in a column format	7 fixed columns of insulin infusion rates
Who would titrate insulin infusion dose	Endocrinology team	Nurses
Basis of insulin dose titration	Dynamic BG pattern reading	Static BG readings
Frequency of titration	Once in 24 h	Whenever two BG values exceed 200 mg/dl or <100 mg/dl

BG: Blood glucose

Similarly, continuous variables in baseline demographics/outcome factors between the two groups were compared using *t*-test while categorical values were tested using Chi-square.

Results

Glucometrics

The number of patients in the control group were 848 and 10,137 BG readings were available for analysis while the intervention group had 827 patients with 10,036 BG readings.

These two sets of patients were similar with regards to age, gender, type of surgery, and baseline glycosylated hemoglobin [Table 2].

The intervention group had lower mean BG in the first 24 postoperative hours as compared to the control group (mean ± standard deviation [SD]) being 167.2 (±51.4) mg/dl versus 161.6 (±47.5) mg/dl ($P < 0.001$), respectively [Table 3]. The mean (±SD) for the second 24 h postoperatively was again lower in the intervention group as compared to control group; 151.2 (±45) mg/dl and 143.3 (±43.6) mg/dl, respectively ($P < 0.001$).

The mean BG at various time points after surgery is compared in Figure 1. The mean BG was the highest immediately after surgery, and the mean BG dropped steadily for the first 24 h. The trend line is lower for the intervention group at most time points as compared to control the group.

The proportion of BG readings more than 250 mg/dl was 4.61% and 3.69% in control and intervention group, respectively ($P = 0.001$) [Table 3]. Proportion of patients

Table 2: Baseline characteristics in the control (June-August 2013) and intervention groups (February-April 2014)

Metric	June-August 2013	February-April 2014	*P*	Statistical test
Number of patients	848	827		
Blood glucose readings recorded	10,137	10,036		
Male: Female	684:164	658:160	0.91	Pearsons Chi-square test
Mean glycosylated hemoglobin (%)	6.75	6.76	0.88	*T*-test equal variance assumed
On-pump surgeries %	7.82	6.27	0.106	Pearson's Chi-square test

Table 3: Comparison of glucometrics between the control (June-August 2013) and intervention groups (February-April 2014)

Metric	June-August 2013	Febraury-April 2014	*P*	Statistical test
BG (1st 24 h after surgery) mean (±SD) mg/dl	167.2 (±51.4)	161.6 (±47.5)	<0.001	*T*-test
BG (from 24 to 48 h after surgery) mean (±SD) mg/dl	151.2 (±45)	143.3 (±43.6)	<0.001	*T*-test
Patients with at least one hypoglycemic episode (BG <60 mg/dl) *n* (%)	49 (5.78)	57 (6.89)	0.329	Pearson's Chi-square test
Proportion of BG readings >250 mg/dl %	4.61	3.69	0.001	Pearson's Chi-square test

SD: Standard deviation, BG: Blood glucose

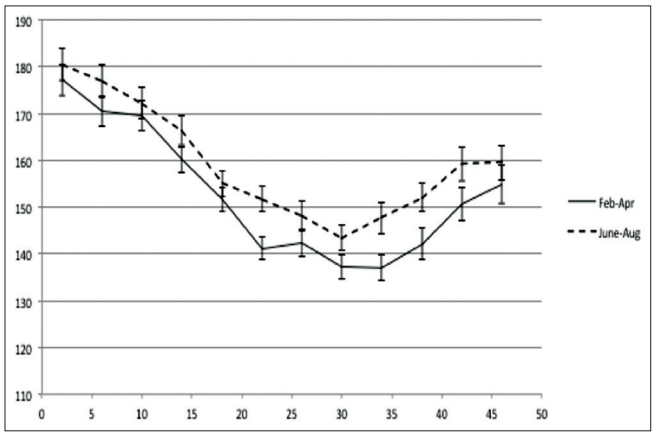

Figure1: Comparison of the time trends of blood glucose after cardiac surgery in February-April 2014 versus June-August 2013

with at least one POC-BG more than 250 mg/dl reduced from 25.6% (control group) to 21.88% (intervention group) ($P < 0.001$).

The proportion of POC-BG readings <60 mg/dl was 0.66% and 0.79%. The proportion of patients with at least one value < 60 were similar in control and intervention groups; 5.78% and 6.89%, respectively [Table 3].

The proportion of patients in various BG ranges in the two groups and the percentages were similar in the two groups.

Nurses' feedback on the protocol

Eleven out of 20 nurses said that the protocol was "very easy to understand," 8 said it was "easy to understand" while 1 reported having some difficulty in understanding.

Sixteen out of 20 nurses said that "time spent" was less with the current protocol as compared to previous glucose charts, 3 found it same as before while one said that time spent was more than before.

The perception regarding the effectiveness of the protocol was mixed. Half of them perceived it as better control, 8 thought it was same as before while two thought that the glucose control was worse than before.

Again, half of them perceived the current protocol as safer with less hypoglycemia, 8 thought that the hypoglycemia episodes were same as before while 2 thought they were more than before.

Nineteen out of 20 wanted the current protocol over the previous one.

In the 3 months of the intervention period, there was no protocol deviation as assessed by endocrinologists.

The mean length of stay (LOS) after surgery was significantly longer in the intervention group (mean ± SD being 8.4 ± 4.4 days) as compared to the control group (mean ± SD being 7.4 ± 3.8 days) ($P = 0.000$). However, LOS was also positively correlated with mean POC-BG values for first 2 days after surgery. Infection and rise in creatinine (i.e., peak creatinine after surgery minus baseline creatinine) did not differ significantly in the two groups.

Discussion

This study showed that a simple insulin protocol implemented in a large volume cardiac surgery unit with 10–15 surgeries daily, improved glycemic control. The protocol implementation was through simple oral and written instructions to the nurses without need for training sessions, and it is being followed religiously over last 8 months. The nurses found the protocol easy to understand and less time-consuming, while most also perceived it as more effective and safe as the previous glucose charts. Empowering the nurses to make adjustments themselves was dually advantageous: Nurses are available in the ICU all the time and can keep a close watch on the POC-BG; second, they get more involved and sensitized towards the cause of good glycemic management.

Despite the simplicity in implementing the protocol, the glycemic control improved significantly without increase in hypoglycemia episodes. The explanation for this is the inherent complexity in the protocol design, as described above.

In comparison with the other types of protocols, this protocol only required a quick look at the table by the nursing staff. This increased acceptability and reduces chances of errors. Despite the ease of use, the response to glucose fluctuation is not compromised because of the "winding up" of gain when BG rises and winding down of gain when BG falls.[16]

This study also emphasizes the utility of glucometrics,[18] and reporting of clinical data for improvement in patient care. Automated data collection at our center led to introspection and improvement in the insulin protocols while providing the means to study these modifications objectively. Since blood gas analysis is done 4 hourly in our cardiac ICUs for the first 2 postoperative days, data collection through blood gas analyzer was feasible. Similarly, there are POC glucometers available in many US hospitals, which facilitate automated data collection. The remote automated laboratory system data published in 2009 and 2011 were a result of this centralized data collection.[19]

The study was done nonintrusively in order to avoid complications of the Hawthorne effect. Since glucose control is one of the multitudes of activities that a nurse has to perform, a study under close observation would naturally lead to improved performance. Apart from the training to use the protocol, none of the nursing staff was aware of the research in progress. For the same reason, the analysis of glucose data was done 3 months after introduction and implementation of the protocol. The data of October–November 2013, that is, immediately after the protocol initiation showed significant improvement in terms of mean BG, however, this could be because of the extra focus being given on the new protocols and initial enthusiasm for new protocols. Therefore, we chose to analyze the data after 3 months, not only to remove any Hawthorne effect but also to judge the sustainability of the protocol, which is an indirect measure of acceptance by nurses and simplicity.

The glucose data were taken from arterial POC-BG measurements using blood gas, which has been shown to be more accurate as compared to those using glucometers.[20]

Our data showed significant correlation between postoperative glycemic control and postoperative LOS, although LOS was higher in the later months. This is probably due to some system-related factors, which need further investigation.

Conclusion

This study shows that a nurse-led column based insulin infusion protocol was easy to implement and sustain in a large volume Indian center. In addition to its simplicity, it proved to be modestly more efficacious than, and as safe as, insulin titration under endocrinologist supervision.

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