International Journal for Quality in Health Care, 2018, 1–8
doi: 10.1093/intqhc/mzy101
Article

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Development of a Provincial initiative to improve glucose control in critically ill patients

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Editorial Decision 10 April 2018; Accepted 19 April 2018

Abstract

Objective: To describe the development, implementation and initial evaluation of an initiative to improve glucose control in critically ill patients.
Design: Glucose control in critically ill patients was chosen by critical care leaders as a target for improvement. This was an observational study to document changes in processes and measures of glucose control in each intensive care unit (ICU). ICU nurse educators were interviewed to document relevant changes between April 2012 and April 2016.
Setting: 16 ICUs in British Columbia, Canada.
Participants: ICU leaders.
Intervention(s): A community of practice (CoP) was formed, guidelines were adopted, two learning sessions were held, and an electronic system to collect data was created. Then, each ICU introduced their own educational and process interventions.
Main Outcome Measure(s): Average hyperglycemic index (area under the curve of serum glucose concentration versus time above the upper limit (10 mmol/l) divided by time on insulin infusion), number of hypoglycemic events (<3.5 mmol/l) divided by time on insulin infusion and standardized mortality rate (actual/predicted hospital mortality) for each 3-month period.
Results: Although there were some isolated points and short trends that indicated special cause variation, there were no major trends over time and no obvious association with any of the process changes for each hospital. However, the average hyperglycemic index was higher in some of the smaller hospitals than in the larger hospitals.
Conclusions: In this, 4-year observation of glucose control in ICUs within a CoP, the lack of sustained improvement suggests the need for more active and durable interventions.

Key words: critical care, collaborative, breakthrough groups, control charts, run charts

Introduction

In February 2009, the British Columbia (BC) Ministry of Health mandated a Provincial quality improvement initiative (Clinical Care Management) as part of the province's 'Innovation and Change Agenda' to improve health outcomes. Clinical Care Management aimed to implement and standardize evidence-based clinical guidelines in nine high-priority areas (including care of critically iIl patients). The change management and implementation of these guidelines was supported by the BC Patient Safety & Quality Council (BCPSQC, a Provincial government body providing system-wide leadership of efforts designed to improve the quality of healthcare in BC). The Critical Care Working Group (CCWG), a multidisciplinary clinical expert group also supported by the Provincial government, whose mandate included promotion of best practices among all intensive care units (ICUs) in BC, was asked to identify an initial topic for improvement and was supported by the BCPSQC to form a community of practice (CoP) around this topic. Communities of practice are 'groups of people who share a concern or passion for something they do and learn how to do it better as they interact regularly' [1].

Given that control of serum glucose concentration applies to most ICU patients, that there was recent evidence to support a particular target concentration [2], and that the findings from that evidence had informed clinical practice guidelines [3, 4], the CCWG chose improvement of glucose control in patients who are receiving intravenous infusions of insulin as the initial focus. The guidelines recommended that ICU teams use an insulin protocol that allows for predefined adjustments in the insulin infusion rate based on serum glucose concentrations and insulin dosage to keep the glucose concentration below a threshold of 10.0 mmol/l, and to avoid hypoglycemic events (<3.5 mmol/l).

The purpose of this study is to describe the development, implementation, initial evaluation, and key learnings of this improvement initiative for critical care clinicians within an entire jurisdiction of care in Canada (Province of BC).

Methods

A BCPSQC quality leader provided quality improvement expertize (change management and improvement science knowledge), and a local critical care physician was contracted to provide provincial clinical leadership for the initiative. In 2011, evidence-informed guidelines regarding glycemic control for patients who were receiving insulin infusions were developed and approved by the CCWG (Table 1). A baseline informal survey of all critical care units in BC indicated that of the 24 units in the province where the guidelines were applicable (a total of five other ICUs that were either pediatric or small community-level ICUs where patients would not be on insulin infusion were excluded), 15 reported that they had not implemented any components of the clinical guidelines, 4 had implemented some components of the clinical guidelines and 5 had fully implemented all components of the clinical guidelines.

From 2011 to 2012, BCPSQC clinical and quality leads focused on engaging multidisciplinary stakeholder groups including dietitians, pharmacists, nurses, respiratory therapists and physicians through virtual meetings, regular electronic newsletters, and by developing an online tool for the CoP to share resources and have discussions. By 2016, the CoP had 272 members (42 physicians; 33 ICU managers; 28 senior leaders; 25 clinical educators; 19 registered nurses; 11 respiratory therapists; 11 informatics nurses; 6 pharmacists; 11 other professionals (paramedics, infection control providers, dietitians, research coordinators, social workers) and 86 others who did not report their profession). The CoP had a glucose control website that included shared resources such as sample insulin protocols, frequently asked questions, definitions of quality metrics, and event listings. Two virtual learning sessions were held, one focused on improving glycemic control and the other on quality measurement in general. Both sessions were well attended (41 and 26 telephone lines connected, respectively). They were recorded and made available through YouTube, generating 480 and 358 separate views respectively as of 15 August 2017. A 'Critical Care Quality Day' in 2013 brought members of the CoP together in person to learn, share strategies, collaborate, and to discuss issues related to glucose control, among other activities.

In 2012, 16 of the 24 eligible ICUs in the province (including all units that provided tertiary and quaternary care) were ready to collect records of every serum glucose concentration (laboratory and point of care testing) and the associated date and time of measurement for each patient who was receiving an intravenous infusion of insulin. Data were entered by trained ICU informatics nurses into an

Table 1 Guideline components with corresponding recommended interventions regarding optimal glucose control for critical care patients who were receiving insulin infusions

Generic guideline component	Recommended specific interventions
Use a validated written or computerized protocol/algorithm for an intravenous insulin regimen that allows for predefined adjustments in the insulin infusion rate based on glucose levels and insulin dosage.	Initiate a regional policy to control glucose at <10.0 mmol/l in all adult critically ill patients. Based on a local context, use strategies to increase compliance with your organization's policies, including the use of computer decision support systems, provider reminder systems, preprinted orders, auditing and feedback.
Use the insulin protocol to control blood glucose below a threshold of 10.0 mmol/l. Avoid hypoglycemic events (reporting threshold of < 3.5 mmol/l).	Develop a protocol for an insulin regimen to control blood glucose, where insulin is infused and titrated as necessary. Ensure that all physicians, nurses, hospital pharmacists, dietitians and other clinical staff in the ICU have been trained in the insulin regimens. Support ongoing peer discussion and provider education. Engage patients and families in their care by increasing awareness and providing education about the importance of glucose control. Identify and immediately remedy patients who are not on the protocol, or do not have appropriate glycemic control. Provide real-time clinician feedback. Analyze and eliminate system failures.
Do not attempt to tightly control glucose to achieve targets of normoglycemia (blood glucose levels of 4.4–6.1 mmol/l).	Identify and collect data on balancing measures, to monitor for unintended consequences of improvement efforts. These should include safety measures, especially episodes of severe hypoglycemic.

existing electronic ICU database [5]. Patients under 18 years of age at the time of admission to ICU were excluded.

In 2013, the CCWG approved provincially standardized operational definitions for process and balancing measures for glycemic control. The patient population was limited to those who were receiving an intravenous infusion of insulin because they were at highest risk for complications from both hyper- and hypoglycemia. Based on a study that examined the association between summative measures of glucose control and mortality [6], the CCWG decided to summarize glucose control as two derived variables: hyperglycemic index and hypoglycemic event rate. Hyperglycemic index is the area under the curve of serum glucose concentration versus time when the glucose concentration is greater than the upper acceptable limit (10.0 mmol/l), divided by the time that the patient was receiving intravenous insulin. A higher value indicates inadequate glucose control. Hypoglycemic event rate, a balancing measure, was calculated as the number of hypoglycemic events (serum glucose concentration <3.5 mmol/l for any period of time) divided by the time receiving intravenous insulin of infusion. A higher value indicates excessive glucose control. Both hyperglycemic index and hypoglycemic event rate were calculated automatically using functions that were built into the database.

Data were reported quarterly to the Ministry of Health for accountability, and were discussed and shared in tabular form, intermittently at CCWG meetings. Medical and administrative leaders were encouraged to review and share their data with their local teams, and to use those data to make improvement to their processes. Provincial targets (≤1.0 for hyperglycemic index, 0 events for hypoglycemic rate) were set in 2013 based on existing best practices and input from CCWG members. Clinical controversies (applicability of recommendations to diabetic ketoacidosis, pediatrics and perioperative states) were brought forward by CoP members and addressed by the BCPSQC clinical lead and members of the CCWG.

For each of the 16 participating ICUs, the values of hyperglycemic index and hypoglycemic event rate for each eligible patient who was admitted during each 3-month period were averaged and plotted as a run chart along with associated standard deviations for each point over a period from April 2012 to April 2016. As an outcome measure, we also calculated the standardized mortality ratio (based on the predicted probability of hospital mortality from the acute physiology and chronic health evaluation (APACHE) II score) and the associated 95% confidence interval for the eligible patients during each 3-month period. Data to calculate these scores were already entered into the ICU database for each patient. The run charts were analyzed for changes not likely due to random fluctuation using probability-based rules [7]:

- Shift—six or more consecutive points either all above or below the median. Data points that fall on the median do not count (skip points on the median).
- Trend—five or more consecutive points all going up or down. Consecutive data points that are the same value do not count towards the trend (skip points if value is equal to previous).
- Runs—a series of points in a row on one side of the median. Too few or too many runs signals that the amount of fluctuation in data is not random. One method for counting number of runs is to count the number of times the data line crosses the median and add one (see Supplementary Table S1 to determine if there are too few or too many runs).
- Astronomical point—an obviously and blatantly different value that everyone studying the chart would agree is unusual. Note that this rule is non-probability based.

In addition to collecting the glucose and time data, a clinical nurse educator at each ICU was interviewed in detail by a member of the research team to record any changes in the process of glucose control that had been implemented during the period of observation. These changes included blood glucose tracking/flowsheets, sliding scale orders for subcutaneous insulin, intravenous insulin protocols, staff education, introduction of new blood glucometers, change from an 'open' to a 'closed' model of ICU administration, preprinted orders and nutrition protocols. Responses to these interviews were summarized as annotations on the respective run charts.

This observational study was conducted according to the STROBE statement [8] as much as possible, and was approved by the UBC/Providence Health Care Research Ethics Board.

Results

Of the 16 participating ICUs (one per hospital), 4 were in small community hospitals (3–6 ICU beds, only temporary mechanical ventilation), 1 was in a larger community hospital (6–7 ICU beds, 1–2 mechanically ventilated), 2 were in smaller intermediate hospitals (4–9 ICU beds, up to 5 mechanically ventilated), 3 were in larger intermediate hospitals (9 ICU beds, all available for mechanical ventilation, some specialty services), 4 were in tertiary hospitals (7–15 ICU beds, all available for mechanical ventilation, most specialty services), and 2 were in quaternary hospitals (15–27 ICU beds, all available for mechanical ventilation, all specialty and sub-specialty services and provincial programs such as burns and spinal cord services).

Although there were some isolated points and short trends that indicated special cause variation, overall analysis of the run charts for hyperglycemic index showed no major trends over time and no obvious association with any of the process changes for each hospital (Fig. 1). However, the average value of this index was higher, especially in some of the smaller hospitals, than in the larger, tertiary care hospitals. About 6 of the 16 hospitals met the target for hyperglycemic index (≤1.0; Fig. 1). Similarly, although there were several points in time that indicated special cause variation, there were no major trends on the run charts for hypoglycemic event rate (Fig. 2). For one hospital (# 16) there was a rising trend in the hypoglycemic event rate that ended at the time that an intravenous insulin protocol was introduced (Fig. 2). The run charts of standardized mortality ratio (Fig. 3) showed no specific trends over time. Nearly, all values included the value of 1 within the confidence limits, which indicates that the observed value is the same as expected. Median values for each variable at each site are shown in Supplementary Table S3.

The variation around each data point (standard deviation for hyperglycemic index and hypoglycemic event rate, and 95% confidence interval for SMR) was less for the larger hospitals than for the smaller hospitals, likely due to more patients admitted during each period at the larger hospitals (Supplementary Table S2).

Discussion

In this 4-year period of observation of 16 ICUs that had collected data and been part of a critical care CoP, we found no major trends in measures of glucose control, despite the introduction of several changes that were aimed at improvement. However, we did note that the average measure of hyperglycemia over the entire period was lower in some ICUs than in others, with some achieving or coming close to reaching the provincial target.

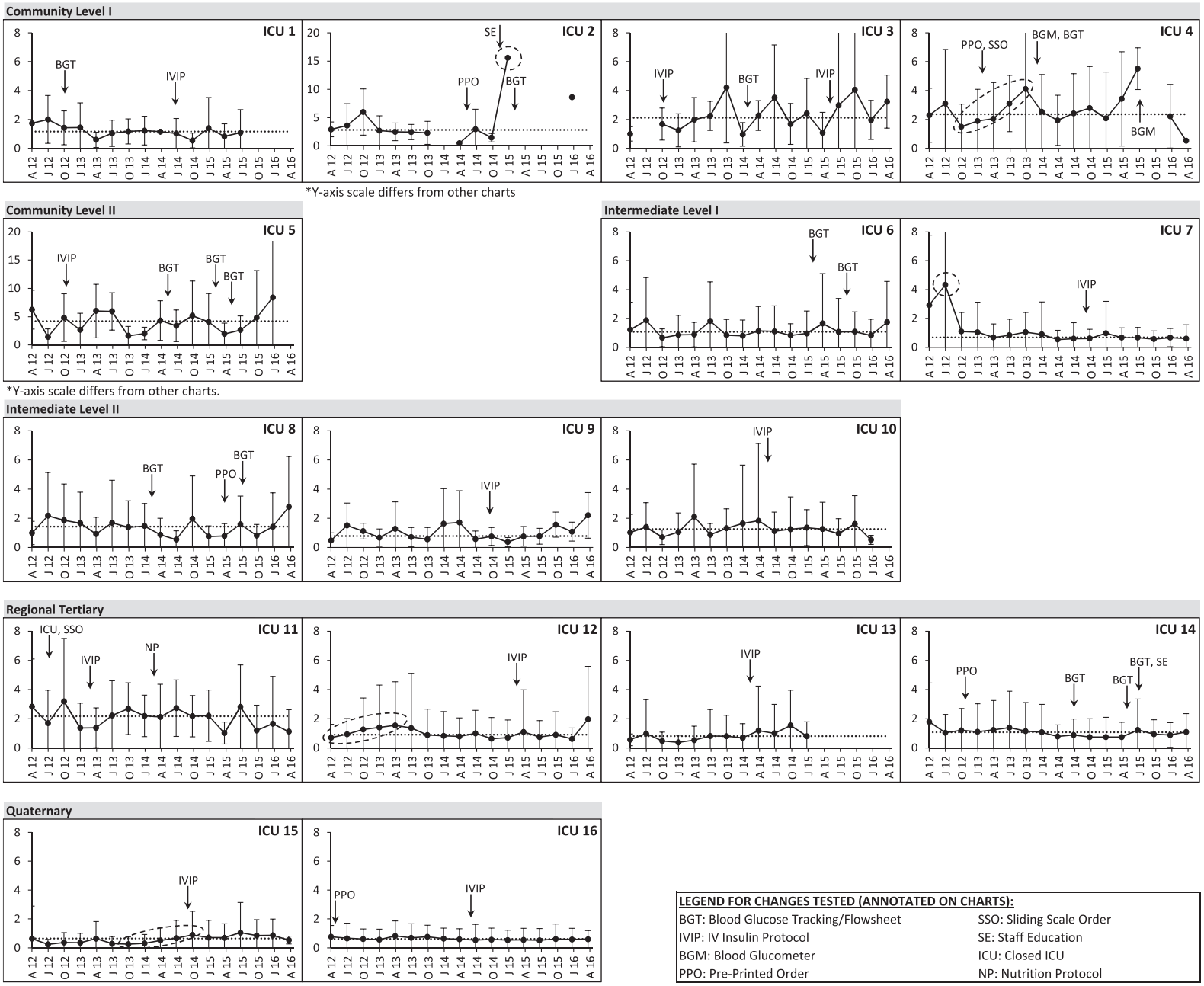

Figure 1 Annotated run chart showing mean of the hyperglycemic indices (area under the glucose-time curve that is above a pre-determined threshold of 10 mmol/l divided by total days on insulin infusion for each patient) and one standard deviation for all patients at each hospital who received intravenous insulin during each 3-month period. Horizontal dotted lines are the median value of all data points on each plot. Circled points or sets of points indicate likely non-random fluctuations according to rules adopted for this study (see text).

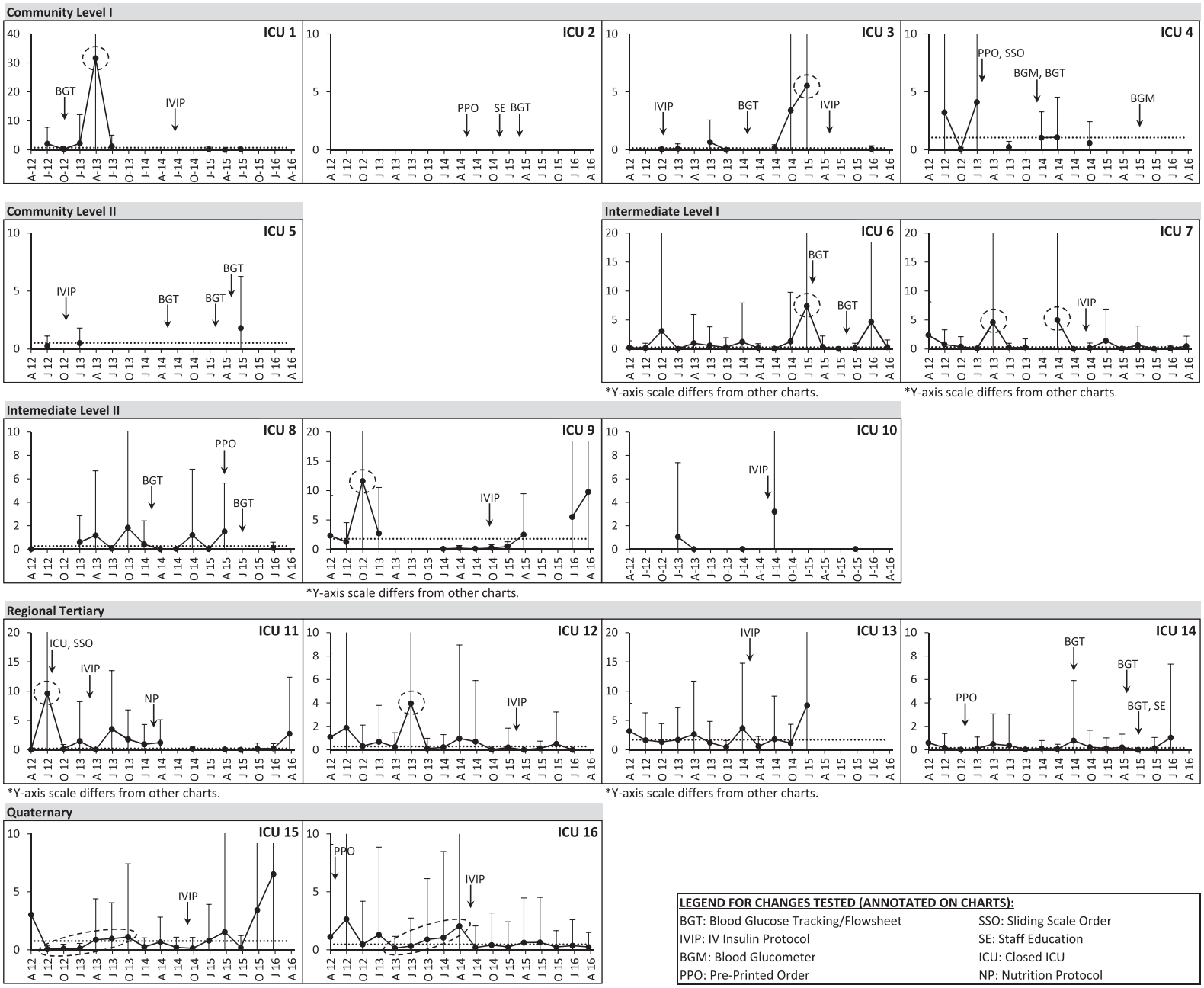

Figure 2. Annotated run chart showing mean of the hypoglycemic event rate (number of periods when serum glucose concentration was <3.5 mmol/l divided by total days on insulin infusion for each patient) and one standard deviation for all patients at each hospital who received intravenous insulin during each 3-month period. Horizontal dotted lines are the median value of all data points on each plot. Circled points or sets of points indicate likely non-random fluctuations according to rules adopted for this study (see text).

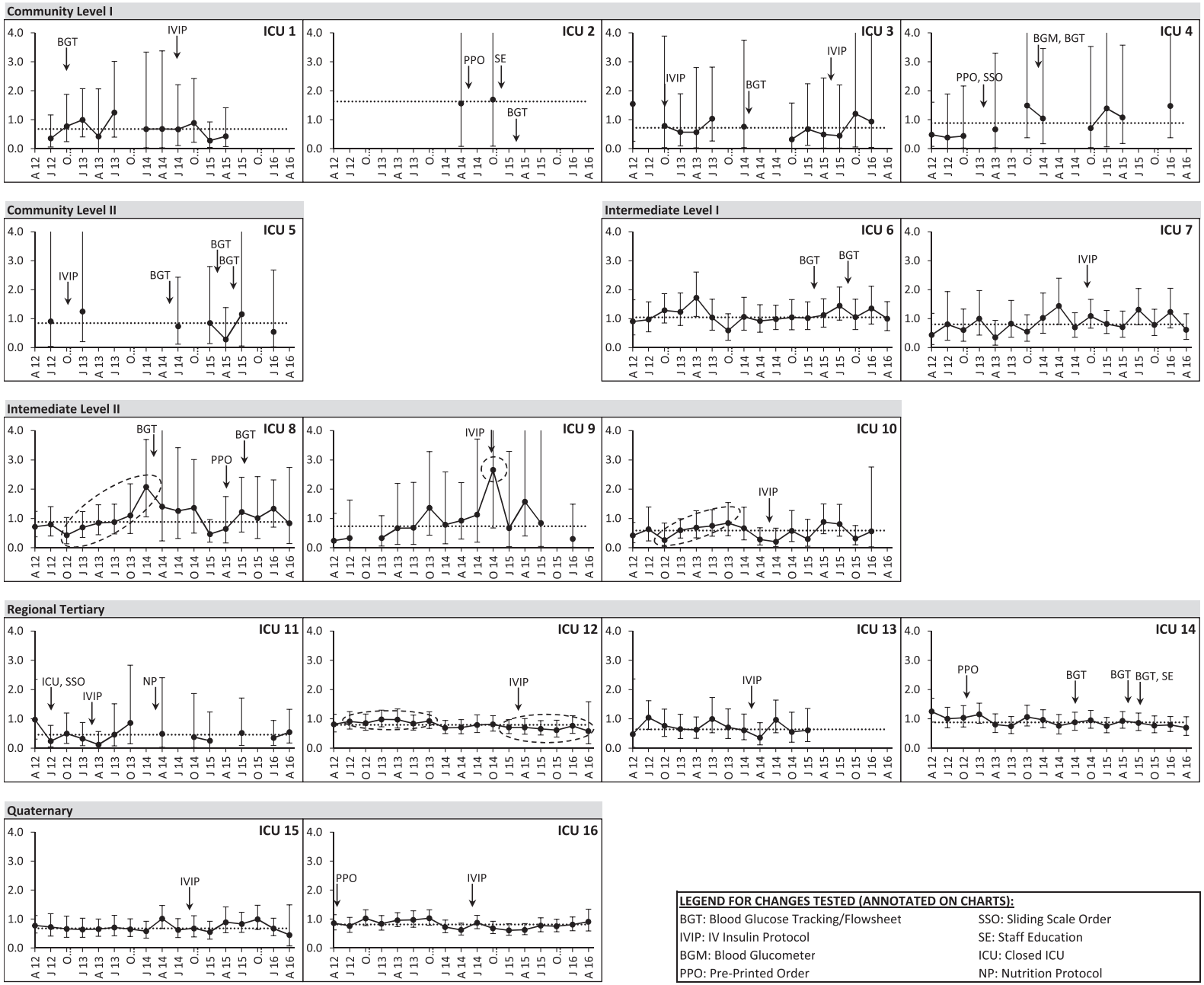

Figure 3. Annotated run chart showing standardized mortality ratio (observed mortality rate divided by predicted mortality rate as calculated using the APACHE II score) and 95% confidence interval for all patients at each hospital who received intravenous insulin during each 3-month period. Horizontal dotted lines are the median value of all data points on each plot. Circled points or sets of points indicate likely non-random fluctuations according to rules adopted for this study (see text).

In 2014, the BCPSQC collaborated with the Michael Smith Foundation for Health Research to commission a research study to enhance understanding of how complex health systems can support the implementation of clinical guidelines, using the Clinical Care Management initiative as a case study [9]. The outcome of this research included recommendations for managing large-scale change within BC's health system, and more specifically, recommendations for future Clinical Care Management initiatives. Although the completion of this research post-dates the time-frame in which the critical care CoP was working on glycemic control, it is a useful lens with which to retrospectively view these results. Most of the recommendations for managing large-scale change (recognizing the effectiveness of networks; having local clinical champions; allowing for local adaptation of guidelines; ensuring consistent communication) were in place within the glucose control initiative. There were two recommendations that may not have been in place: ensuring timely, locally-relevant data were available for staff and clinicians; and leadership commitment including resourced support for change management activities. Although the ICU database allowed for leaders at individual sites to extract data and then generate tabular reports, and the glycemic control guidelines encouraged auditing and feedback, the reports were not easily generated at a local level or shared regularly with frontline teams. The ICUs in the critical care CoP may not have been aware of how to access internal quality improvement support to take action on these data, and there may have been competing priorities for improvement activities.

One strategy for accelerating improvement in healthcare is the formation of a quality improvement collaborative among several institutions. An improvement collaborative is a time limited, highly structured approach involving a shared aim, spread of established practices, a defined cohort, regular meetings, and required reports on progress. This structure is typically led by members of one organization or an individual. Based on the Institute for Healthcare Improvement's Breakthrough Series Collaborative [10], this approach has been very successful in neonatal [11–13] and adult [14–16] ICUs. One of these ICU collaboratives included all hospitals within a jurisdiction of care in the USA and was very successful [15, 17], likely because it addressed each of the success factors for large-scale change listed above.

In contrast to an improvement collaborative, a CoP is unstructured, often distributes leadership roles, allows for creation of new knowledge and sharing of untested ideas, and does not require participants to attend meetings or report on their progress (Table 2). Most of the literature on CoPs describes how they were established and documents their activities [18, 19] but does not report the impact on patient outcomes. There are limited published descriptions of achievements arising from communities of practice in critical care [20]. In Canada, there are no published reports about quality improvement collaboratives in critical care, but there are examples of quantifiable successful improvement in outcomes in other settings [21, 22]. Considering these approaches and the condition under which each is typically used [23], an improvement collaborative may have been a more effective and reliable method for achieving results in this context.

Lessons learned from the current project as applied to large-scale improvement in a critical care context include the need to survey local baseline practices, develop a common insulin nomogram that allows for local adaptation where appropriate, leverage networks to share innovative and successful strategies between sites, conduct broad educational activities and provide consistent communication for and between teams, develop common graphical reports and frequent presentation of these reports to improvement teams at individual sites, solicit ideas for change from members of the CoP regularly, and provide structured improvement activities with commitment from local leaders to take action on data. Strengths of this study include long-term measurement in an entire jurisdiction of care (except for the smallest ICUs), a mixture of process, balancing, and outcome measures, and appropriate presentation and analysis of temporal data. Limitations include self-reported structure and process changes without verification of actual practice, and no analysis to explain why some sites performed better than others.

In conclusion, in this observation of glucose control in critically ill patients in ICUs within a CoP without participation in highly structured improvement activities, we found no major trends. The lack of sustained improvement suggests the need for more active and durable interventions.

Table 2 Comparison of typical features: Institute for Healthcare Improvement (IHI) Breakthrough Series Collaboratives and Communities of Practice

Feature	IHI Breakthrough Series Collaborative	Communities of practice
Duration	Time limited; typically 6–18 months	Indefinite
Scope	Clearly defined shared aim (including definition of achievement, time-frame and magnitude of change)	Common goal or interest
Membership	Structured teams with defined roles	Individuals, teams or organizations
Measures	Common and comparable outcome metrics	Undefined metrics
Leadership	Individual or lead organization	May have facilitators or distributed leadership
Participation	Expected for registered teams. Participation is supported by an Executive Sponsor or senior leader	Voluntary
Reporting	Required monthly	Not required
Shared learning	Structured	Unstructured
Knowledge	Evidence-based and tested best practices	Creation of new knowledge and sharing of ideas
Methodology	Model for improvement	Undefined

Supplementary material

Supplementary material is available at *International Journal for Quality in Health Care* online.

Acknowledgements

The authors thank Christina Clarke for interviewing ICU nurse educators about process changes related to glucose control at each ICU.

Funding

This work was supported by the British Columbia Patient Safety and Quality Council.

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