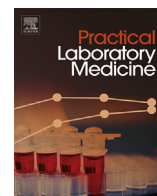


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Practical Laboratory Medicine

journal homepage: www.elsevier.com/locate/plabm

Effective interventions to improve the quality of critically high point-of-care glucose meter results



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ARTICLE INFO

Keywords:

Point-of-care testing
Glucose
Critical result
Repeat testing

ABSTRACT

Objectives: Point-of-care testing (POCT) is testing performed outside the traditional laboratory, often at the patient bedside. In hospital settings, blood glucose is the most common POCT. Staff performing POCT are not usually laboratory trained; they are clinical staff with a primary focus on treating patients. Clinical staff find POCT quality assurance (QA) practices burdensome and are often non-compliant. In hospitals within EORLA (Eastern Ontario Regional Laboratories Association), all critically high POCT glucose results must be repeated prior to acting, according to policy. Compliance with this policy is audited regularly.

Design: and methods: All POCT glucose tests performed in participating sites between January and June 2018 and June and December 2019 were audited for compliance with the critical repeat policy. The discordant repeat rate was also determined for each audit period. Between January and May 2019, there were interventions aimed at improving compliance with the repeat policy.

Results: Compliance with the critical repeat policy increased from 30 to 57% in 2019 compared to 2018, following nursing education and implementation of notifications on the glucose meters themselves. The rate of discordant repeat results (>20% different from initial) also improved at most sites in 2019 compared to 2018. Nurses cited insufficient cleaning of patient hands prior to initial testing as the primary reason for discordant repeats.

Conclusions: Operator compliance with POCT QA policies is an ongoing challenge requiring continual audit, feedback and education. A strong POCT multi-disciplinary committee with supports from senior and clinical leadership in an organization are key to improving compliance.

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<https://doi.org/10.1016/j.plabm.2020.e00184>

Received 20 August 2020; Accepted 16 October 2020

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1. Introduction

Point of care testing (POCT) refers to testing performed near to the patient, outside of the central laboratory and often at the patient bedside. The testing is typically performed by clinical staff who have no formal laboratory training, such as Nurses and Physicians. This fact poses a challenge to the laboratory, which is responsible for oversight of POCT in hospital settings in most jurisdictions. Clinical staff performing POCT often do not appreciate the importance of quality assurance practices for POCT that are put in place by the laboratory [1]. Clinical staff find these practices a burden to their already busy workload and see them as directing their attention away from the patients who are their focus. These realities often lead to clinical staff not complying with procedures put in place to ensure quality of POCT.

POCT for measurement of blood glucose concentrations is widely used in hospitals to provide rapid results and facilitate timely treatment for both hypoglycemia and hyperglycemia. There are data demonstrating that maintenance of glycemic control for hospitalized patients leads to better outcomes [2,3]. A large proportion of adult hospitalized patients have diabetes, in particular type two diabetes, which also necessitates regular monitoring of blood glucose concentrations [4]. A study by Umpierrez et al., in 2002 [5] reviewed 2000 patient charts from a community teaching hospital in the United States. They found that 38% of patients had hyperglycemia while admitted, 26% of whom had a documented history of diabetes. An inpatient audit by the National Health Service of the United Kingdom in 2016 found that 17% of admitted patients had diabetes [6].

The Eastern Ontario Regional Laboratories Association (EORLA) is the laboratory service provider for a network of sixteen hospitals in Eastern Ontario, Canada. The Ottawa Hospital is a large, academic, tertiary care centre, which houses most of the reference laboratories for EORLA. There are POCT glucose programs in-place at each EORLA member hospital, the largest of which is at The Ottawa Hospital, which has more than 350 glucose meters in place across inpatient units, outpatient clinics, intensive care units, emergency departments and in operating and recovery rooms. There are policies within each EORLA member hospital, which state that all critically high POCT glucose results must be repeated prior to being acted upon. A critically high result is defined as >28 mmol/L in adults. Repeat tests must be performed within 10 min of the initial result and the repeat can be by POCT or by sending a venous specimen to the central laboratory for glucose measurement. Repeat testing of critical results prior to release is common practice in laboratories to ensure accuracy of the result, however several studies have suggested that this practice has limited utility by demonstrating a low prevalence of discordant repeat results. A study by Onyenekwu et al. [7] analyzed differences between initial and repeat values for sodium, potassium, calcium and magnesium when performed on a large chemistry instrument in the central laboratory. They found no significant differences between initial and repeat results, indicating that there is limited utility in repeat measurements, especially considering that repeats cause delays in turnaround time for result reporting. A study by Toll et al. [8] made similar conclusions following an analysis of repeat values for hematology parameters. There are a paucity of data on the utility of repeating critical results for testing performed outside the central laboratory, by POCT.

Within EORLA, the recommendation is that all critical POCT glucose results (low or high) be repeated prior to acting, however only critically high results are audited for repeat. This decision was made by the EORLA regional POCT committee in consultation with hospital POCT multidisciplinary committees in light of concerns over delaying treatment for hypoglycemia to perform a repeat test. The rationale was that there is less risk to delay of treatment for hyperglycemia and providing insulin to a patient based on a falsely high glucose result is dangerous.

Several quality indicators are monitored by EORLA laboratories on a monthly basis. The indicator chosen for POCT was compliance of clinical operators with the procedure for repeat of all critically high glucose results. This indicator was chosen based on literature demonstrating a high error rate for critical POCT glucose measurements [9–12]. Monthly quality indicator data from EORLA member hospitals illustrated consistent and systemic non-compliance with the critical repeat policy at most sites, prompting a thorough investigation and development of strategies aimed at improving compliance. The objectives of this study were to compare compliance with repeat of critical POCT glucose tests and the rate of discordant repeat results before and after interventions aimed at improving compliance of clinical staff with POCT policies at eleven EORLA member hospitals.

2. Methods

2.1. POCT data extraction

Patient POCT glucose results were extracted from Cobas IT 1000 middleware (Roche Canada, Laval QC), which is in-use at EORLA member hospitals. Results from all POCT glucose tests performed at eleven member hospitals between June and December 2018 and June and December 2019 were analyzed. Complete audit data was not available from the remaining five hospitals and these sites were excluded from the analysis.

2.2. POCT data analysis

POCT data were analyzed using Microsoft Excel. Briefly, data were sorted to identify glucose results >28 mmol/L. Data were then sorted by patient medical record number (MRN) as well as date/time of testing to determine whether results >28 mmol/L were repeated by POCT. Data from each hospital laboratory information system were used to identify whether repeat testing was performed in the central laboratory. Repeats were considered valid if repeated within 10 min of the initial result. Where repeats are performed in the central laboratory, sample collection must take place within 10 min of the initial result. Results >28 mmol/L were excluded from analysis if the patient had a previous critical result by POCT or central laboratory testing in the preceding 12 h, as per the laboratory

critical results communication policy at The Ottawa Hospital.

2.3. Prospective audit for causes of discordant repeat results

All POCT glucose results from September to November 2018 were extracted from Cobas IT 1000 middleware at The Ottawa Hospital for the purpose of identifying results that were repeated within 10 min and found to be discordant upon repeat. A discordant result was defined as a repeat result $\geq 20\%$ different from the original result. This criteria is based on the total allowable error limits published by the Institute of Quality Management in Healthcare (IQMH) and has been used elsewhere [7].

For each discordant finding, the Nurse who performed the testing was contacted and asked why the test was repeated and why they felt the repeat result was different from the initial result.

2.4. Statistics

The overall effect of the improvement project was assessed using Fisher's exact test with the statistical programming language R (version 3.6.2) [13]. Individual site effects before and after the intervention were assessed using Fisher exact posthoc test with Bonferroni adjustment for multiple comparisons with the R companion package.

3. Results

3.1. Baseline critical glucose repeat compliance

We analyzed POCT glucose tests between January to June 2018 for each hospital to determine compliance with the glucose repeat procedure (i.e. all glucose results > 28 mmol/L should be repeated within 10 min either by POCT or by sending a venous specimen to the central laboratory). This represented 351,883 glucose results from the eleven sites included, with a total of 782 critically high results (0.2% of total results). Fig. 1 shows the percentage of critically high (> 28 mmol/L) results requiring repeat that were repeated at each site from January to June 2018. On average, 30% of critically high results were repeated across all sites with a range from 0 to 100% depending on the site. As shown in Fig. 1, there were three critically high results at site 9, none of which were repeated.

3.2. Discordant repeat results

Analysis of repeat critical glucose tests from January to June 2018 identified that a relatively high percentage of repeat results were discordant ($> 20\%$ different from initial result). Across all sites, on average, 25% of results were discordant when repeated. Fig. 2 shows the percentage of repeat critical results that were discordant upon repeat either by POCT or in the central laboratory for each hospital site. The total number of critically high results that were repeated at each site is indicated above each bar.

3.3. Causes of discordant results

Based on the high discordant rate (Fig. 1 sites 1–11), a follow-up audit of all critical results with discordant repeats was performed from September to November 2018 at The Ottawa Hospital site. The Ottawa Hospital was chosen for this audit because there are a larger

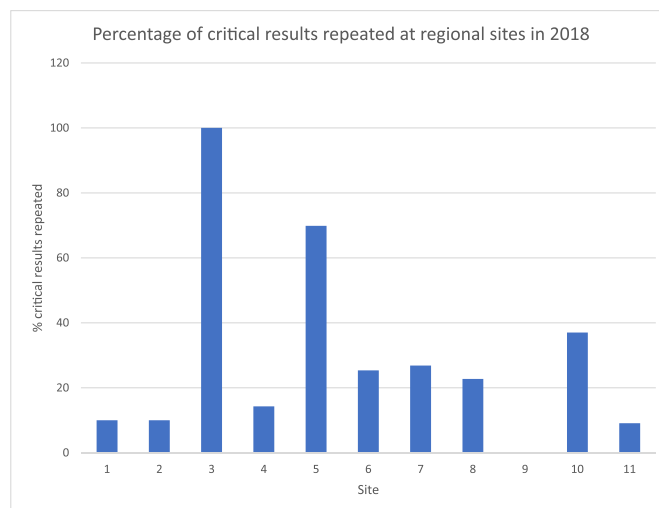


Fig. 1. Percentage of results > 28 mmol/L requiring repeat that were repeated at each site.

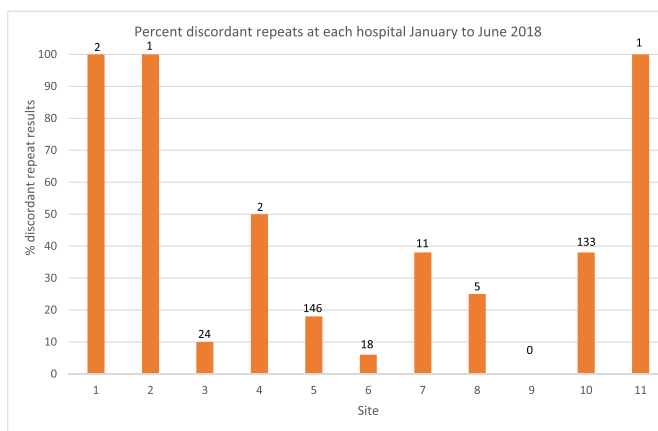


Fig. 2. Percentage of discordant repeat results (>20% different from initial result) by site. Numbers above bars indicate the total number of critically high results repeated.

number of critical results at this site compared to the other sites in the study, which allowed for collection of a sufficient amount of data over a relatively short time period. A total of 31 discordant repeat results were identified during this time. The results of this audit are shown in Table 1. In all cases presented, repeat testing was performed by POCT. Follow-up with the Nurses who performed the testing revealed that the most common reason cited for discordant results was the Nurse suspecting that the patient’s hands were not thoroughly cleaned after eating, prior to initial testing.

3.4. Strategies aimed at improving compliance

The issue of operator non-compliance with the critical glucose repeat procedure was discussed at the EORLA Regional POCT committee and at each of the Hospital Site POCT Multi-disciplinary committees. Several strategies were undertaken with the aim of improving compliance with this procedure. A summary of the strategies employed at each site can be found in Table 2 below. All initiatives were in place by May 2019.

Table 1
Summary of discordant repeat data with operator response for discordant reason.

Initial result (mmol/L)	Repeat result (mmol/L)	Difference	% Difference	Time between results (min)	Reason for Discordance	Diabetes status
31.4	14.7	16.7	53	3 min	Patient was eating raisins prior to first test. Subsequently washed hands thoroughly and repeated testing	type 2
28.3	20.4	7.9	28	3 min	Nurse stated repeat testing after insulin given	type 2
>33.3	6.9	>26.4	>79	10 min	No reason provided.	type 1
30.1	7.3	22.8	76	2 min	Initial sample drawn from an intravenous line where D50 was infused previously.	type 2
>33.3	12.8	>20.5	>62	5 min	No reason provided.	type 2
>33.3	14.3	>19	>57	3 min	Patient’s finger hit the test strip	type 2
28.4	8.1	20.3	71	2 min	Patient was eating, washed hands thoroughly and repeated testing	type 2
>33.3	6.7	>26.6	>80	2 min	No reason provided.	type 2
31	14.7	16.3	53	2 min	No reason provided.	unknown
25.6	18.5	7.1	28	3 min	Nurse didn’t believe the high number was correct based on clinical situation	type 1
20.9	12.4	8.5	41	2 min	No reason provided.	type 1
33.2	13.7	19.5	59	2 min	Patient drinking juice, washed hands thoroughly and repeated testing	type 1
28.4	22.1	6.3	22	3 min	No reason provided.	type 2
>33.3	5.8	>27.5	>83	1 min	No reason provided.	type 2
29.2	22.4	6.8	23	4 min	Nurse did not wipe first drop of blood before testing	type 1
31.9	15.7	16.2	51	4 min	No reason provided.	type 2
>33.3	5.4	>27.9	>84	2 min	No reason provided.	unknown
>33.3	22.7	>10.6	>32	2 min	Nurse cleaned one finger but tested from another	type 2
27	8.4	18.6	69	1 min	No reason provided.	unknown
29.1	8.4	20.7	71	1 min	Patient was eating a donut, washed hands thoroughly and repeated testing	type 2
30.3	7.8	22.5	74	2 min	Patient was eating lunch, washed hands thoroughly and repeated testing	type 2

Table 2

Summary of strategies employed at each site with the aim of improving compliance with POCT glucose policies and procedures.

Site	Updated POCT policy	Critical repeat alert on meter	Nurse Education	Discussed at Medical Advisory Committee
1	x	x	x	X
2	x		x	
3				
4		x	x	
5	x	x	x	
6	x			
7			x	
8		x	x	
9		x	x	
10		x	x	
11	x	x	x	X

3.5. Post-intervention critical glucose repeat compliance

Analysis of all POCT glucose tests completed from June to December 2019 was performed to determine whether compliance with the procedure for repeat of critically high glucose results improved after implementation of strategies aimed at improving compliance. [Table 3](#) summarizes the repeat compliance, by each site for the pre-intervention period (2018) and post-intervention period (2019). The data show that compliance with the critical repeat policy increased at the majority of sites in the post-intervention period. Across all sites, 58% critical results were repeated post-intervention compared to 30% pre-intervention, which was a statistically significant improvement. Five individual sites improved significantly, one worsened significantly and two sites showed decreased compliance, however the decreases were not significant.

The percentage of discordant repeat results also improved at the majority of sites in 2019, post-intervention as summarized in [Table 4](#). The discordant rate is marked as unknown when none of critical results were repeated at the site for the audit period.

4. Discussion

Audit data from January to June 2018 revealed that only 30% of all critically high glucose results were repeated as per the hospital policies across all eleven sites included in this study. When tests were repeated, approximately one quarter were discordant, defined as >20% different than the initial result. This repeat criteria has been used in previous studies [9], with similar findings. A Q-probes study in 2016 [10] found that only half of all critical results were repeated. This study examined all critical results, both high and low, whereas our study only studied critically high results. The Q-probes study also cited a relatively high discordant repeat rate. They found that 36.8% of results did not meet the requirement for repeat (>20% for results > 27.8 mmol/L).

In the present study, follow-up with individual nurses who performed testing resulting in discordant repeat results revealed that they initiated repeat measurements because they did not believe the first result. In the majority of cases, the repeat result was significantly lower than the initial result and no longer critical. Nurses cited the patient's hands not being sufficiently clean prior to the initial test as the primary reason for the discordant repeat. These findings suggest pre-analytical errors rather than analytical errors as contributing to falsely elevated results.

Education campaigns for nursing staff performing POCT glucose testing at each site focused on the importance of repeating critically high results and of cleaning patient hands thoroughly prior to testing. Notifications on the glucose meters themselves were also implemented. These notifications alerted operators to the need for repeat when a critical result was obtained. In some of the hospital sites, a requirement to repeat critically high glucose measurements was found to be absent from the POCT glucose policy upon review. This addition was made to the policy and included in education for POCT operators. Both the education and notifications led to an overall improvement in compliance with the repeat procedure across all sites, that was significantly significant with improvements found at most individual sites, some statistically significant. The rate of discordant repeat results also improved at most individual sites.

Three of the sites in this study showed poorer compliance with the critical glucose repeat policy in 2019 compared to 2018 (Sites 3, 5 and 11). Sites 3 and 5 both had changes in Nurse Educator personnel in 2019, which they believe contributed to a slide in compliance of Nurses with the repeat policy. Site 3 experienced issues with scanning of patient armbands that were implemented in 2019, which led to patient identification errors. They believe the challenge with scanning contributed to lower compliance from the Nurses. Site 5 cited a large turnover of nursing staff with the implementation of a new hospital information system in June 2019 as another challenge leading to poor compliance. There was a shift to more online POCT training in place of hand-on training during the hospital information system post-implementation period. Site 11 did not have an explanation for the change in compliance, albeit minor at this site with the small number of critical results.

A study by Schiffman et al., in 2014 [9] found results from repeat tests were more likely to match if both tests were performed by the same operator. In the sites part of this study, it is common practice for the initial and repeat tests to be performed by the same operator. For both the audit periods in this study, an average of 98% of repeat tests were performed by the same operator. A Q-probes study in 2016 [10] found that the majority of institutions studied had no criteria to define what constitutes a confirmed repeat result. The initial audit in 2018 identified this gap in our sites' POCT procedures, which prompted the definition and sharing of acceptability criteria for repeat results with clinical operators and the addition of this information to applicable procedures.

Table 3
Summary of compliance at each site with critical repeats in before and after improvement initiatives.

Site	Pre-intervention			Post-intervention			% Change	p-value baseline vs. post-intervention
	Total critical results	Total critical results repeated	% Repeated	Total critical results	Total critical results repeated	% Repeated		
1	20	2	10	7	5	71	61	0.02
2	10	1	10	11	5	45	35	0.25
3	24	24	100	34	27	79	-21	0.08
4	14	2	14	15	10	67	52	0.02
5	209	146	70	229	112	49	-21	<0.001
6	71	18	25	51	32	63	37	<0.001
7	41	11	27	19	14	74	47	0.01
8	22	5	23	14	5	36	13	0.6
9	3	0	0	32	14	44	44	0.38
10	357	133	37	355	223	63	26	<0.001
11	11	1	9	3	0	0	-9	1
Total	782	343	44	770	447	58	14	<0.001

Table 4
Discordant repeat results at each site pre and post-intervention.

Site	Pre-intervention		Post-intervention		Change in discordant % pre. vs. post-intervention
	Total critical results repeated	Total discordant repeat results	Total critical results repeated	Total discordant repeat results	
1	2	1	5	0	-50
2	1	1	5	2	-60
3	24	3	27	1	-9
4	2	1	10	0	-50
5	146	17	112	13	0
6	18	6	32	1	-30
7	11	3	14	5	8
8	5	1	5	3	40
9	0	unknown	14	1	unknown
10	133	51	223	71	-7
11	1	1	0	unknown	unknown

The nature of POCT is such that there is a constant need for audit and feedback to clinical operators of the importance of following quality assurance policies and procedures. Audits, feedback and continuous education of POCT operators represents a significant amount of work and highlight the need for dedicated resources from the laboratory to oversee POCT programs. In addition, the study highlights the risks associated with point of care testing. In particular, giving insulin based on erroneous glucose results is a significant patient care [14] risk. Detailed chart audits are required, as a next step, to determine whether patients in our institutions have experienced hypoglycemic events due to treatment based on falsely elevated glucose results. Findings from this study also demonstrate that collaboration between the laboratory and clinical leaders and educators can lead to improvements in compliance with QA practices by clinical operators. These initiatives require leadership from POCT multi-disciplinary committees with representation from senior and clinical management from the hospital to ensure consistent messaging across organizations.

CRediT authorship contribution statement

Julie LV. Shaw: Data curation, Formal analysis, conception and design of the study, Writing - original draft. **Christopher R.**

McCudden: Formal analysis, conception and design. **David A. Colantonio:** conception and design. **Danny C. Lin:** conception and design. **Ivan M. Blasutig:** conception and design. **Thomas Moran:** acquisition of data, Project administration. **Dana Trofimczuk:** acquisition of data, Project administration. **Chantal Carriere:** acquisition of data, Project administration. **Anas Gharra:** acquisition of data, Project administration. **Cheryl Portelance:** acquisition of data, Project administration. **Chantal Tremblay:** acquisition of data, Project administration. **Diane Dupaul:** acquisition of data, Project administration. **Nathalie Breton:** acquisition of data, Project administration. **Merina Angelkovski:** acquisition of data, Project administration. **Chetan Jariwala:** acquisition of data, Project administration. **Maureen Embleton:** acquisition of data, Project administration. **Christine Campbell:** acquisition of data, Project administration. **Kristina Groulx:** acquisition of data, Project administration. **Karen Larmour:** acquisition of data, Project administration.

Declaration of competing interest

J. Shaw has served as an advisory board member for Roche POCT.

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