CLINICAL & BASIC RESEARCH

Impact of Educational Activities in Reducing Pre-Analytical Laboratory Errors
A quality initiative

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أثر الأنشطة التعليمية في خفض أخطاء ما قبل التحليل المختبري

مبادرة جودة

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abstract: *Objectives:* Pre-analytic errors during diagnostic laboratory investigations can lead to increased patient morbidity and mortality. This study aimed to ascertain the effect of educational nursing activities on the incidence of pre-analytical errors resulting in non-conforming blood samples. *Methods:* This study was conducted between January 2008 and December 2015. All specimens received at the Haematology Laboratory of the Sultan Qaboos University Hospital, Muscat, Oman, during this period were prospectively collected and analysed. Similar data from 2007 were collected retrospectively and used as a baseline for comparison. Non-conforming samples were defined as either clotted samples, haemolysed samples, use of the wrong anticoagulant, insufficient quantities of blood collected, incorrect/lack of labelling on a sample or lack of delivery of a sample in spite of a sample request. From 2008 onwards, multiple educational training activities directed at the hospital nursing staff and nursing students primarily responsible for blood collection were implemented on a regular basis. *Results:* After initiating corrective measures in 2008, a progressive reduction in the percentage of non-conforming samples was observed from 2009 onwards. Despite a 127.84% increase in the total number of specimens received, there was a significant reduction in non-conforming samples from 0.29% in 2007 to 0.07% in 2015, resulting in an improvement of 75.86% ($P <0.050$). In particular, specimen identification errors decreased by 0.056%, with a 96.55% improvement. *Conclusion:* Targeted educational activities directed primarily towards hospital nursing staff had a positive impact on the quality of laboratory specimens by significantly reducing pre-analytical errors.

Keywords: Healthcare Quality Assurance; Quality Control; Specimen Handling; Blood Specimen Collection; Hematology; Oman.

الملخص: الهدف: الأخطاء التي تسبق التحليل المخبري في المختبرات التشخيصية تؤدي إلى زيادة معدلات المرض و الوفيات. هدفت هذه الدراسة إلى إيضاح أثر الأنشطة التعليمية للممرضات على حفض معدل أخطاء ما قبل التحليل مما يؤدي إلى الحصول على عينات دم غير مطابقة للمواصفات. **الطريقة:** هذه الدراسة تم اجراءها بين يناير 2008 و ديسمبر 2015. كل العينات التي تم استلامها في مختبر أمراض الدم بمستشفى جامعة السلطان قابوس تم تجميعها و تحليلها وقتيا كذلك فإن تم تجميع بيانات لعينات من عام 2007 بأثر رجعي واستخدمت كأساس للمقارنة. تم تعريف العينات الغير المطابقة لتشمل عينات متخثرة أو عينة بها دم متكسر أو حفظت في مادة تخثر خاطئ أو تجميع كمية غير كافية من الدم أو أنه لا يوجد عليها ملصق تعريفي أو وجود ملصق تعريفي خاطئ أو أنه لا يوجد عينة مع وجود طلب للعينة في النظام. بدأ من 2008 تم تنفيذ دورات تدريبية و تعليمية منتظمة بشكل دوري موجهة بشكل أساسي إلى الممرضات في المستشفى و طلبة التمريض الذين تقع عليهم مسؤولية تجميع عينات الدم. **النتائج:** بعد بدأ الاجراءات التصحيحية في عام 2008، لوحظ انخفاض كبير في عدد العينات الغير مطابقة للمواصفات من عام 2009 فصاعدا. بالرغم من وجود زيادة 127.84% في عدد العينات التي تم استلامها إلا أنه هناك انخفاض ملحوظ في عدد العينات الغير مطابقة للمواصفات من 0.29% في عام 2007 إلى 0.07% في عام 2015 مما أدى إلى 75.86% تحسن (0.050> P). وكان التحسن أكثر وضوحا في مجال الخطأ في التعرف على العينة حيث انخفض بمقدار 0.056% مما يعني تحسن نسبته 96.55%. **الخلاصة:** كان للتدريب التعليمي الموجه إلى طاقم التمريض بالمستشفى أثر إيجابي في جودة العينات المخبرية و الحد بشكل كبير من الأخطاء التي تسبق التحليل المختبري.

الكلمات المفتاحية: ضمان الجودة الصحية؛ الجودة الرقابية؛ معالجة العينة؛ جمع عينات الدم؛ أمراض الدم؛ عمان.

Advances in Knowledge
- This study demonstrates the impact of sustained targeted nursing educational activities in reducing non-conforming blood samples, a common cause of pre-analytical laboratory errors.

Application to Patient Care
- Improving the quality of laboratory results is essential for optimal and efficient patient care. The findings of this study indicate that implementing appropriate training and nursing educational activities can have a major impact on reducing pre-analytical errors.

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Laboratory testing constitutes a cornerstone in the effective delivery of healthcare as diagnostic investigations have a major impact on ensuring correct diagnoses and determining appropriate therapy. However, the integrity and quality of the sample is fundamental to the testing process. Errors involving laboratory testing are varied and can occur at the pre-analytical, analytical or post-analytical phases. Pre-analytically, the proper procurement of an appropriate blood sample and its secure transportation to the laboratory prior to analysis is essential to achieve reliable results; however, this phase is thought to be the most vulnerable part of the testing process and presents the greatest challenge to laboratory professionals.[1] Up to 70% of laboratory diagnostic errors are due to non-conforming samples, defined as specimens which result from inappropriate or improper sample collection, patient preparation or specimen acquisition, handling, transport and/or storage.[2,3] In particular, improperly identified specimens can have serious and potentially life-threatening consequences, including unnecessary tests and treatments, critical transfusion reactions, increased hospital stays and delays in diagnosis or the initiation of therapy.[4,5]

Care and quality standards are necessary to avoid pre-analytical errors. Recently, the European Federation of Clinical Chemistry and Laboratory Medicine highlighted the importance of such measures by initiating a special working group to provide official guidelines and recommendations regarding pre-analytical activities and enable continuous education for laboratory professionals and other healthcare operators.[6] It is the responsibility of each laboratory provider to assess the impact of such errors and institute corrective measures as part of their quality improvement procedures in order to ensure credible diagnostic results. These corrective measures should be aimed at eliminating common causes of non-conforming samples to prevent their occurrence and include advances in information technology, appropriate and timely quality control measures and continuous education for healthcare personnel.[6,7]

Educating nursing staff on blood sample handling and processing procedures has been recognised as a vitally important step in reducing pre-analytical errors.[7] At the Sultan Qaboos University Hospital (SQUH), a tertiary care centre and one of the main referral hospitals in Muscat, Oman, blood samples are collected almost exclusively by nurses. Specialist nurse phlebotomists are currently appointed only in the outpatient department, inpatient wards and day care facilities. Under current hospital policy, nurses are in charge of both general and critical blood collection and although physicians or other healthcare providers may collect blood samples in emergency situations, this is rare. The current study therefore aimed to evaluate the impact of nursing educational activities implemented as part of a quality initiative on the incidence of non-conforming samples received at the SQUH Haematology Laboratory over a nine-year period.

Methods

This study was conducted between January 2008 to December 2015. All general haematology test specimens received at the Haematology Laboratory at SQUH from January 2008 to December 2015 were prospectively collected and analysed to determine the incidence of pre-analytic errors in the form of non-conforming samples. Data between January and December 2007 were collected retrospectively and constituted the baseline for comparative purposes. Specimens included in the study comprised those obtained from both inpatient and outpatient clinics and all departments of the hospital as well as both adult and paediatric samples. All laboratory results were automatically generated by the TrakCare healthcare information system (InterSystems Corp., Cambridge, Massachusetts, USA), an automated electronic patient record system used at SQUH since 2006. Non-conforming samples were defined as either clotted samples, haemolysed samples, use of the wrong anticoagulant, insufficient quantities of blood collected, incorrect/lack of labelling on a sample or lack of delivery of a sample in spite of a sample request.

Based on the initial audit of data collected retrospectively for 2007, nursing training activities were instituted in 2008 as part of a hospital-wide quality improvement initiative. These activities were conducted every three months in 2008 for groups of 12–15 nurses and 20–25 student nurses at SQUH. Thereafter, the activities were conducted annually for the purposes of reinforcement. The initiative was comprehensive and involved numerous forms of information delivery. First, a general lecture was given to all nursing staff and students to present the findings of the initial audit. Second, details of the proper methods for sample collection and handling were provided, initially among small groups of nurses in each ward/section of the hospital and subsequently as part of a hospital-wide lecture to all relevant personnel, including senior nurses. Third, leaflets were distributed during hospital exhibits like the Quality Open Day depicting common pre-analytical laboratory errors associated with the receipt of non-

conforming samples and how they were to be avoided. Fourth, nurses were invited to visit the Haematology Laboratory for a hands-on demonstration of various non-conforming sample errors. During their visit, the nurses were also educated regarding the choice of collection tubes for different tests; the order in which samples were to be collected; the appropriate ratio of blood to anticoagulant in samples; and the proper labelling, transportation and storage of samples. Finally, the induction programme for new nurse recruits was modified to include a lecture on proper blood collection and sample handling.

These educational training activities were prospectively evaluated during an annual audit to assess their impact and to implement corrective measures. Every year, the nursing staff and hospital administration were appraised of the results of the previous year at the Quality Open Day, showcasing trends in various subcategories of non-conforming samples. The educational activities did not target the same nurses each time but were instead aimed to cover as much of the nursing staff as possible. As midwives were considered part of the general pool of nursing staff at SQUH and had received similar educational training, they were also included in the target audience. Attendance at any of the lectures or activities was not obligatory as SQUH is a large hospital and the nursing staff is widely distributed; it was therefore impossible for all nursing staff to attend at once, even if they chose to do so. Thus, only those who could spare the time attended each training session or lecture. However, those who missed a particular activity were free to attend subsequent training sessions, as they were held at regular intervals.

Data were expressed as the total number of samples received along with the number of non-conforming samples for every year between 2007 and 2015 and their relative percentages. Data obtained in 2007 were used as the reference baseline for comparison with data obtained between 2008–2015. Percentages of improvement were calculated successively, utilising the 2007 values as a baseline. Thus, any improvement was relative to 2007 and thereafter calculated on a yearly basis. Reductions in the actual number of non-conforming samples and the relative percentages were tabulated. Significant differences were calculated via the Wilcoxon signed-rank test using the Statistical Package for the Social Sciences (SPSS), Version 23 (IBM Corp., Armonk, New York, USA). A P value of <0.050 was considered statistically significant.

This study received ethical approval from the hospital administration at SQUH as part of their Quality Management Corrective Action Plan to conform with remedial action as necessitated by the certification standards of the International Organization for Standardization and Accreditation Canada International. The methods and findings of this study were continuously assessed on a yearly basis to monitor the effectiveness of the interventions involved in the quality initiative.

Results

A total of 63,800, 81,024, 93,768, 102,400, 114,588, 116,820, 122,316, 131,064 and 145,365 samples were received at the SQUH Haematology Laboratory each year between 2008 and 2015, respectively. During these years, there were 184, 234, 233, 215, 262, 133, 103, 98 and 102 non-conforming samples, respectively, accounting for 0.29%, 0.29%, 0.25%, 0.21%, 0.23%, 0.11%, 0.08%, 0.07% and 0.07% of all samples for each year [Table 1]. There was an absolute reduction of 0.22% in non-conforming samples from 0.29% at baseline to 0.07%, with an overall 75.86% improvement (P <0.050). The incorrect labelling of a sample (i.e. blood taken from the wrong patient or the incorrect labelling or categorisation of a sample) was the most critical error noted [Table 2]; there was an overall reduction of 0.056% in this type of error, yielding a 96.55% improvement.

Table 1: Distribution of total and non-conforming blood samples received at the Haematology Laboratory of the Sultan Qaboos University Hospital, Muscat, Oman, from 2007–2015

Year	2007*	2008	2009	2010	2011	2012	2013	2014	2015
Number of samples	63,800	81,024	93,768	102,400	114,588	116,820	122,316	131,064	145,365
Percentage change per year	-	27.00	15.73	9.20	11.90	1.95	4.70	7.15	10.91
Number of non-conforming samples	184	234	233	215	262	133	103	98	102
Percentage of all samples	0.29	0.29	0.25	0.21	0.23	0.11	0.08	0.07	0.07
P value†	-	-	0.586	0.258	0.406	<0.001	<0.001	<0.001	<0.001

*Data for this year was collected retrospectively to form the baseline for comparative purposes.
†Calculated using the Wilcoxon signed-rank test.

Table 2: Distribution of incorrectly labelled blood samples received at the Haematology Laboratory of the Sultan Qaboos University Hospital, Muscat, Oman, from 2007–2015

Year	2007*	2008	2009	2010	2011	2012	2013	2014	2015
Number of incorrectly labeled samples	37	20	13	7	4	5	4	2	3
Percentage of all samples	0.058	0.025	0.014	0.007	0.003	0.004	0.003	0.002	0.002

Data for this year was collected retrospectively to form the baseline for comparative purposes.

Discussion

Pre-analytical errors constitute one of the most important elements in the laboratory testing process and greatly impact the quality of laboratory results delivered. In general, major health centres with rapid staff turnover face significant risks when it comes to maintaining high standards in relation to blood sample collection and processing. As experienced staff leave the institution, new or inexperienced staff may require additional training to maintain quality initiative objectives. In addition, hospitals with nursing staff who come from different educational and training backgrounds may require continuous monitoring and reinforcement to ensure that best practice guidelines are followed. In consideration of these factors, hospital administrators should seek to institute and maintain quality initiatives to reduce non-conformity in blood testing.

In the current study, the main types of non-conforming errors identified at SQUH—such as incorrectly selected anticoagulants or collection tubes, mislabeled samples and clotted samples—were similar to those observed at other institutions.[5,8,9] The educational activities introduced as part of the quality initiative aimed to resolve these errors primarily by reinforcing best practices in sample collection and processing. Such analytical quality control initiatives focus on quality goals and specify high-quality operational procedures and the assessments needed to meet the quality objectives. Such measures not only reduce the occurrence of pre-analytical errors, but may also improve patient satisfaction due to rapid test turnaround times and reduced costs as they alleviate the need for repeated blood testing, unnecessary investigations or prolonged hospital stays. In the current study, use of the TrakCare information system (InterSystems Corp.) may have encouraged compliance with sample collection standards, as the system specifies the exact type of tube required for each test as well as the exact amount of blood required prior to sample collection. However, the educational activities were helpful in reinforcing proper sample collection approaches, as well as labelling and transportation protocols, hence reducing the frequency of non-conforming samples.

In the present study, the implementation of hospital-wide nursing educational activities resulted in a progressive reduction in pre-analytical laboratory errors, particularly those that were a direct result of staff collection procedures, such as incorrectly labeled samples, the use of the wrong anticoagulants/tubes and samples submitted without labelling. Previous research has also identified such pre-analytical errors to be the most frequent.[4,8,10] The actual number and percentage of non-conforming samples in the current study progressively reduced over the subsequent eight-year period following the introduction of the quality initiative in 2008. Although the number of non-conforming samples had improved by 2009, it was not until 2012 that this improvement reached statistical significance. Nevertheless, there were marginal increases in certain years for certain errors, including clotted samples and insufficient quantities of blood in a sample. Maintenance of the blood/additive ratio is extremely important and insufficient blood quantities can contribute to wastage and errors, necessitating repeat sampling and at times resulting in unnecessary delays in instituting therapy.[6]

The appointment of specialist nurse phlebotomists at SQUH would not only help in reducing pre-analytical laboratory errors, but would also reduce the current burden on nursing staff working in special areas like intensive care units, day care facilities and delivery wards, as well as encourage job creation within the healthcare system in Oman. One limitation of the current study was that no proper objective method was used to quantatively assess non-conforming samples. To address this shortcoming, implementation of the Sigma methodology as a statistical tool to validate quality is highly recommended in future research.[11]

Conclusion

Non-conforming samples are a critical obstacle to valid laboratory results, wasting both time and resources and impeding patient care. In the current study, the implementation of targeted educational activities primarily directed at nurses resulted in a significant reduction in the incidence of pre-analytical errors at a haematology laboratory. These findings highlight the

need for continuing education and the reinforcement of best practice guidelines for sample collection and processing.

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