Türk Klinik Biyokimya Derg 2025; 23(1): 14-27 Araştırma Makalesi / *Research Article*

https://doi.org/10.56615/tkbd.2025.03

Observation of the Venous Blood Collection Process: Association with Preanalytical Errors

Venöz Kan Alma Sürecinin İzlenmesi: Preanalitik Hata Kaynaklarıyla İlişkisi

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Received / Başvuru Tarihi: 26.02.2025 *Accepted* / Kabul Tarihi: 03.04.2025

ABSTRACT

Aim: Preanalytical errors, particularly during venous blood collection, are a significant source of laboratory diagnostic inaccuracies, accounting for most laboratory mistakes. Addressing these errors through systematic monitoring and targeted interventions is critical for improving laboratory quality and ensuring patient safety.

Material and Methods: This prospective study was conducted over five days in the central blood collection unit of a university hospital. A total of 300 venous blood collection procedures performed by 12 phlebotomists were directly observed. Data were collected using a Venous Blood Collection Observation Form based on the European Federation of Clinical Chemistry and Laboratory Medicine and Clinical and Laboratory Standards Institute guidelines. Compliance with guidelines and common error rates were analyzed, and the impact of training interventions was assessed through statistical methods, including the two-proportion z-test and chi-square test.

Results: The most common reasons for sample rejection were "Insufficient Sample," "Clotted Sample," and "Hemolyzed Sample," which accounted for 78.69% of all rejections. After the implementation of a training program in June 2024, a statistically significant reduction in sample rejection rates was observed in July 2024 ($p < 0.05$). The primary areas of non-compliance involved improper tube filling, incorrect mixing, and extended tourniquet application.

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Ethical approval for the study was obtained from the Ethics Committee for Non-Interventional Scientific Research at Bakırköy Dr. Sadi Konuk Training and Research Hospital, with the decision dated 24.06.2024 and numbered 2024-04-18.

Conclusion: The findings demonstrate that preanalytical errors, particularly in venous blood collection, can be reduced through systematic training and adherence to standardized protocols. Continuous education and quality control measures are essential for minimizing error rates, improving sample integrity, and enhancing patient safety. Future efforts should focus on regular observational audits and ongoing staff education to maintain improvements.

Keywords: preanalytical errors; venous blood collection; sample rejection; staff training; patient safety.

ÖZET

Amaç: Preanalitik hatalar, özellikle venöz kan alma sürecinde ortaya çıkanlar olmak üzere, laboratuvar tanısal yanlışlarının başlıca kaynağını oluşturur ve laboratuvar hatalarının önemli bir kısmından sorumludur. Bu hataların sistematik izlenmesi ve hedefe yönelik müdahalelerle azaltılması, laboratuvar kalitesini artırmanın ve hasta güvenliğini sağlamanın temel koşullarından biridir.

Gereç ve Yöntem: Bu prospektif gözlem çalışması, bir üniversite hastanesinin merkezi kan alma biriminde 5 gün boyunca yürütülmüştür. Toplam 12 flebotomist tarafından gerçekleştirilen 300 venöz kan alma işlemi doğrudan gözlemlenmiştir. Veriler, European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) ile Clinical and Laboratory Standards Institute (CLSI) yönergelerine dayalı bir "Venöz Kan Alma Gözlem Formu" aracılığıyla toplanmıştır. Kılavuzlara uyum ve yaygın görülen hata oranları değerlendirilmiş, eğitim müdahalelerinin etkisi ikioran z testi ve ki-kare testi gibi istatistiksel yöntemler kullanılarak analiz edilmiştir.

Bulgular: Numune reddinin en yaygın nedenleri "Yetersiz Numune," "Pıhtılı Numune" ve "Hemolizli Numune" olup, tüm reddedilen numunelerin %78,69'unu oluşturmuştur. Haziran 2024'te uygulanan eğitim programının ardından, Temmuz 2024'te numune reddi oranlarında istatistiksel olarak anlamlı bir azalma gözlenmiştir ($p < 0,05$). Kılavuzlara uyum açısından en sık rastlanan eksiklikler arasında tüpün uygunsuz doldurulması, hatalı karıştırma ve turnikenin gereğinden uzun süre uygulanması yer almıştır.

Sonuç: Bulgularımız, özellikle venöz kan alma sırasında görülen preanalitik hataların, sistematik eğitim ve standardize protokollere uyum yoluyla azaltılabileceğini göstermektedir. Hata oranlarını düşürmek, numune bütünlüğünü korumak ve hasta güvenliğini artırmak için sürekli eğitim ve kalite kontrol önlemleri kritik önem taşımaktadır. İleride yapılacak çalışmalarda, düzenli gözlemsel denetimler ve sürekliliği sağlanan personel eğitimiyle elde edilen iyileştirmelerin korunması ve yaygınlaştırılması hedeflenmelidir.

Anahtar Kelimeler: preanalitik hatalar; venöz kan alma; numune reddi; personel eğitimi; hasta güvenliği.

INTRODUCTION

Laboratories are essential to healthcare, providing critical data for diagnosing, treating, and managing diseases. Accurate lab results are crucial for clinical decisions, from illness identification to patient monitoring, ensuring high-quality care. Achieving accuracy demands careful attention to each testing phase, as unique challenges arise in maintaining diagnostic integrity, essential for effective management, disease prevention, and treatment decisions [1-2].

Laboratory testing is divided into key phases: pre-preanalytical, preanalytical, analytical, postanalytical, and post-postanalytical. The preanalytical phase is most prone to errors, accounting for up to 70% of lab mistakes. This includes activities from test ordering to sample preparation, such as patient preparation, sample collection, handling, transportation, and preparation for analysis [3]. Preanalytical errors, like misidentification, incorrect labeling, hemolysis, clotting, insufficient volume, and improper transport, can lead to inaccurate results, misdiagnoses, delayed treatment, and adverse outcomes. Therefore, addressing these errors is vital for ensuring the integrity of diagnostic processes and safeguarding patient safety [4].

Preanalytical errors are particularly challenging to detect and prevent due to the

decentralized nature of activities, many of which occur outside the laboratory environment, limiting laboratory personnel's control. Multiple manual processes carried out by various healthcare workers create opportunities for human error, particularly in settings where standardized protocols are not strictly enforced [5]. Despite technological advancements that have significantly reduced analytical errors, the preanalytical and postanalytical phases remain highly susceptible to mistakes due to their reliance on human factors [6]. Compliance with existing standards, particularly for blood sampling and sample handling, is often low and this lack of standardization contributes to significant variability in managing unacceptable specimens and reporting test results, ultimately impacting the quality of patient care [7].

Global efforts, such as those by the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM), aim to harmonize practices to reduce variability, minimize errors, and improve result reliability, especially in the preanalytical phase [1]. To mitigate risks, laboratories must implement standardized procedures, continuous staff training, rigorous quality control, and automation where possible. Additionally, fostering a culture of continuous improvement across all sites is essential for ensuring consistent quality [6].

Phlebotomy, the practice of drawing blood, is a critical aspect of the preanalytical phase. Errors in phlebotomy, including misidentification, poor techniques, and improper handling, are major sources of preanalytical issues. Standardizing phlebotomy practices through guidelines is vital for reducing these errors and ensuring reliable lab results [6].

Preanalytical errors impact more than immediate test accuracy, potentially triggering repeat tests, higher healthcare costs, and patient discomfort. These errors can delay diagnoses and treatments, worsening patient outcomes [8]. To counter these risks, labs should use monitoring systems to detect preanalytical errors promptly [9]. Corrective and preventive measures, including continuous staff training, standardized protocols, and automation, are essential for reducing errors and improving patient outcomes [8].

In this study, the primary aim is to observe venous blood sampling processes directly, with a focus on identifying preanalytical errors as they occur. By conducting real-time observations, we aim to pinpoint specific areas where errors are most likely to happen and develop targeted interventions to address these issues. This approach will enable us to plan and implement corrective and preventive actions more effectively, ultimately improving the quality of laboratory diagnostics and enhancing patient safety.

MATERIALS AND METHODS

This prospective study was conducted over five days at the Venous Blood Collection Unit of the University of Health Sciences, Bakırköy Dr. Sadi Konuk Training and Research Hospital, based on the direct observation of phlebotomists during venous blood collection (phlebotomy) procedures. For this purpose, a Venous Blood Collection Observation Form consisting of 35 items was created, based on the EFLM-COLABIOCLI Joint Recommendation for Venous Blood Sampling [10].

The EFLM guidelines recommend observing at least 20 blood collection procedures performed by a minimum of three different phlebotomists (at least three attempts per phlebotomist), without any positive or negative intervention [10]. In line with this guideline, a total of 300 venous blood collection procedures were observed in the field, with each of the 12 phlebotomists performing 25 procedures. These observations were conducted by two observers during weekdays, between 08:00

and 16:00, in the central blood collection unit. The personnel were coded using the number of the collection booth, the date (month and day) on which the form was filled, and the observed attempt number.

Patients whose blood tests were ordered by clinicians during outpatient clinic hours and who were referred to the central blood collection unit for venous blood collection, and who did not meet the exclusion criteria specified by the EFLM guidelines (patients who were unconscious, under the age of 18, or had blood samples taken via catheter) were included in the study. The observation questionnaire included "Yes-No" questions. Correct procedures were represented by a "Yes" response, and non-compliant procedures by a "No" response, with the study investigating the compliance of venous blood collection with the CLSI (Clinical and Laboratory Standards Institute) GP-41 guideline [11].

For the statistical analysis of the research data, SPSS (Statistical Package for the Social Sciences) version 27.0.1 was used. Descriptive statistics, including counts and frequency analysis, were performed. Data from the same observation week (June 10-14, 2024), 1-month data (June 2024), and 1-year data (June 2023-2024) were obtained from the Laboratory Information System (LIS).

During June, the month in which the observational study was conducted, the personnel working in the blood collection unit and those responsible for sample transport from the blood collection unit to the laboratory sample acceptance unit were trained on correct practices and common errors. To evaluate the effect of this training, sample rejection rates and reasons for July (post-training) were compared with those of June (pre-training) using the two-proportion z-test and the Chi-square test.

Ethical approval for the study was obtained from the Ethics Committee for Non-Interventional Scientific Research at Bakırköy Dr. Sadi Konuk Training and Research Hospital, with the decision dated 24.06.2024 and numbered 2024-04-18. The study was conducted in accordance with the Declaration of Helsinki.

RESULTS

A total of 300 venous blood collection procedures, conducted by 12 different nurses (each performing 25 procedures), were directly observed over the course of one week. The data obtained from these observations are presented in Table 1.

According to the CLSI GP-41-Collection of Diagnostic Venous Blood Specimens guideline [11], the results of the phlebotomy procedures observed were evaluated for compliance, and the findings are presented in Figure 1.

The total number of test requests, the total number of sample rejections, and the reasons for sample rejections were obtained from the LIS for the one-week observation period, as well as the one-month and one-year periods that include this week. These data are presented in Table 2.

In the Pareto analysis conducted for the frequency of sample rejection reasons, "Insufficient Sample," "Clotted Sample," and "Hemolyzed Sample" were identified as the main causes across all time periods (Figure 2).

The rejection data for June 2024, when the observation study was conducted, and for July 2024, following the training, are presented in Figure 3.

To compare the sample rejection rates between the two time periods before and after training, a two-proportion z-test was performed. The result was a Z-statistic of 4.55 and a p-value < 0.05 (0.00000542).

Additionally, the chi-square test yielded a Pearson chi-square value (x^2) of 20.68 and a

p-value of 0.0000059 ($p < 0.05$). These test results confirm that the difference in rejection rates between the two periods is statistically significant.

Table 1. Venous blood collection observation form - data observed during sample collection
Tablo 1. Venöz kan toplama gözlem formu - örnek toplama sırasında gözlemlenen veriler

		YES n (%)	NO n (%)
1	Was the blood collection area separated by a curtain or similar system to ensure patient privacy?	300 (100)	0
2	Is there a properly arranged cabinet/cart that ensures the material is clearly visible and easily accessible for safe use?	300 (100)	0
3	Is there a blood collection tray with enough space and a section for a sharps container?	300 (100)	0
4	Did the person collecting the sample prepare all necessary materials before the procedure?	300 (100)	0
5	Did the person collecting the sample check the expiration dates of all the materials used?	0	300 (100)
6	Did the person collecting the sample properly verify the patient's identity?	202 (67,33)	98 (32,67)
7	Did the person collecting the sample check if the patient had fasted and was appropriately prepared for phlebotomy?	68 (22,67)	232 (77,33)
8	Was the request form reviewed when preparing the tubes?	300 (100)	0
9	Did the person disinfect their hands before the procedure?	93 (31)	207 (69)
10	Was the blood collection chair suitable for this procedure?	300 (100)	0
11	Were the tubes labeled (barcoded) in the presence of the patient?	300 (100)	0
12	Did the person collecting the sample use a tourniquet during blood collection?*	289 (96,33)	11 (3,67)
	If yes, a) Did the person collecting the sample tie the tourniquet approximately four fingers (10 cm) above the blood collection site?	241 (83,39)	48 (16,61)
	b) Was the tourniquet applied for less than 2 minutes?	127 (43,94)	162 (56,06)
13	Was an appropriate venous access site chosen according to recommended practice?	300 (100)	0
14	Did the person collecting the sample wear a clean, new pair of gloves for each patient?	58 (19,33)	242 (80,67)
15	Was the venous access site cleaned?	300 (100)	0
	If yes, indicate the method of wiping: a. Circular from outside to inside b. Circular from inside to outside: c. One straight line d. Random wiping	a. 34 times (11,33) b. 38 times (12,66) c. 137 times (45,66) d. 91 times (30,33)	
16	Did the person leave the blood collection site to dry for 30 seconds?	101 (33,67)	199 (66,33)
17	Did the person collect the sample without touching the site again after cleaning?	160 (53,33)	140 (46,67)
18	Did the person ensure the fist was relaxed when blood flow started?	133 (44,33)	167 (55,67)
19	Did the person release the tourniquet when blood flow started?	41 (14,19)	248 (85,81)

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		YES n (%)	NO n (%)
20	Did the person use a closed system for blood collection?	300 (100)	0
21	Did the person follow the correct tube sequence as per the guidelines?**	209 (69,67)	91 (30,33)
	If no, specify the tube sequence:	purple-yellow: 63 times (69.23) yellow-blue: 12 times (13.19) purple-blue-yellow: 6 times (6.59) purple-yellow-blue: 5 times (5.49) yellow-blue-purple: 5 times (5.49)	
22	Were the tubes filled to the appropriate volume?***	219 (73)	81 (27)
	If any tubes were overfilled or underfilled, specify:	Underfilled citrate tube: 27 times (33.33) Overfilled EDTA# tube: 22 times (27.16) Overfilled citrate tube: 19 times (23.46) Underfilled EDTA tube: 13 times (16.05)	
23	Were all tubes gently inverted immediately according to the manufacturer's instructions?	65 (21,67)	235 (78,33)
24	Did the person place a clean gauze pad on the venous access site after the procedure?	300 (100)	0
25	Was the needle safety mechanism (needle guard) immediately activated?	266 (88,67)	34 (11,33)
26	Was the needle or system disposed of safely and promptly?	281 (93,67)	19 (6,33)
27	Did the person pay attention to the fill level of the sharps container?	273 (91)	27 (9)
28	Were all tubes inverted again four times?	18 (6)	282 (94)
29	Was the patient instructed to apply pressure to the site until the bleeding stopped and not bend their arm?	209 (69,67)	91 (30,33)
30	Was the patient advised to rest for 5 minutes in the blood collection unit to ensure the bleeding had stopped?	146 (48,67)	154 (51,33)
31	Was the blood collection successful, with all required tubes filled in one attempt?	289 (96,33)	11 (3,67)
32	Did the person monitor for potential complications at the venous access site?	296 (98,67)	4 (1,33)
33	Did the person record their identity information?	300 (100)	0
34	Were the samples delivered to the laboratory without delay?	130 (43,33)	170 (56,67)
35	Were the samples handled with care to avoid shaking during transportation?	90 (30)	210 (70)

n: number of observations (n = total of 300 observations), %: frequency
*For question 12, observations only include those where a tourniquet was used (n = 289 observations).
**For question 21, observations include only those with incorrect tube sequencing (n = 91 observations).
***For question 22, observations include only those with overfilled or underfilled tubes (n = 81 observations).
EDTA, ethylenediaminetetraacetic acid.

Table 2. Rejection rates according to the rejection criteria of the clinical laboratory during the one-week, one-month, and one-year LIS periods
Tablo 2. Bir haftalık, bir aylık ve bir yıllık LIS dönemlerinde klinik laboratuvarın red kriterlerine göre red oranları

	One-week LIS Period		One-month LIS Period		One-year LIS Period	
Total test requests	32 850		154 770		1 979 855	
Total rejections	338		1778		19 581	
Total rejection rate	1,03%		1,15%		0,99%	
Error Type	Error (n)	%	Error (n)	%	Error (n)	%
Insufficient sample	134	39,64	561	31,55	8256	42,16
Clotted sample	122	36,09	622	34,98	7617	38,90
Hemolyzed sample	52	15,38	189	10,63	1505	7,69
Incorrect test request	22	6,51	163	9,17	1053	5,38
Incorrect tube	8	2,37	119	6,69	495	2,53
Missing parameter			36	2,02	281	1,44
Lipemic sample			28	1,57	156	0,80
Incorrect barcode			38	2,14	96	0,49
Contaminated sample			20	1,12	93	0,47
Improper transport conditions			2	0,11	29	0,15

Rejection rates were calculated by the following formula: number of rejected samples/total numbers of samples × 100.

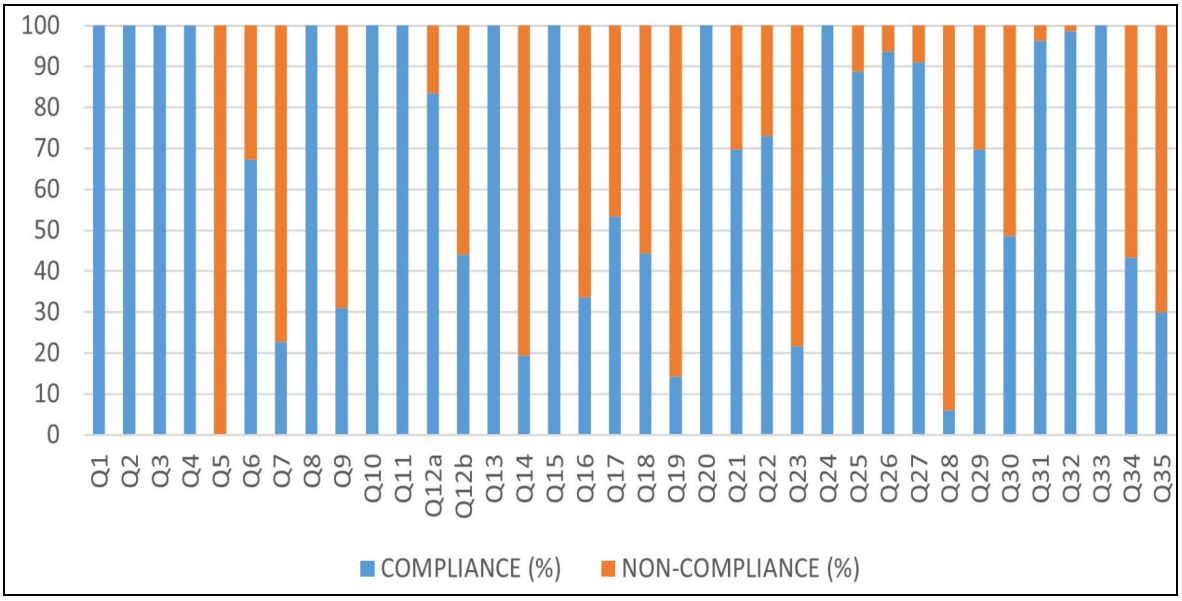

Figure 1. Compliance and non-compliance percentages according to the CLSI GP-41 guideline. The figure illustrates the rate of adherence to the specified procedures for each observed item, highlighting areas of high and low compliance across the dataset.

Şekil 1. CLSI GP-41 kılavuzuna göre uyum ve uyumsuzluk yüzdeleri. Şekil, her bir gözlemlenen madde için belirlenen prosedürlere uyum oranını göstererek, veri setinde yüksek ve düşük uyum gösterilen alanları vurgulamaktadır.

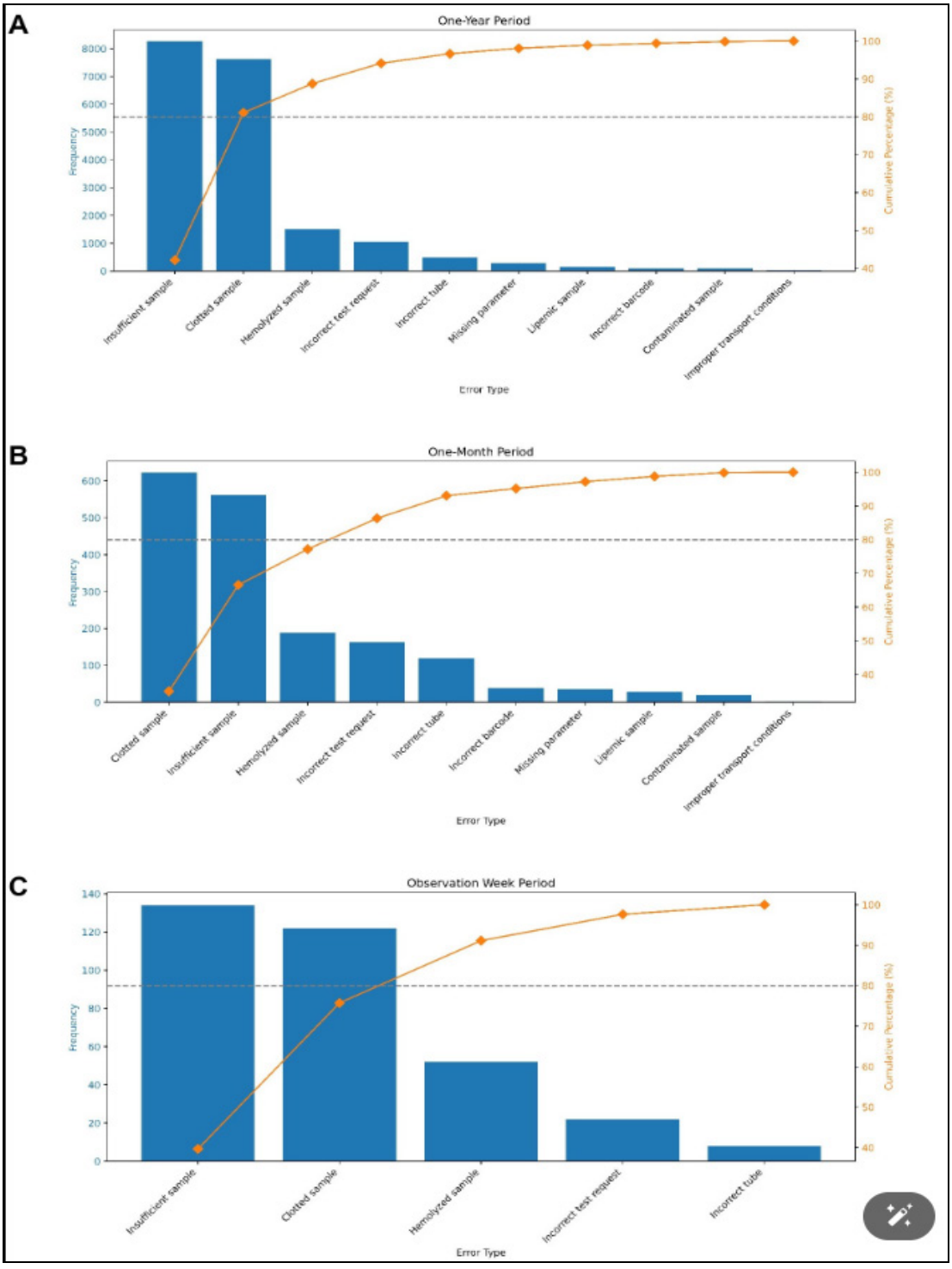

Figure 2. Evaluation of rejection reasons through Pareto analysis. Frequency and cumulative percentage of error types across different time periods: (A) One-year period, (B) One-month period, and (C) Observation week period. The bar graphs represent the frequency of each error type, while the orange line indicates the cumulative percentage. The most common errors across all periods include "Insufficient sample", "Clotted sample", and "Hemolyzed sample".

Şekil 2. Red nedenlerinin Pareto analizi ile değerlendirilmesi. Farklı zaman dilimlerinde hata türlerinin sıklığı ve kümülatif yüzdesi: (A) Bir yıllık dönem, (B) Bir aylık dönem ve (C) Gözlem haftası dönemi. Çubuk grafikler her bir hata türünün sıklığını gösterirken, turuncu çizgi kümülatif yüzdesini göstermektedir. Tüm dönemler boyunca en sık görülen hatalar arasında "Yetersiz örnek", "Pıhtılı örnek" ve "Hemolizli örnek" yer almaktadır.

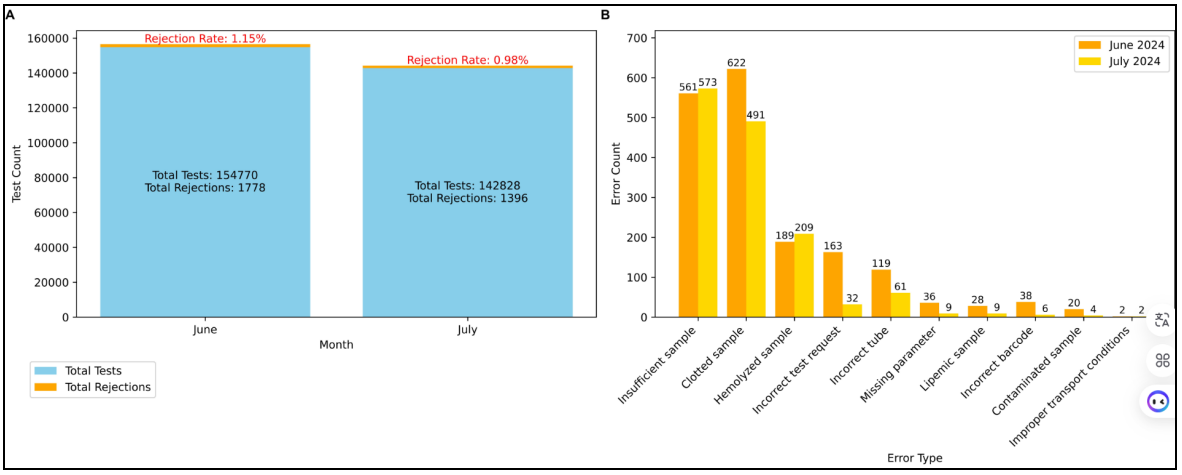

Figure 3. Comparison of test rejection rates and error types before and after training. (A) The bar charts show the total number of tests and rejections for both months. The rejection rate decreased from 1.15% in June to 0.98% in July. (B) The frequency of various error types in both months is shown, with "Insufficient sample," "Clotted sample," and "Hemolyzed sample" being the most common errors. The errors are represented by bars for June (orange) and July (yellow).

Şekil 3. Eğitim öncesi ve sonrası test red oranları ve hata türlerinin karşılaştırılması. (A) Çubuk grafikler her iki ay için toplam test sayısını ve red sayılarını göstermektedir. Red oranı Haziran ayında %1,15'ten Temmuz ayında %0,98'e düşmüştür. (B) Her iki ayda görülen farklı hata türlerinin sıklığı gösterilmekte olup, en sık karşılaşılan hatalar "Yetersiz örnek", "Pıhtılı örnek" ve "Hemolizli örnek" olmuştur. Hatalar Haziran ayı (turuncu) ve Temmuz ayı (sarı) için çubuklarla gösterilmiştir.

DISCUSSION

Preanalytical errors are critical factors directly impacting laboratory test outcomes. Errors in sample collection, transportation, storage, and processing, which occur outside the laboratory, can compromise test accuracy and reliability. Regular monitoring and evaluation of these phases are crucial for identifying specific steps prone to errors, allowing root causes to be addressed through targeted corrective actions. This proactive approach strengthens the laboratory's quality management system and upholds patient safety.

Venous blood collection is an essential step in the preanalytical phase and one of the most frequently performed invasive procedures in healthcare. Errors may occur at any stage—before, during, or after collection—posing significant risks for patient safety.

In our study, the most common cause for sample rejection was "Insufficient Sample." This issue often stems from inadequate blood collection techniques, such as insufficient blood volume during venipuncture or improper needle placement, resulting in underfilled tubes. Incorrect tube selection, particularly underfilling vacuum tubes containing anticoagulants, disrupts the blood-to-additive ratio, rendering tests invalid. Insufficient blood mixing can lead to hemolysis or non-homogeneous samples, necessitating rejection. Incorrect storage and transport, such as temperature mismanagement or excessive delays, degrade sample quality, leading to unusable samples. In addition, inexperienced personnel or faulty equipment can result in inadequate sample collection, while patient-specific factors like low blood pressure or improper preparation may also limit sample adequacy. In pediatric patients or those with challenging venous access, obtaining an adequate blood sample is especially difficult. Adherence to preanalytical protocols, comprehensive personnel training, and the

use of reliable equipment are thus essential to prevent insufficient sampling [12].

"Clotted Sample" was identified as the second most frequent rejection reason. Factors contributing to clotting include inadequate blood collection techniques, insufficient anticoagulant, poor mixing, delays in processing, or improper storage. Patient factors like coagulation disorders or medication use can also play a role. Insufficiently trained staff or the use of faulty equipment may further increase clotting risks.

Our findings show that 27% of observed procedures involved improper tube filling. Specifically, 33.33% of citrate tubes were underfilled, which affects the plasma-to-anticoagulant ratio and compromises coagulation test reliability. Tests such as Prothrombin Time (PT), International Normalized Ratio (INR), and Activated Partial Thromboplastin Time (aPTT) are particularly impacted, leading to erroneous clotting times and potential misinterpretation. Conversely, overfilling citrate tubes results in insufficient anticoagulant, which can cause falsely shortened clotting times. For EDTA tubes, 27.16% were overfilled, and 16.05% were underfilled. In hematological testing, incorrect blood-to-anticoagulant ratios lead to inaccurate results. Underfilled EDTA tubes disrupt this balance, causing cellular shrinkage and hemolysis, potentially leading to inaccurate values in tests like complete blood count (CBC). Overfilled tubes, however, reduce anticoagulant effectiveness, increasing clotting risks and invalidating samples [12].

Incorrect tube inversion was also observed, with samples not inverted gently post-collection in 78.33% of cases, and not inverted at least four times in 94%. Furthermore, an incorrect draw order was followed in 30.33% of cases, with blood collected into purple-capped tubes before yellow-capped ones in 69.23% of instances. Although closed blood collection systems are claimed to mitigate contamination risk, studies still show higher contamination rates with incorrect draw orders, making it advisable to adhere to recommended draw sequences to minimize risk [13-14].

The third most common rejection cause was "Hemolyzed Sample." Factors leading to hemolysis include improper blood collection techniques, excessive shaking of tubes, and the use of overly fine needles. Drawing blood too quickly or slowly can also damage cells, while friction from small needles or poor venipuncture technique may rupture cells, leading to hemolysis. Incorrect tube selection, such as using tubes without anticoagulants or underfilling, can cause clotting and eventually lead to hemolysis. Additionally, improper storage, prolonged sample retention, or inappropriate centrifugation techniques raise hemolysis risks. Following best practices at every stage minimizes these potential issues [15].

During our study, 96.33% of cases involved tourniquet use, with application lasting over 2 minutes in 56.06% of these instances. In 55.67% of cases, the phlebotomist did not ensure the patient released their fist when blood flow started, and in 85.81%, the tourniquet was not released once the procedure was completed.

Extended tourniquet use can increase analyte concentrations through hemoconcentration, artificially elevating levels of protein-based analytes and blood cells. Guidelines recommend limiting tourniquet use to no more than 1 minute, particularly when veins are visibly accessible, to minimize this effect [10-11,16]. Clenching or pumping the fist can lead to pseudohyperkalemia and cause alterations in some other biochemical and hematological parameters [17].

In 70% of cases, the samples were transported inappropriately, often being thrown into transport bags and shaken during transfer. Additionally, in 56.67% of cases, the samples were not delivered to the laboratory within the required time frame after collection. Blood samples should be transported to the laboratory within 2 hours of collection to prevent analyte degradation and

ensure accurate test results. Delays beyond this period can lead to significant preanalytical errors, including hemolysis and inaccurate test results [18]. Samples should be transported upright to avoid agitation and minimize the risk of hemolysis. Transporting samples horizontally or upside down increases the risk of agitation, which can cause the sample to mix with air or clot activators, compromising the sample's integrity. Tubes should be transported with their lids securely closed to prevent contamination, spillage, and exposure to air, which could affect the sample's quality. Ensuring proper sealing also prevents evaporation and maintains the correct sample volume [18].

Venous blood collection should be performed in a clean, quiet, well-lit, and well-ventilated area specifically designated for this procedure. The supply cabinet, cart, or tray should be organized to ensure that all necessary materials are easily accessible and clearly visible, allowing phlebotomists to work safely and efficiently [11,16]. In the central blood collection unit, procedures are conducted in separate cubicles to ensure patient privacy. An adjustable blood collection chair is available to provide patient support. Additionally, there is a designated area where materials needed for blood collection are easily accessible.

In the central blood collection unit, no checks were made for the expiration dates of the materials used. Expired vacuum blood collection tubes may not draw the appropriate volume of blood, which is particularly problematic in additive-containing tubes, where the correct ratio of blood to additive is crucial. Furthermore, chemical degradation of additives can occur in expired tubes. To ensure sample quality, expired tubes should be discarded, and materials should be checked before use. The expiry dates of needles and the integrity of sterile seals should also be checked carefully. It is essential to follow the manufacturer's expiration dates [19].

In the central blood collection unit, patients referred from outpatient clinics are given a barcode during the registration process, and when the phlebotomist scans this barcode, the requested test tubes and patient information are matched. Patient identification is vital for accuracy, ideally requiring multiple identifiers like full name, birth date, and insurance number. In line with CLSI H3-A6 guidelines, blood tubes should be labeled after filling and in the patient's presence; however, only 53.4% of observed procedures followed this practice, and labeling was absent in the patient's presence in 29.6% of cases, elevating error risk [20-21].

In 77.33% of the procedures we observed, the patient's preparation for blood collection was not queried. Each patient should be asked about their fasting status, physical activity, and therapeutic drug intake prior to blood collection by phlebotomy. Ideally, the fasting period should be at least 12 hours for most blood tests, and any physical activity should be avoided 72 hours before blood sampling. Information about therapeutic drug intake should also be provided to the laboratory staff [22].

In our study, only 19.33% of procedures involved fresh gloves for each patient, essential for infection control. Venipuncture sites were cleaned before all procedures, but correct cleaning technique was followed in only 12.66% of cases, with drying for at least 30 seconds observed in just 33.67% of cases. Proper site preparation requires cleaning with 70% alcohol in a circular motion from the center outward, followed by air drying for 30 seconds without further contact to ensure effective disinfection [23-24].

Observed sample rejection rates were 1.03% over one week, 1.15% for one month, and 0.99% for one year, primarily due to insufficient samples, clots, and hemolysis. These rejection reasons are consistent with previous studies, which also identified high error rates in phlebotomy, emphasizing the need for regular monitoring and training [25-31].

In a study by EFLM, compliance with the CLSI H3-A6 guidelines was assessed across 12 European countries through an observational audit of 336 blood sampling procedures. The findings revealed a concerning median error rate of 26.9%, particularly in the critical areas of patient identification and tube labeling. These results highlight widespread non-compliance with established standards, emphasizing the need for improved training and stricter adherence to protocols to enhance patient safety and the accuracy of laboratory diagnostics [28].

Educational interventions have proven effective in reducing preanalytical errors. For instance, one study reported a reduction in sample rejection from 2.35% to 1.56% after targeted training on sample collection [30]. Ongoing training, particularly in high-error areas like emergency departments, improves compliance with sample collection techniques and enhances lab quality [29-31].

A survey revealed significant variability in phlebotomy training across Europe, with only 36% of countries offering specific phlebotomy training as part of continuous professional education. In 21% of countries, nurses did not receive any formal phlebotomy training as part of their qualification, while in 32% of countries, laboratory technicians lacked similar training. These findings underscore the need for harmonized guidelines and structured education programs to improve phlebotomy practices and reduce preanalytical errors. Implementing standardized training and European-wide guidelines, as advocated by the EFLM, is essential for improving the quality of laboratory testing and patient care [32].

Over the past decades, significant advancements in laboratory technology, automation, assay standardization, and information technology have led to a marked reduction in analytical errors. Key contributors to this improvement include the establishment of strict internal quality control protocols, the implementation of effective quality assurance programs, and the training of laboratory personnel [33].

Additionally, the recognition that laboratory errors are part of the broader issue of diagnostic errors has driven a focus on the total testing process (TTT) to identify and mitigate errors. International Organization for Standardization ISO 15189:2007 for Accreditation of Medical Laboratories underscores the need for systematic monitoring and evaluation to enhance the laboratory's role in patient care and continuous improvement [34].

Republic of Türkiye Ministry of Health, through the Department of Quality and Accreditation in Healthcare has outlined that personnel responsible for sample collection must receive training on the pre-analytical phase. Additionally, staff involved in the proper management and timely transfer of samples must also receive training on these procedures [35].

In our study, the results of the two-proportion z-test and chi-square test revealed that the training provided in June 2024 led to a statistically significant decrease in sample rejection rates in July 2024. This notable reduction in rejection rates following the training demonstrates that education and process monitoring can reduce errors in blood collection and sample transport, improving overall practice. These findings suggest that regular training programs can be an effective method for enhancing the quality and efficiency of laboratory processes. Education increases the level of confidence and improves the quality of procedures [36]. However, the effects are usually short-term, which is why education should be continuously repeated [37].

CONCLUSION

Standardization of several preanalytical activities can indeed be achieved by adhering to available guidelines, implementing a total quality management system that includes preanalytical requirements, and providing continuous education for healthcare staff responsible for blood sampling.

To prevent preanalytical errors, it is essential to develop clear written procedures that guide all related processes. Increasing the education and training of healthcare professionals, including laboratory staff, phlebotomists, and sample transport personnel, is critical, with a focus on the negative consequences of improper practices. Automating both support and analytical operations can help reduce human error, while monitoring quality indicators ensures continuous improvement. Lastly, enhancing communication among healthcare professionals and encouraging interdepartmental collaboration are key strategies for minimizing preanalytical mistakes and improving overall laboratory accuracy.

In conclusion, the training intervention proved successful in improving laboratory processes, and continuing similar efforts in the future is recommended. It is advised that observational audits be conducted in clinical and blood collection units at least once a year to ensure adherence to best practices. Furthermore, healthcare institutions should establish systems for continuous monitoring, retraining, and certification to maintain high levels of competency among all staff through regular and ongoing theoretical and practical training.

ACKNOWLEDGEMENTS

None.

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