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PRE-ANALYTICAL SPECIMEN REJECTION IN HEMATOLOGY: EVALUATION OF REJECTION RATES, CAUSES, AND ASSOCIATED FACTORS IN A TERTIARY CARE TEACHING HOSPITAL

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ABSTRACT

Background: Pre-analytical errors are an important source of laboratory non-conformities and may compromise specimen integrity, delay reporting, necessitate repeat phlebotomy, and adversely affect patient care. Monitoring specimen rejection is therefore an important quality indicator, particularly in hematology, where appropriate collection, anticoagulation, and specimen handling are essential for reliable results. The aim is to evaluate pre-analytical hematology specimen rejection rates and identify the major causes and associated factors in the clinical laboratory of a tertiary care teaching hospital.

Materials and Methods: A prospective, observational, laboratory-based cross-sectional study was conducted in the Department of Pathology at Dr. Rajendra Gode Medical College and Hospital, Amravati from 1 March to 30 June 2026. Hematology specimens received for routine investigations were assessed according to established laboratory acceptance and rejection criteria. Rejected specimens were categorized according to the documented pre-analytical non-conformity and analyzed with respect to patient characteristics, clinical location, requesting department, specimen type, and investigation requested. Categorical variables were summarized as frequencies and percentages.

Results: During the four-month study period, 116 hematology specimens were rejected against a recorded hematology workload of 10,847, corresponding to an observed rejection proportion of 1.07%. Clotted specimens were the predominant cause of rejection (83.6%), followed by hemolyzed specimens (3.4%) and insufficient specimen quantity (1.7%); other/uncategorized documented reasons accounted for 11.2%. Most rejected specimens originated from inpatient services (81.0%). Orthopedics (25.0%), critical care units (23.3%), and Medicine (21.6%) contributed the largest proportions of rejected specimens. CBC (47.4%) and PT/INR (38.8%) were the investigations most frequently represented among rejected specimens. The observed monthly rejection proportion declined from 2.20% in March to 0.38% in June.

Conclusion: Pre-analytical hematology specimen rejection in the present setting was predominantly attributable to clotting, highlighting specimen collection, adequate anticoagulation, tube filling, and immediate post-collection handling as priority areas for quality improvement. Regular competency-based training, adherence to standardized phlebotomy procedures, department-specific feedback, and continuous monitoring of rejection indicators may help reduce preventable specimen rejection and improve laboratory quality and patient safety.

Keywords: Pre-analytical errors; specimen rejection; hematology; clotted specimen; quality indicators; laboratory quality management.

INTRODUCTION

Laboratory investigations are integral to clinical diagnosis, therapeutic decision-making, disease monitoring, and assessment of prognosis; consequently, the reliability of laboratory results is a fundamental component of patient safety. The total testing process is conventionally divided into pre-analytical, analytical, and post-analytical phases. The pre-analytical phase encompasses the processes occurring before actual analysis, including test requesting, patient preparation and identification, specimen collection, selection of an appropriate collection tube and anticoagulant, labeling, transportation, storage, processing, and preparation of the specimen for analysis. Despite substantial improvements in analytical accuracy through automation, internal quality control, and external quality assessment, the pre-analytical phase remains particularly vulnerable because many of its activities involve manual procedures and interactions between laboratory and non-laboratory personnel. Unsuitable specimens arising from hemolysis, clotting, inadequate volume, collection into an incorrect container, misidentification, contamination, or inappropriate transport may therefore compromise the integrity of the testing process and necessitate specimen rejection.[1,2] In a large laboratory study involving more than one million blood collection tubes, the overall specimen rejection rate was 0.65%, with insufficient volume, request-related errors, clotting, and hemolysis among the important causes of rejection.[3] Monitoring these events as pre-analytical quality indicators is therefore an important component of laboratory quality management.[4]

The consequences of pre-analytical errors are especially relevant in hematology because the cellular composition and coagulation characteristics of whole blood are highly dependent on appropriate specimen collection and anticoagulation. For routine hematological investigations, blood must be adequately mixed with the prescribed anticoagulant immediately after collection. Inadequate mixing or delayed transfer of blood into an anticoagulant-containing tube can permit fibrin formation and clotting, potentially entrapping platelets and other cellular components and making the specimen unsuitable for reliable cell counting. Conversely, inappropriate blood volume may alter the blood-to-anticoagulant ratio and is particularly important in sodium citrate specimens used for coagulation testing. Hemolysis may result from traumatic venipuncture, inappropriate collection or transfer techniques, vigorous manipulation, or unsuitable transportation and can interfere with the reliability of laboratory measurements. Other preventable non-conformities include incorrect patient or specimen identification, inappropriate containers, specimen leakage, contamination, and delays in transport or processing.[1,2-5] Evidence from hematology laboratories demonstrates the magnitude of these problems: Alshaghdali et al. evaluated 95,002 hematology specimens and identified pre-analytical errors in 9.3%, with clotted specimens (3.6% of all specimens) among the most frequent abnormalities.[6] Similarly, an Indian study of 26,638 specimens demonstrated that use of an evacuated blood collection system produced approximately 100-fold and 200-fold reductions in hemolysis and insufficient specimen quantity, respectively, compared with open needle-and-syringe collection, illustrating the potentially preventable nature of many pre-analytical errors.[6,7]

Specimen rejection is necessary when pre-analytical non-conformities may jeopardize result validity; however, rejection itself has important consequences, including repeat phlebotomy, patient discomfort, additional consumables and staff workload, delayed turnaround time, and possible delays in clinical decision-making. Importantly, rejection patterns are not uniform across institutions. A hematology study from a Sri Lankan teaching hospital reported an overall rejection rate of 3.3%, with clotting as the leading cause and PT/INR specimens showing the highest rejection rate,[8] whereas other laboratory studies have reported hemolysis or insufficient specimen volume as predominant causes.[3,9] This variability reflects differences in patient populations, collection practices, clinical locations, staff training, transportation systems, and institutional rejection criteria and highlights the need for laboratories to generate their own quality-indicator data rather than relying exclusively on external benchmarks. Systematic evaluation of the frequency, causes, and clinical distribution of rejected hematology specimens can identify high-risk processes and provide an objective basis for targeted corrective and preventive measures. Therefore, the present study was undertaken to evaluate pre-analytical hematology specimen rejection rates, characterize the major causes and distribution of rejected specimens, and assess associated factors in the clinical laboratory of a tertiary care teaching hospital, with the broader objective of identifying opportunities for improvement in pre-analytical quality and patient safety.

MATERIALS AND METHODS

This prospective, observational, laboratory-based cross-sectional study was conducted in the Department of Pathology at Dr Rajendra Gode Medical College and Hospital Amravati over a period of four months from 1 March 2026 to 30 June 2026. All hematology specimens received in the clinical laboratory during this period for routine investigations were included for evaluation. These comprised samples for complete blood count (CBC), peripheral blood smear examination, erythrocyte sedimentation rate (ESR), blood grouping, sickling test, and coagulation profile including prothrombin time/international normalized ratio (PT/INR) and

activated partial thromboplastin time (APTT). Specimens received from inpatient wards, outpatient departments, and intensive/critical care units were assessed according to the laboratory's predefined specimen acceptance and rejection criteria. and patient confidentiality was ensured by anonymization of all data.

Each specimen was evaluated at the time of receipt in the laboratory for compliance with standard pre-analytical quality requirements as per institutional standard operating procedures. Specimens deemed unsuitable for analysis due to pre-analytical errors were rejected and documented in the laboratory rejection register. The rejection criteria included clotted specimens, hemolyzed samples, insufficient specimen volume, incorrect blood-to-anticoagulant ratio, improper or incomplete labeling, use of inappropriate collection containers, specimen leakage, delayed or improper transport, and other documented pre-analytical non-conformities. Analytical and post-analytical errors were excluded from the study. Data were collected prospectively using a structured proforma and laboratory records, capturing variables such as patient demographics, type of patient (inpatient/outpatient/ICU), requesting department, type of investigation, specimen type, reason for rejection, and repeat specimen status where available.

The primary outcome measure was the overall pre-analytical hematology specimen rejection rate, calculated as the proportion of rejected specimens relative to the total number of hematology specimens received during the study period, expressed as a percentage. Secondary outcome measures included the distribution of rejection causes and their association with patient category, clinical department, and type of investigation requested. Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0. Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation or median with interquartile range, as appropriate. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test, as applicable. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1: Month-wise hematology workload and specimen rejection rate

Month	Total hematology workload, n	Rejected specimens, n	Rejection rate (%)
March 2026	2,088	46	2.20
April 2026	2,642	36	1.36
May 2026	2,923	22	0.75
June 2026	3,194	12	0.38
Total	10,847	116	1.07

During the predefined study period from 1 March to 30 June 2026, a total of 116 rejected hematology specimens were identified. The corresponding hematology workload recorded for March–June 2026 was 10,847, giving an overall rejection proportion of 1.07%. Month-wise, the highest rejection proportion was observed in March (2.20%), followed by April (1.36%), May (0.75%), and June (0.38%) [Table 1].

Table 2: Characteristics of rejected hematology specimens (n = 116)

Characteristic	Category	n	%
Age group	≤17 years	1	0.9
	18–39 years	27	23.3
	40–59 years	33	28.4
	≥60 years	26	22.4
	Not recorded	29	25.0
Sex	Male	56	48.3
	Female	38	32.8
	Not recorded	22	19.0
Patient category	Inpatient	94	81.0
	Outpatient	9	7.8
	Health camp	6	5.2
	Not recorded	7	6.0
Specimen/container type	EDTA tube	64	55.2
	Sodium citrate tube	45	38.8
	EDTA + sodium citrate	1	0.9
	Not recorded	6	5.2

Among the 116 rejected specimens, age was documented in 87 cases. The median age was 48 years (interquartile range, 34–64.5 years), with the largest proportion belonging to the 40–59-year age group (28.4%), followed by 18–39 years (23.3%) and ≥60 years (22.4%). Male patients constituted 48.3% of all rejected specimens and females 32.8%, whereas sex was not documented in 19.0%. Most rejected specimens originated from the inpatient setting (81.0%), while 7.8% were from the outpatient department and 5.2% from health-camp collections. EDTA specimens accounted for the largest proportion of rejected samples (55.2%), followed by sodium-citrate specimens (38.8%) [Table 2].

Table 3: Distribution of documented causes of hematology specimen rejection

Cause of rejection	n	%
Clotted specimen	97	83.6
Hemolyzed specimen	4	3.4
Insufficient specimen quantity	2	1.7
Other/uncategorized documented rejection reason	13	11.2
Total	116	100.0

Clotting was the predominant documented cause of specimen rejection, accounting for 97 of 116 rejected specimens (83.6%). Hemolysis accounted for 4 cases (3.4%) and insufficient specimen quantity for 2 cases (1.7%). Thirteen specimens (11.2%) were recorded with other or result-related rejection descriptions, including platelet-related, leukocyte-related, or unusually high-value flags that could not be reliably reclassified into a specific pre-analytical category from the available records [Table 3].

Table 4: Distribution of rejection causes according to requesting clinical department

Clinical department/area	Clotted	Hemolyzed	Insufficient quantity	Other/uncategorized	Total, n (%)
Orthopedics	28	1	0	0	29 (25.0)
Critical care units*	21	1	0	5	27 (23.3)
Medicine	16	2	0	7	25 (21.6)
Surgery	6	0	1	1	8 (6.9)
ENT	4	0	0	0	4 (3.4)
Acute medical care	3	0	1	0	4 (3.4)
Ophthalmology	2	0	0	0	2 (1.7)
Obstetrics and Gynecology	2	0	0	0	2 (1.7)
Pediatrics	1	0	0	0	1 (0.9)
MSW	1	0	0	0	1 (0.9)
Department not recorded	13	0	0	0	13 (11.2)
Total	97	4	2	13	116 (100.0)

The distribution of rejected specimens according to requesting clinical area showed that Orthopedics contributed the highest number of rejected specimens (25.0%), followed by critical care units (23.3%) and Medicine (21.6%). Surgery accounted for 6.9%, while smaller proportions were received from ENT, acute medical care, Ophthalmology, Obstetrics and Gynecology, Pediatrics, and MSW-related services. Department information was unavailable in 11.2% of cases. Clotted specimens predominated across nearly all clinical areas, accounting for 28 of 29 rejected Orthopedics specimens, 21 of 27 specimens from critical care units, and 16 of 25 specimens from Medicine [Table 4].

Table 5: Distribution of rejection causes according to investigation requested

Investigation	Clotted	Hemolyzed	Insufficient quantity	Other/uncategorized	Total, n (%)
CBC	43	0	0	12	55 (47.4)
PT/INR	39	4	1	1	45 (38.8)
CBC + blood grouping	5	0	0	0	5 (4.3)
CBC + peripheral smear	3	0	0	0	3 (2.6)
CBC + blood grouping + ESR	3	0	0	0	3 (2.6)
ESR	1	0	1	0	2 (1.7)
CBC + ESR	1	0	0	0	1 (0.9)
CBC + PT/INR	1	0	0	0	1 (0.9)
Sickling test	1	0	0	0	1 (0.9)
Total	97	4	2	13	116 (100.0)

With respect to investigations requested, CBC accounted for 55 rejected specimens (47.4%), followed by PT/INR with 45 specimens (38.8%). The remaining rejected specimens were associated with combined CBC-based requests, ESR, sickling testing, and other hematology investigations. Clotting was the predominant cause in both CBC and PT/INR specimens, occurring in 43 and 39 rejected specimens, respectively. All four hemolyzed specimens were associated with PT/INR requests [Table 5].

DISCUSSION

Pre-analytical specimen rejection is an important indicator of laboratory quality because it reflects deficiencies occurring before analysis and identifies processes in which corrective interventions may improve both analytical reliability and patient safety. In the present study, 116 hematology specimens were rejected during the four-month study period, corresponding to an observed rejection proportion of 1.07% against the recorded hematology workload. Clotting was overwhelmingly the predominant documented reason for rejection (83.6%), whereas hemolysis (3.4%) and insufficient specimen quantity (1.7%) were relatively uncommon. Most rejected specimens originated from inpatient services (81.0%), and Orthopedics, critical care units, and Medicine together accounted for approximately 70% of all rejected specimens. CBC (47.4%) and PT/INR (38.8%) constituted the investigations most frequently represented among rejected specimens. Collectively, these findings indicate that the principal

pre-analytical vulnerability in the present laboratory was related to specimen collection and anticoagulation, particularly the occurrence of clotted blood specimens.

The observed rejection proportion of 1.07% is lower than the pooled estimate reported by Getawa et al. in a systematic review and meta-analysis of 26 studies comprising 16,118,499 blood specimen requests, in which the pooled rejection prevalence was 1.99% (95% CI, 1.73–2.25%); the pooled estimate was higher in Asian studies at 2.82%.[10] Comparable hematology-specific studies have also reported variable rates. Iqbal et al. evaluated 67,892 hematology specimens at a tertiary-care center and reported rejection of 886 specimens (1.3%), a value relatively close to that observed in the present study.[11] In contrast, Dilshika et al. reported an overall hematology specimen rejection rate of 3.3% at a teaching hospital in Sri Lanka,[8] while Noor et al. analyzed 231,008 CBC specimens and documented 11,897 rejected specimens (5.15%).[12] Alshaghdali et al., in a three-year assessment involving 95,002 hematology specimens, identified 8,852 specimens (9.3%) with pre-analytical errors.[6] Such variability between institutions is expected because studies differ in the spectrum of investigations included, definitions of rejection and pre-analytical error, patient populations, collection systems, personnel responsible for phlebotomy, and whether all pre-analytical non-conformities or only specimens actually rejected by the laboratory are counted.

The most striking finding of the present study was the predominance of clotted specimens, which constituted 83.6% of all documented rejections. This proportion is considerably higher than the pooled estimate reported by Getawa et al., in which clotting represented 32.23% (95% CI, 21.02–43.43%) of rejected blood specimens, followed by hemolysis (22.87%) and insufficient volume (22.81%).[10] Nevertheless, the predominance of clotting has been demonstrated in several hematology-oriented studies. Lay et al. analyzed 971,780 biological specimens, of which 26,070 (2.7%) were rejected; clotted specimens accounted for 55.8% of all rejections, followed by inadequate volume at 29.3%.[13] Dilshika et al. similarly identified clotting as the major cause of hematology specimen rejection.[8] Furthermore, Alshaghdali et al. reported clotted specimens in 3.6% of all 95,002 hematology specimens, making clotting one of the two most frequent pre-analytical quality problems in their laboratory.[6] Thus, although the proportion in the present study is particularly high, the pattern is consistent with the recognized susceptibility of hematology specimens to clot-related pre-analytical non-conformities.

The predominance of clotting is biologically and procedurally plausible. Whole-blood hematology specimens require prompt and adequate contact between the collected blood and anticoagulant. Failure to achieve appropriate anticoagulation may permit fibrin formation and micro- or macroclot development, potentially entrapping platelets and leukocytes and rendering cell counts unreliable. Tube mixing is therefore an important component of specimen handling. Lippi and Plebani noted that conventional recommendations generally advocate gentle inversion of additive-containing blood tubes immediately following collection and discussed evidence that prolonged failure to mix anticoagulated blood may permit thrombin generation.[14] The markedly high proportion of clotted specimens in our study therefore suggests potential opportunities for improvement in blood collection, immediate post-collection handling, tube filling, and staff adherence to standardized phlebotomy procedures. Importantly, an Indian investigation involving 26,638 specimens demonstrated that evacuated blood collection markedly reduced several pre-analytical quality defects compared with open needle-and-syringe collection, including approximately 100-fold lower hemolysis and 200-fold lower insufficient-volume events, supporting the principle that collection practices can substantially influence specimen quality.[7]

Hemolysis constituted only 3.4% of rejected specimens in the present study, substantially lower than its contribution in several published series. In the meta-analysis by Getawa et al., hemolysis represented 22.87% of rejected blood specimens.[10] Noor et al. reported hemolyzed specimens in 15.13% of rejected CBC samples,[12] whereas a recent hospital-based investigation by Jeraiby involving 321,465 specimens found 7,223 (2.25%) rejected overall, with hemolysis (45.3%) and clotting (33.6%) dominating the documented errors.[15] Importantly, the distribution differed by laboratory section: hematology was particularly characterized by clotted specimens and insufficient samples, whereas hemolysis predominated in biochemistry.[15] These differences emphasize that rejection profiles are strongly dependent on the type of laboratory testing under evaluation. The relatively low proportion of hemolysis in our study may therefore partly reflect its hematology-focused design and the dominance of clot-related non-conformities.

Insufficient specimen quantity represented only 1.7% of rejected specimens in our study, which contrasts substantially with several reports. Iqbal et al. found insufficient specimens to be the most frequent pre-analytical error, constituting 54.17% of 886 rejected hematology specimens.[11] Atay et al., evaluating 1,035,743 blood collection tubes, reported an overall rejection rate of 0.65% and found insufficient specimen volume to constitute 34% of rejection causes; the coagulation group had a particularly high rejection rate of 2.28%, with insufficient-volume errors accounting for 1.38%.[3] Similarly, Lay et al. reported inadequate volume in 29.3% of rejected specimens.[13] These marked differences illustrate that individual laboratories may have distinctly different pre-analytical failure patterns. In our

setting, clotting appears to be a substantially greater quality concern than underfilling, although the relatively small number of rejected specimens and reliance on the documented rejection reason should be considered when interpreting these differences.

The distribution of rejected specimens according to patient location also provides useful information for targeted quality improvement. In the present study, 81.0% of rejected specimens originated from inpatient services. Jeraiby likewise reported that 76.2% of rejected specimens originated from inpatient departments.[15] Lay et al. found that 54.3% of clotted specimens were received from adult inpatient services and another 26.8% from pediatric inpatient services, with inadequate-volume problems particularly evident in premature, neonatal, intensive-care, and oncology settings.[13] Rooper et al. similarly observed that 85% of rejected specimens originated from the emergency department and eight inpatient care areas and reported that registered nurses collected approximately 85% of rejected specimens, compared with only 4% collected by laboratory phlebotomy personnel.[16] These findings support the concept that collection environment and personnel may substantially influence pre-analytical quality. Inpatients, especially those requiring intensive or repeated monitoring, frequently undergo repeated venipuncture and may have difficult vascular access, intravenous lines, or urgent sampling requirements, potentially increasing opportunities for collection-related errors.

Within the present dataset, Orthopedics (25.0%), critical care units (23.3%), and Medicine (21.6%) contributed the largest proportions of rejected specimens. Clotting accounted for 21 of 27 rejected specimens from critical care units, while Medicine contained a broader distribution of documented rejection categories. However, these figures should be interpreted as the distribution of rejected specimens rather than department-specific rejection rates, because the total number of specimens submitted by each department was not available as a denominator. It would therefore be inappropriate to conclude that Orthopedics or critical care units had a greater risk of specimen rejection solely from these counts. Nevertheless, the concentration of rejection events within these clinical areas identifies them as practical targets for audit, staff education, and prospective quality monitoring. This approach is supported by evidence that rejection patterns differ substantially among patient-care areas and that interventions should be directed toward locally identified sources of error.[13,16]

Regarding the investigations requested, CBC accounted for 47.4% and PT/INR for 38.8% of rejected specimens. Clotting predominated in both groups, accounting for 43 of 55 rejected CBC specimens and 39 of 45 rejected PT/INR specimens. Dilshika et al. similarly reported that specimens submitted for PT/INR had the highest rejection rate in their hematology laboratory.[8] Coagulation testing is particularly sensitive to pre-analytical conditions because both clot formation and inappropriate filling of sodium-citrate tubes can compromise specimen suitability. Atay et al. found that coagulation specimens had a 2.28% rejection rate, significantly higher than other investigated test groups.[3] In our study, however, the absolute number of rejected CBC and PT/INR specimens should not be interpreted as investigation-specific rejection rates unless the corresponding number of specimens submitted for each individual investigation is used as the denominator.

An additional finding was the progressive decrease in the observed monthly rejection proportion, from 2.20% in March to 1.36% in April, 0.75% in May, and 0.38% in June. This pattern is noteworthy, but the present observational design does not permit attribution of the decline to a specific intervention or causal mechanism. Nevertheless, longitudinal monitoring of pre-analytical quality indicators can itself support quality improvement. Alshaghdali et al. observed a reduction in overall pre-analytical error frequency from 11.6% to 6.5% during their three-year monitoring period.[6] Similarly, quality-indicator surveillance allows laboratories to identify recurrent non-conformities, establish baselines, assess corrective and preventive actions, and monitor whether improvements are sustained. Future prospective surveillance at our institution would be useful to determine whether the downward monthly pattern persists beyond the four-month observation period.

Interpretation: Overall, the present study demonstrates that pre-analytical hematology specimen rejection in this tertiary-care laboratory was characterized predominantly by clot-related non-conformity, with clotting accounting for more than four-fifths of all rejected specimens. The observed rejection proportion of 1.07% was lower than the pooled prevalence of 1.99% reported in the systematic review by Getawa et al.[10] and lower than several hematology-specific reports, although direct comparisons must account for differences in study definitions and denominators. The concentration of rejected specimens among inpatient services and the predominance of clotting in CBC and PT/INR specimens indicate that specimen collection, adequate anticoagulation, appropriate tube filling, and immediate post-collection handling should be priority areas for quality improvement. Periodic competency-based training of personnel involved in phlebotomy, reinforcement of standardized collection and tube-mixing procedures, department-wise feedback, and continuous monitoring of specimen rejection as a quality indicator may help reduce avoidable repeat collections and improve the overall quality of hematology laboratory services.

CONCLUSION

The present study demonstrated an overall pre-analytical hematology specimen rejection proportion

of 1.07%, with clotted specimens (83.6%) constituting the predominant cause of rejection. Most rejected specimens originated from inpatient services, particularly Orthopedics, critical care units, and Medicine, while CBC and PT/INR were the most frequently represented investigations. These findings highlight specimen collection, adequate anticoagulation, appropriate tube filling, and immediate post-collection handling as important targets for quality improvement. Regular competency-based training of personnel involved in phlebotomy, strict adherence to standard operating procedures, department-specific feedback, and continuous monitoring of specimen rejection as a quality indicator are recommended to minimize preventable errors and repeat blood collection. The findings should, however, be interpreted considering the single-center design, relatively short four-month study period, incomplete documentation of some variables, and absence of department-specific specimen denominators, which precluded calculation of department-specific rejection rates. Larger multicenter studies with longer surveillance periods and standardized documentation are recommended to establish robust benchmarks and evaluate the effectiveness of targeted corrective and preventive interventions.

Limitations: The present study has certain limitations. First, it was a single-center study conducted over a relatively short four-month period, which may limit the generalizability of the findings and may not account for seasonal or long-term variations in specimen rejection patterns. Second, although the overall laboratory workload was available, rejection documentation, appropriate subgroup denominators, and assessment of pre- and post-intervention quality indicators would provide more robust evidence.

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