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Assessing Pre-Analytical Error Prevalence and Associated Costs: Findings from a Multinational Survey and Literature Review

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Background

Errors in the pre-analytical phase of the total testing process account for approximately 60–70% of all laboratory diagnostic errors, making them the most common quality failures in the laboratory testing process. The prevalence and costs associated with the errors, including mistakes in patient identification, inappropriate specimen collection, and improper sample handling, remain uncertain.[1] Many perceive that laboratory performance depends solely on the analytical phase, but this view is inaccurate. Total quality in the laboratory means that every activity throughout the entire testing process is performed correctly. The laboratory testing process consists of three phases: pre-analytical, analytical, and post-analytical. Together, these phases make up what is known as the total testing process (TTP). Errors in any of these phases can significantly impact accurate diagnoses and overall patient health.

In recent years, laboratories have experienced significant automation in the analytical phase, shifting from mainly manual processes to advanced integrated systems that utilize robotics and sophisticated analyzers. These systems can perform multiple tests on large sample volumes with minimal human intervention.[2] As a result of this automation, errors in the analytical phase have notably decreased. However, a considerable number of errors still occur during the pre-analytical phase, which adversely affects the overall accuracy of test results. To address this issue, artificial intelligence (AI) tools, such as machine learning (ML) algorithms, have been proposed to improve the detection of pre-analytical errors (PAEs). Although the presence of PAEs is documented in the literature, the full extent of their prevalence and their impact on hospitals, laboratories, and patients is not completely understood.

The pre-analytical phase consists of a series of processes that begin when a physician requests laboratory tests and continues until the sample is prepared for testing. These processes include patient preparation, sample collection, sample transportation, sample preparation, and sample storage. Control over this phase is challenging because most activities occur outside of the laboratory environment. Due to its complexity and variability, standardizing the pre-analytical phase has proven to be difficult.[3] Consequently, it is not surprising that the majority of errors in the total testing process (TTP) occur during this phase. According to the literature, it is estimated that about 70% of all laboratory testing errors happen during the pre-analytical phase, with most of these errors originating during the sample collection process.[4,5]

Table 1. Frequency of Pre-Analytical Error Types

Type of Error	Frequency (%)*
Sample Hemolyzed	10–77%
Sample Clotted	14–52%
Insufficient Quantity	3–26%
Inappropriate Container	2–12%
Incorrect or Missing Information	0.5–10%
IV Contamination	0.05–2%
Icterus	0.05–1%
Lipemia	0.01–0.5%

**Frequency = Samples rejected due to a pre-analytical error type/total samples rejected due to pre-analytical errors.*[6-15]

PAE prevalence varies significantly across studies. Lippi et al. (2006) reported rejection rates of 0.37% (outpatient) and 0.82% (inpatient).[6] In contrast, Begum (2014) found higher rates of 3.69% and 6.61% respectively.[9] Global differences also exist. Getawa et al. (2023) noted a 0.55% rejection rate in the Americas and 3.19% in Southeast Asia.[14]

Hemolysis and clotting together account for over 70% of all PAEs, followed by insufficient quantity, incorrect containers, and missing information—all of which contribute another 25%.[6-15] Icterus and lipemia, though less common, also impact test results. While often patient-related rather than procedural, they are monitored for quality control.

The most common PAE types —including hemolysis, clotting, insufficient sample quantity, or use of inappropriate containers— are frequently caused by improper sample collection. Unlike many laboratory-controlled processes, sample collection typically occurs outside the laboratory and involves multiple healthcare providers who operate beyond the laboratory's direct oversight.

Improper collection—often due to inadequate training, disregard for protocols, or workload pressures—is a leading cause of these errors.[12,16]

Methods

We conducted both primary and secondary research on the prevalence and costs of pre-analytical errors (PAEs). Initially, we conducted a survey during September–October 2024 among a multinational group of academic laboratory directors (MD, PhD, or MD/PhD) in North America, Asia, and Africa, focusing on their insights regarding the prevalence of PAEs in their local setting.

Subsequently, based on the insights from this survey, we developed search terms to identify current evidence on the prevalence of PAEs and their associated direct and indirect costs. To do so, we screened MEDLINE (via PubMed) and Google Scholar for peer-reviewed studies, published in English between 2000 and 2024. The direct costs of PAEs included personnel time and resources used for resampling, retesting, and investigating/reporting PAEs. Indirect costs were reported to arise from treating safety failures and/or extended hospital stays due to incorrect or delayed diagnosis or treatment. Based on these findings, we then conducted a narrative review

The search strategy included combinations of keywords such as "pre-analytical errors," "laboratory testing," "specimen rejection," "laboratory quality," "economic impact," "cost," and "healthcare costs." Inclusion criteria were:

1. original studies reporting data on the prevalence of PAEs;
2. studies quantifying the direct or indirect costs of PAEs; and
3. studies focused on hospital, outpatient, or clinical laboratory settings.

Editorials, opinion pieces, non-English articles, and studies without clear data on PAE prevalence or associated costs were excluded.

Titles and abstracts of 744 records were initially screened. After applying the inclusion and exclusion criteria, 21 articles were selected for full-text review and inclusion in this analysis. Of these, 13 provided prevalence data on PAEs, and 8 provided economic data related to PAEs. Data extracted from the studies included type and frequency of PAEs, reported rejection rates, types of tests or sample settings involved, direct and indirect cost estimates, and any related assumptions or modeling methods used to quantify economic burden

Results

Thirteen laboratory directors responded to our survey. 69% (9/13) reported to measure the frequency of PAEs with a prevalence of 3% or less of the total samples. In contrast, among those 31% (4/13) who did not report measuring the frequency of PAEs, 50% (2/4) estimated their frequency at 3% or higher and 50% (2/4) expressed uncertainty.

In the subsequent literature research, a total of 744 abstracts/titles were screened, resulting in the inclusion of 21 articles for detailed analysis. Thirteen of these studies focused on the prevalence of PAEs, and 8 studies examined the associated costs. The reported prevalence of PAEs varied, with sample rejection rates ranging from 0.37% to 6.61%. In clinical laboratories, the direct costs of PAEs may constitute up to 10% of the annual testing budget. Furthermore, when considering both direct and indirect costs, PAEs can account for 0.2% to 1.2% of total hospital operating costs, compared to 2–3% of hospital operating costs for overall laboratory costs.

Until recently, there has been limited awareness of the financial costs associated with PAEs. Depending on when PAEs are identified, they can lead to various significant expenses. These costs may include re-sampling, re-testing, and additional time spent by personnel on tasks such as inspecting samples, verifying test results, and investigating and reporting errors. While several studies have estimated the financial impact of PAEs on laboratories and hospitals, there is still a notable lack of systematic research focused on the costs associated with these errors.[17]

The direct costs associated with PAEs related to specific laboratory tests are significant. Burrows (2012) reported three PAEs per day in inpatient CBC testing at Sunnybrook, Canada. Depending on the need for retesting, the cost per PAE ranged from $47.94 to $54.03 (2024-adjusted), totaling over $283,000 annually for all PAEs.[18] Kulkarni et al. (2020) found similar cost burdens in INR testing—about $40.69 per PAE, totaling ~$54,737 annually.[17]

Cadamuro et al. (2015) estimated annual costs related to hemolysis alone at €122,077 ($179,314 USD 2024).[19] Eker (2022) and Hjelmgren (2023) calculated total PAE costs at $103,427 (Turkey)[20] and $114,754 (Sweden)[21], respectively.

Furthermore, some studies encompass an even broader scope by considering both direct and indirect costs associated with PAEs. Green (2013) estimated the average North American PAE cost at $285 per incident, totaling $1.64 million annually for a 650-bed hospital.[22]

PAEs have a direct effect on laboratory costs through personnel time and effort. Personnel time accounts for 95–100% of direct PAE costs, with investigation and documentation as the most time-consuming. Burrows estimated 35 minutes per investigation, costing ~$31.20 per error;[18] Kulkarni's analysis found similar results ($34.39 per error).[17] These costs continue to rise steadily, driven by increasing labor rates and persistent staffing shortages.

Conclusions

Our research suggests that prevalence and costs of PAEs vary considerably, depending on patient populations and laboratory settings. Nevertheless, PAEs impose a significant financial burden on healthcare budgets. Determining and benchmarking prevalence and costs of PAEs can help laboratories to detect inadequate sample quality more easily, improve the quality of laboratory testing process and patient care and reduce overall cost of care.

Pre-analytical errors create substantial clinical and financial burdens. They risk patient safety and diagnostic accuracy, often occurring in uncontrolled settings like sample collection. Despite automation reducing analytical errors, PAEs remain a dominant challenge.

Personnel-related costs significantly exceed material expenses, primarily due to time spent on investigation and reporting. As labor shortages and wages increase, reducing time spent on PAEs could yield significant savings. Investments in training, automation, and AI-based quality tools may help mitigate these costs and improve diagnostic quality.

References

1. Rohr UP, Binder C, Dieterle T, Giusti F, Messina CG, Toerien E, Moch H, Schäfer HH. The value of in vitro diagnostic testing in medical practice: a status report. PloS one. 2016 Mar 4;11(3):e0149856.
2. Armbruster DA, Overcash DR, Reyes J. Clinical chemistry laboratory automation in the 21st century-amat victoria curam (Victory loves careful preparation). The Clinical Biochemist Reviews. 2014 Aug;35(3):143.
3. Lippi G, Becan-McBride K, Behúlová D, Bowen RA, Church S, Delanghe J, Grankvist K, Kitchen S, Nybo M, Nauck M, Nikolac N. Preanalytical quality improvement: in quality we trust. Clinical Chemistry and Laboratory Medicine (CCLM). 2013 Jan 1;51(1):229-41.
4. Plebani M. Diagnostic errors and laboratory medicine–causes and strategies. Ejifcc. 2015 Jan;26(1):7.
5. Carraro P, Plebani M. Errors in a stat laboratory: types and frequencies 10 years later. Clinical chemistry. 2007 Jul 1;53(7):1338-42.
6. Lippi G, Bassi A, Brocco G, Montagnana M, Salvagno GL, Guidi GC. Preanalytic error tracking in a laboratory medicine department: results of a 1-year experience. Clinical chemistry. 2006 Jul 1;52(7):1442-3.
7. Salvagno GL, Lippi G, Bassi A, Poli G, Guidi GC. Prevalence and type of pre‐analytical problems for inpatients samples in coagulation laboratory. Journal of evaluation in clinical practice. 2008 Apr;14(2):351-3.
8. Chawla R, Goswami B, Tayal D, Mallika V. Identification of the types of preanalytical errors in the clinical chemistry laboratory: 1-year study at GB Pant Hospital. Laboratory medicine. 2010 Feb 1;41(2):89-92.
9. Begum F. A study of pre-analytical errors in a hospital based clinical biochemistry laboratory and formulation of measures for correction. Age. 2014;758:6-18.
10. Zaini R, Dahlawi HA, Siddiqi A. Identification of the types and frequencies of pre-analytical errors in the clinical biochemistry laboratory: 1-year study at Hera'a General Hospital. Archiv Med. 2016;8(1).
11. Rooper L, Carter J, Hargrove J, Hoffmann S, Riedel S. Targeting rejection: analysis of specimen acceptability and rejection, and framework for identifying interventions in a single tertiary healthcare facility. Journal of Clinical Laboratory Analysis. 2017 May;31(3):e22060.
12. Alavi N, Khan SH, Saadia A, Naeem T. Challenges in preanalytical phase of laboratory medicine: rate of blood sample nonconformity in a tertiary care hospital. Ejifcc. 2020 Mar;31(1):21.
13. Sonmez C, Yıldız U, Akkaya N, Taneli F. Preanalytical phase errors: experience of a central laboratory. Cureus. 2020 Mar;12(3).
14. Getawa S, Aynalem M, Melku M, Adane T. Blood specimen rejection rate in clinical laboratory: A systematic review and meta-analysis. Practical Laboratory Medicine. 2023 Jan 1;33:e00303.
15. Atay A, Demir L, Cuhadar S, Saglam G, Unal H, Aksun S, Arslan B, Ozkan A, Sutcu R. Clinical biochemistry laboratory rejection rates due to various types of preanalytical errors. Biochemia medica. 2014 Oct 15;24(3):376-82.
16. Vermeersch P, Frans G, von Meyer A, Costelloe S, Lippi G, Simundic AM. How to meet ISO15189: 2012 pre-analytical requirements in clinical laboratories? A consensus document by the EFLM WG-PRE. Clinical Chemistry and Laboratory Medicine (CCLM). 2021 May 1;59(6):1047-61.
17. Kulkarni S, Piraino D, Strauss R, Proctor E, Waldman S, King J, Selby R. The cost of pre-analytical errors in INR testing at a tertiary-care hospital laboratory: potential for significant cost savings. Laboratory Medicine. 2020 May 6;51(3):320-4.
18. Burrows JM. The Cost of Preanalytical Errors in the Context of Inpatient Complete Blood Count Testing (Doctoral dissertation). 2012.
19. Cadamuro J, Wiedemann H, Mrazek C, Felder TK, Oberkofler H, Fiedler GM, Haschke-Becher E. The economic burden of hemolysis. Clinical Chemistry and Laboratory Medicine (CCLM). 2015 Oct 1;53(11):e285-8.
20. Eker P. Direct cost analysis for 32,783 samples with preanalytical phase errors. Northern Clinics of Istanbul. 2022 Jul 1;9(4).
21. Hjelmgren H, Heintz E, Ygge BM, Andersson N, Nordlund B. Direct costs of blood drawings with pre-analytical errors in tertiary paediatric hospital care. Plos one. 2023 Aug 25;18(8):e0290636.
22. Green SF. The cost of poor blood specimen quality and errors in preanalytical processes. Clinical biochemistry. 2013 Sep 1;46(13-14):1175-9.

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