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REVIEW

The Contribution of Education to the Correction of Preanalytical Errors in Laboratory Testing: A Systematic Review

Aporte de la educación en la corrección de errores preanalíticos en un examen de laboratorio: una revisión sistemática

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ABSTRACT

Introduction: laboratory medicine generates clinical information by analyzing various analytes in body fluids. This process requires trained personnel capable of developing strategies to prevent errors that could compromise patient safety. Recent studies highlight the importance of training and the implementation of protocols to reduce these errors.
Objective: to identify available evidence on the contribution of education to correcting preanalytical errors in clinical laboratory testing.
Method: a systematic review was conducted using Google Scholar and PubMed, including articles in English, Spanish, and Portuguese published between 2020 and 2024. Only peer-reviewed journal articles were considered.
Results: three main thematic categories were identified: Impact of Training in Laboratory Settings, Educational Interventions on Preanalytical Errors, and Methodologies to Reduce Preanalytical Errors Linked to Education.
Conclusion: reducing preanalytical errors in the laboratory depends on continuous training and protocol adherence. Initial and ongoing education is key to improving sample quality and patient safety.

Keywords: Blood Chemical Analysis; Quality of Health Care; Pre-Analytical Phase; Laboratory Test.

RESUMEN

Introducción: La medicina del laboratorio genera información clínica mediante el análisis de diversos analitos en fluidos. Este proceso requiere personal capacitado que desarrolle estrategias para prevenir errores que podrían comprometer la seguridad del paciente.
Estudios recientes destacan la importancia de la capacitación e implementación de protocolos para reducir estos errores.
Objetivo: conocer la evidencia disponible sobre el aporte de la educación en la corrección de errores preanalítico en exámenes de laboratorio clínico
Método: se realizó una revisión integrativa en Google Scholar y Pubmed, incluyendo artículos en inglés, español y portugués publicados entre 2020 y 2024. Solo se consideraron artículos de revistas con revisión por pares.

Resultado: se identificaron tres grandes categorías o temas: Impacto de la Capacitación en Entornos de Laboratorio, Intervenciones Educativas sobre Errores Preanalíticos y Metodologías para Reducir los Errores Preanalíticos Vinculados a la Educación.
Conclusión: la reducción de errores preanalíticos en el laboratorio depende de una formación continua y la adherencia a protocolos. La educación, tanto inicial como continua, es clave para mejorar la calidad de las muestras y la seguridad del paciente.

Palabras claves: Análisis Químico de la Sangre; Calidad de la Atención de Salud; Fase Preanalítica; Prueba de Laboratorio.

INTRODUCTION

Laboratory medicine is a discipline that generates clinical information by analyzing the concentration, composition, and structure of various biological fluids,[1] contributing to 70-80 % of medical diagnostic decisions. The laboratory analytical process is divided into three phases: pre-analytical, analytical, and post-analytical, with the pre-analytical phase being the most error-prone (75 %).[2]

With automation and quality indicators, the pre-analytical phase remains challenging due to a lack of standardization and adequate monitoring.[3] To improve, ISO 15189:2012 recommends the use of quality indicators at all stages of the analytical process.[4,5]

Laboratory errors can cause loss of confidence, medical non-compliance, unnecessary costs, anxiety, and discrediting of the contract laboratory.[6] Various organizations promote quality in the pre-analytical phase through education and consensus guidelines.[7]

Reducing pre-analytical errors involves raising awareness of their importance, researching and analyzing errors, and establishing education programs and standardizing procedures.[8] It is critical to recognize the challenges faced by laboratory professionals to ensure the necessary competencies throughout the laboratory process to improve the quality of results.[9]

METHOD

An integrative review was conducted, the aim of which was to gather facts to gain a better understanding of a phenomenon.[10] The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were used to ensure quality and transparency.[11]

The first phase was to develop the research question: What is the available evidence on the contribution of education in correcting pre-analytical errors in a laboratory examination?

The second phase was the collection of scientific evidence. The inclusion criteria were research articles related to the topic, published in English, Portuguese, and Spanish, full text, and open access within 5 years (2020 to 2024). Google Scholar and PubMed databases were used with the AND boolean. The keywords were: 'Pre-analytical phase,' "Laboratory," and 'Education,' applied in the title, abstract or full text.

The study selection process included a meticulous review to verify compliance with the inclusion criteria. Data collection of the selected reports was performed by two reviewers independently, following a standardized protocol, and in the third phase, two reviewers independently assessed the data.

The analysis included reduction, visualization, comparison, and synthesis of the results. Finally, the results were presented in 3 categories: Impact of Training in Laboratory Settings, Educational Interventions on Pre-analytical Errors, and Methodologies to Reduce Pre-analytical Errors Linked to Education.

A PRISMA flowchart was used to document the study selection process, showing the number of studies identified, included, and excluded and the reasons for exclusion. The overall objective was To ascertain the available evidence on the contribution of education in correcting pre-analytical errors in clinical laboratory examinations.

RESULTS

This integrative review identified 1,191 research studies in databases, 1,170 from Google Scholar and 21 from PubMed. Of these records, 49 articles were excluded due to duplication and 101 due to language. Subsequently, 1041 records were reviewed, of which 992 were excluded for being unrelated to the research topic. Finally, 49 articles were included in the final review (figure 1).

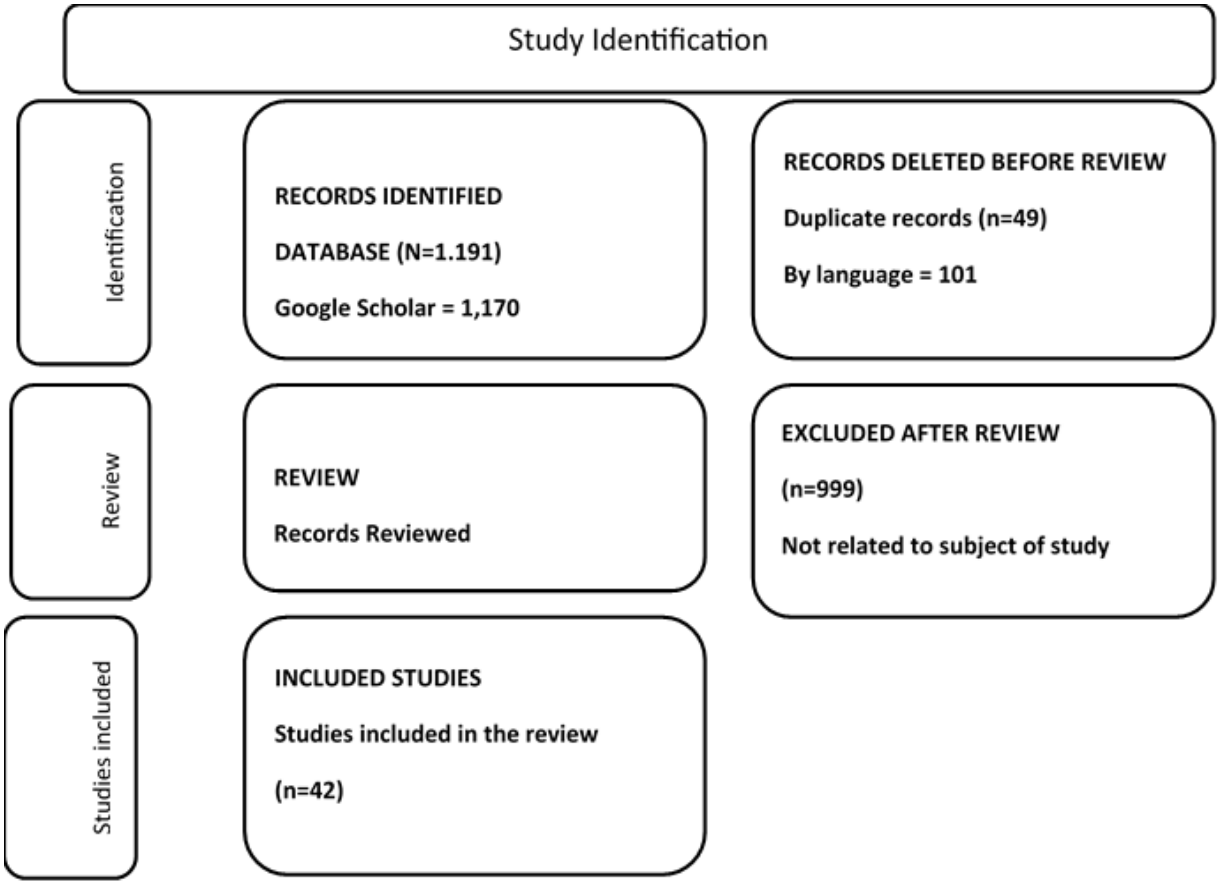

Figure 1. PRISMA flowchart: Summary of study selection process

Table 1. Characteristics of selected studies

Author	Country of origin	Year	Database	Objectives	Methodology
Alcantara, et al.	Saudi Arabia	2022	Google Scholar	Identify errors in the pre-analytical phase of testing in a clinical chemistry diagnostic laboratory.	Analysis of laboratory data
Alshaghdali	Saudi Arabia	2022	Pubmed	Review quality indicators	Quantitative. Retrospective review
Ballestero	Argentina	2021	Google Scholar	Describe factors influencing nursing organisation and management.	Descriptive study
Panjeta	Bosnia and Herzegovina	2022	Pubmed	Investigate frequency and types of errors during laboratory work.	Retrospective and descriptive study
Dos Santos	Brazil	2020	Google Scholar	To investigate phlebotomists' perception of interference in the pre-analytical phase..	questionnaire
Sawadogo	Burkina Faso	2022	Google Scholar	To assess the knowledge, attitudes and practices of health professionals in the pre-analytical phase in the haematology laboratory.	Cross-sectional study with self-administered questionnaire and direct observations.
Zaki	Egypt	2022	Google Scholar	To assess nurses' malpractices during blood collection	Knowledge assessment questionnaire and observational verification of practice
Elsayed	Egypt	2023	Google Scholar	To explore nurses' performance in preventing haemolysis during venous blood sampling.	Knowledge assessment questionnaire and observational verification of practice

Romero	Spain	2020	Google Scholar	Cost-error analysis of pre-analytical errors in two hospital laboratories	Statistical analysis
Degfe	Ethiopia	2023	Google Scholar	Identify extra-analytical errors and associated factors	Prospective study
Mesganaw	Ethiopia	2024	Google Scholar	Evaluate rejection rate and associated factors in submitted samples	Prospective cross-sectional study design
Toth	Hungary	2020	Google Scholar	Detecting pre-analytical errors in the laboratory	Statistical description
Gaur	India	2020	Google Scholar	Evaluate types and frequencies of pre-analytical errors in a diagnostic centre.	Prospective study
Mehndiratta	India	2021	Google Scholar	Identify using quality indicators, incidence of pre-analytical errors	Descriptive study in a clinical biochemistry laboratory
Aggarwal	India	2022	Google Scholar	Identify phlebotomy errors through direct observation of the interaction between laboratory professionals and patients.	Prospective study
Shaji R	India	2022	Google Scholar	Optimising blood culture collection in emergency departments	Prospective study
Dey S	India	2023	Google Scholar	To assess knowledge, attitude and practice of phlebotomy in nurses in a tertiary hospital.	Prospective study
Subhan	India	2023	Google Scholar	Investigate the impact of training on the reduction of pre-analytical errors.	Prospective observational
Arthy	Kenya	2021	Google Scholar	Identifying pre-analytical quality indicators and associated errors	Descriptive through questionnaire
Stonys	Lithuania	2024	Pubmed	Determine the level of compliance with phlebotomy of nurses	Questionnaire application
Stonys	Lithuania	2024	Pubmed	To assess the attitude of non-laboratorial health professionals in Lithuania on the importance of patient preparedness	Questionnaire application
Modibo	Mali	2020	Google Scholar	Investigate the impact of phlebotomy training on pre-analytical non-compliances.	Prospective study
Hanane	Morocco	2022	Google Scholar	Reduce pre-analytical errors through a simulation workshop focusing on pre-analytical requirements.	Simulation workshop
Ojeda	Mexico	2020	Google Scholar	To identify physicians' level of knowledge of the pre-analytical phase and the interpretation of arterial blood gases.	Prospective, observational, cross-sectional study
Naseem	Pakistan	2020	Google Scholar	Optimise nursing knowledge and practice in blood culture sampling with an educational intervention.	Quasi-experimental design
Jafri	Pakistan	2022	Google Scholar	Develop an asynchronous virtual classroom to teach pre-analytical factors of laboratory tests.	Questionnaire application and development of interactive scenarios in Moodle

Muzzamil	Pakistan	2022	Google Scholar	Assessing knowledge and attitudes about pre-analytical errors among health care workers in a teaching hospital	Application of an online questionnaire
Tasneem	Pakistan	2024	Google Scholar	Identify the frequency and types of pre-analytical errors within a clinical laboratory.	Retrospective, cross-sectional, retrospective methodology
Alizai	Pakistan	2024	Google Scholar	To assess the knowledge of junior doctors and nurses about the pre-analytical phase.	Cross-sectional study using questionnaires
Ellahi	Pakistan	2024	Google Scholar	Identify types and frequency of pre-analytical errors in the haematology laboratory.	Prospective
Rana	Pakistan	2024	Google Scholar	Assessing the degree of compliance with the updated CLSI guidelines	Observational study
Bench	United Kingdom	2020	Google Scholar	To understand adult critical care nurses' views on point-of-care testing.	Qualitative study
Oprea	Romania	2023	Google Scholar	Developing and testing a new phlebotomy assessment tool for nurses	Prospective with application of standardised knowledge test, three blind phlebotomy audits and prospective follow-up.
Bandara	Sri Lanka	2022	Google Scholar	Optimise the process and management practices of sample reception in a clinical laboratory.	Mixed-methods intervention project: desk review, checklist, focus group discussions and staff satisfaction survey
Du Toit	South Africa	2022	Pubmed	To determine the impact of a training workshop on coagulation sample rejection rates.	Three-month retrospective audit
Bashir	Sudán	2020	Google Scholar	Evaluate the practice of phlebotomists, analyse the degree of compliance with the guidelines	Observational study
Hjelmgren	Sweden	2022	Google Scholar	To describe the experiences of paediatric nurses in collecting blood samples from children.	Qualitative study
Sonmez	Turkey	2020	Google Scholar	Identify frequency and types of errors in the pre-analytical phase of a clinical laboratory.	Observation of technique
Aykal	Turkey	2020	Google Scholar	Implement the venous blood collection training programme.	Observational study with theoretical education and post-observation of technique
Zorbozan	Turkey	2022	Pubmed	Determine the performance of the extra-analytical phase of the laboratory through quality indicators.	Revision in the laboratory information system
Dundar	Turkey	2023	Google Scholar	To determine causes and factors of pre-analytical errors in a tertiary hospital laboratory.	Retrospective study
Erdim	Turkey	2023	Google Scholar	To assess the practice and level of knowledge of midwives and nurses in the pre-analytical phase in neonates.	Pre-analytical Phase Evaluation Form

Content analysis identified three thematic axes that highlight the importance of education in reducing pre-analytical errors. The emerging categories are:

1. Educational Interventions on Pre-analytical Errors: In this category, educational actions aim to reduce errors in this critical phase.
2. Methodologies to Reduce Pre-analytical Errors Linked to Education: This category mentions various methodologies to complement staff training and ensure continuous improvement in laboratories.
3. Impact of Training in Laboratory Environments: This category includes research on the impact of training as a key element in reducing errors in the pre-analytical phase.
4. Table 2 presents the different articles organized by thematic category.

Table 2. Characteristics of selected studies

Thematic Axis	Title	Author	Country	Year
Impact of training in laboratory settings	Knowledge, attitudes and practices of caregivers and laboratory agents on the pre-analytical phase of hematological analyses in Burkina Faso.	Sawadogo	Burkina Faso	2022
	Nurses' Malpractices during Blood Samples Withdrawal at Neonatal Intensive Care Unit	Zaki	Egypt	2022
	Nurses' Performance Regarding Prevention of Hemolysis in Venous Blood Sampling: Suggested Nursing Guidelines	Elsayed	Egypt	2023
	Cost analysis of a training intervention for the reduction of preanalytical errors in primary care samples.	Romero	Spain	2020
	Analyzing preanalytical sample errors in a tertiary care hematology laboratory	Gaur	India	2020
	Assessment of phlebotomy errors by direct observation of sample collection procedure in a NABL Accredited Hospital: An Observational study	Aggarwal	India	2022
	A Knowledge, Attitude, and Practice (KAP) Study on Phlebotomy Among Nurses in a Tertiary Hospital in Patna, India	Dey	India	2023
	A survey on the practice of phlebotomy in Lithuania and adherence to the EFLM-COLABIOCLI recommendations: continuous training and clear standard operating procedures as tools for better quality.	Stonys	Lithuania	2024
	High preanalytical non-compliance and sample rejection rate in clinical biochemistry laboratory is decreased by nurse staff training in phlebotomy and sample handling. GSC Biol Pharm Sci. 2020;13(3):113-118. https://doi.org/10.30574/gscbps.2020.13.3.0400.	Modibo	Mali	2020
	Knowledge of the pre-analytical and post-analytical phase of arterial blood gas analysis in residents and interns.	Ojeda	Mexico	2020
	Assessment of Standard Nursing Practices Implementation during Blood Culture Sampling in Emergency Department	Naseem	Pakistan	2020
	Pre-analytical Quality Assurance; An Important Milestone to be Achieved	Alizai	Pakistan	2024
	Pre-analytical Errors in Hematology Laboratory of a Tertiary Care Hospital: A Cross-Sectional Study of northern Pakistan	Ellahi	Pakistan	2024
	Observational Study on Adherence to modified Clinical and Laboratory Standard Institute H3-A6 Guidelines on Blood Sampling Procedures	Rana MZ	Pakistan	2024
	Processes and Practices Improvement of Sample Receiving Counter at Government Clinical Laboratory in Sri Lanka	Bandara	Sri Lanka	2022

	Auditing of the phlebotomy system in medical laboratories in Port Sudan City	Bashir	Sudan	2020
	Nurses' experiences of blood sample collection from children: a qualitative study from Swedish pediatric hospital care	Hjelmgren	Sweden	2022
	Preanalytical Errors in Clinical Biochemistry Laboratory and Relationship with Hospital Departments and Staff: A Record-Based Study	Dundar	Turkey	2023
	Investigation of the preanalytical process practices in primary care in Istanbul regarding the newborn screening tests.	Erdim	Turkey	2023
	Analysis of preanalytical errors in a clinical chemistry laboratory: A 2-year study. Medicine	Alcantara	Saudi Arabia	2022
Educational interventions on pre-analytical errors	Effect of training on improvement in the preanalytical errors in venous blood sampling at a tertiary care center.	Subhan	India	2023
	Assessing Non-Laboratory Healthcare Professionals' Attitude towards the Importance of Patient Preparation for Laboratory Tests	Stonys	Lithuania	2024
	Role of a Simulation Workshop Training in the Preanalytical Phase in Medical Biology: Experience of the Biochemistry Laboratory of the University Hospital of Tangier – Morocco	Hanane	Morocco	2022
	Development of a virtual classroom for pre-analytical phase of laboratory medicine for undergraduate medical students using	Jafri	Pakistan	2022
	Awareness of pre-analytical errors amongst healthcare workers of DHQ teaching hospital, Sahiwal, Pakistan	Muzzamil	Pakistan	2022
	Frequency and types of pre-analytical errors in a clinical laboratory of a specialized healthcare hospital	Tasneem	Pakistan	2024
	Critical Care Nurses' Views and Experiences of Preanalytical Factors Influencing Point-of-Care Testing: A Qualitative Study	Bench	United Kingdom	2020
	A novel multimodal approach for the assessment of phlebotomy performance in nurses	Oprea	Romania	2023
	The impact of laboratory staff training workshops on coagulation specimen rejection rates	Du Toit	South Africa	2022
	Preanalytical Phase Errors: Experience of a Central Laboratory	Sonmez	Turkey	2020
	The results of a close follow-up of trainees to gain good blood collection practice.	Aykal	Turkey	2020
	Evaluation of preanalytical and postanalytical phases in clinical biochemistry laboratory according to IFCC laboratory errors and patient safety specifications	Zorbozan	Turkey	2022
	Preanalytical Errors in a Hematology Laboratory: An Experience from a Tertiary Care Center	Alshaghdali	Saudi Arabia	2022
Methodologies to reduce pre-analytical errors linked to education	Nursing organization and management in the practice of blood sample collection	Ballestero	Argentina	2021
	Types and Frequency of Errors in the Pre-Analytical Phase in the Clinical Laboratory - Single Center Study from Bosnia and Herzegovina.	Panjeta	Bosnia and Herzegovina	2022
	Percepção dos flebotomistas frente aos cuidados pré-analíticos nas unidades básicas de saúde no agreste pernambucano.	Dos Santos	Brazil	2020
	Magnitude of extra-analytical errors and associated factors in medical laboratories in thirteen Public Hospitals in Addis Ababa, Ethiopia	Degfe	Ethiopia	2023

	Laboratory specimen rejection rate and associated factors among referred specimens at Debre Markos Referral Hospital, Ethiopia: prospective cross-sectional study	Mesganaw	Ethiopia	2024
	Detection of haemolysis, a frequent preanalytical problem in the serum of newborns and adults	Tóth	Hungary	2020
	Quality Indicators for Evaluating Errors in the Preanalytical Phase	Mehndiratta	India	2021
	Effectiveness of Multimodal Intervention to Improve Blood Culture Collection in the Emergency Department.	Shaji	India	2022
	Assessment of pre-analytical quality indicators and the associated errors in clinical laboratory testing at Kombewa Sub County Hospital, Kenya.	Arthy	Kenya	2021

DISCUSSION

Impact of training in laboratory settings

Training in clinical laboratories is key to improving quality and reducing pre-analytical errors. Gaur[12] found an error rate of 2,14 %, linked to coagulated samples. Dey[13] and Naseem[14] found improvements in safety and accuracy after phlebotomy training. In Egypt, Zaki[15] and Elsayed[16] highlighted the need for nursing guidelines to prevent hemolysis. In Mali, Modibo[17] reported improvements in sampling with technical training. Romero[18] in Spain demonstrated economic benefits after an educational intervention. Sawadogo[19] in Burkina Faso and Hjelmgren[20] in Sweden highlighted how lack of training impacts safety and generates frustration among staff. Stonys and Vitkus[21] noted that continuous training and clear protocols improve quality. In Pakistan, Rana[22] identified low adherence to standards, while Aggarwal[23] assessed errors by direct observation. Ojeda[24] in Mexico and Alizai[25] in Pakistan found educational gaps among professionals. Bashir[26] in Sudan highlighted the importance of auditing the phlebotomy system. Bandara[27] in Sri Lanka reported improvements after training. In Turkey, Dundar[28] and Erdim[29] noted that institutional organization influences pre-test errors, reinforcing the need for management intervention.

Educational interventions on pre-analytical errors

Continuing education is essential to reduce errors. Sonmez[30] and Alcántara[31] reported high percentage errors such as hemolysis and non-receipt of samples. Tasneem[32] identified a 41,6 % rate of hemolysis. Subhan[33] reported improvements after training. Jafri[34] and Pasha[35] promoted using virtual classrooms and Moodle. Khalki[36] showed that simulation workshops reduce errors such as mislabelling. Stones and Vitkus[21] reported low adherence to procedures. Muzzamil[37] reported a lack of knowledge of protocols. Oprea[38] revealed discrepancies between theory and practice. Bench[39] remarked that technical training improves safety. Aykal[40] and Ballestero[41] noted improvements with follow-up and training. Zorbozan[42] highlighted the usefulness of audits. Du Toit[43] showed that workshops reduce sample rejection.

Methodologies to reduce pre-analytical errors linked to education

Automation has been effective in reducing human error. Tóth[44] developed hemolysis detection systems. Mehndiratta[45] reported errors due to misuse of tests. Alshaghdali[46] noted a decrease in mistakes following corrective measures. Mesganaw[47] highlighted the effectiveness of regular training. Degfe[48] linked the lack of procedures to a higher incidence of errors. Arthy[49] identified frequent failures. Panjeta[50] noted recurrent errors. Dos Santos[51] highlighted the critical perception of phlebotomists. Shaji[52] showed that a multimodal intervention improves culture taking.

CONCLUSION

The reduction of pre-analytical errors in the clinical setting depends on robust and continuous training of healthcare personnel, from the early stages to throughout their careers. Education, rigorous assessment and adherence to protocols are essential to improve sample quality and patient safety. Several studies reviewed in different geographical and clinical contexts highlight the need for multifaceted approaches that combine continuing education and process optimisation to ensure accuracy in laboratory testing.

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CONFLICTS OF INTEREST

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