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Integrating AI in Clinical Biochemistry: A Qualitative Study of Laboratory Technicians' Knowledge, Skills, and Challenges in Al Khums, Libya

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دمج الذكاء الاصطناعي في الكيمياء الحيوية السريرية: دراسة نوعية لمعرفة ومهارة وتحديات فنيي المختبرات في مدينة الخمس، ليبيا

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Abstract:
This study aims to assess the existing knowledge and proficiency of laboratory technicians in using Artificial Intelligence (AI) tools to interpret laboratory data in clinical biochemistry laboratories in Al Khums, Libya. It seeks to identify gaps in understanding, evaluate technicians' educational preparedness, and examine the challenges and competencies required for the effective integration of AI into laboratory practices as well. This qualitative descriptive cross-sectional study adopts a descriptive-analytical approach, employing semi-structured interviews with a sample of 105 laboratory technicians working in both governmental and private clinical biochemistry laboratories. The interview framework explores key themes, including awareness of AI technologies, perceived benefits and challenges of AI adoption, necessary training and skill development, ethical considerations, and general attitudes toward AI integration in laboratory workflows. The results indicate varying levels of familiarity and confidence among laboratory technicians regarding AI applications in laboratory practice. While many participants demonstrated an awareness of AI and expressed openness to its adoption, substantial gaps in technical knowledge and hands-on experience were identified. The study underscores the necessity for enhanced training programs that encompass both the technical and ethical dimensions of AI. Additionally, it highlights the importance of interdisciplinary collaboration between laboratory professionals and AI developers to facilitate effective implementation.

Keywords: Artificial intelligence; laboratory medicine; clinical biochemistry; diagnostic interpretation; clinical decision support.

الملخص
تهدف هذه الدراسة إلى تقييم المعرفة والكفاءة الحالية لفنيي المختبرات في استخدام أدوات الذكاء الاصطناعي (AI) لتفسير البيانات المخبرية في مختبرات الكيمياء الحيوية السريرية بمدينة الخمس، ليبيا. وتسعى الدراسة إلى تحديد فجوات الفهم، وتقييم الاستعداد التعليمي للفنيين، وبحث التحديات والكفاءات المطلوبة للدمج الفعال للذكاء الاصطناعي في الممارسات المخبرية. تتبنى هذه الدراسة النوعية منهجاً تحليلياً وصفياً، وتستخدم المقابلات شبه المنظمة مع عينة مكونة من 105 فنيي مختبرات يعملون في مختبرات الطب السريري الحكومية والخاصة. يستكشف إطار المقابلة محاور رئيسية، تشمل الوعي بتقنيات الذكاء الاصطناعي، والفوائد والتحديات المتصورة لاعتماد الذكاء الاصطناعي، والتدريب وتطوير المهارات الضرورية، والاعتبارات الأخلاقية، والمواقف العامة تجاه دمج الذكاء الاصطناعي في سير العمل المخبري. تشير النتائج إلى تباين مستويات الإلمام والثقة بين فنيي المختبرات فيما يتعلق بتطبيقات الذكاء الاصطناعي في الممارسات المخبرية. وعلى الرغم من أن العديد من المشاركين أظهروا وعياً بالذكاء الاصطناعي وعبروا عن انفتاحهم على تبنيه، تم تحديد فجوات كبيرة في المعرفة التقنية والخبرة العملية. تؤكد الدراسة على ضرورة برامج تدريب معززة تشمل الأبعاد التقنية والأخلاقية للذكاء الاصطناعي. بالإضافة إلى ذلك، تسلط الضوء على أهمية التعاون متعدد التخصصات بين المتخصصين في المختبرات ومطوري الذكاء الاصطناعي لتسهيل التنفيذ الفعال.

الكلمات المفتاحية: الذكاء الاصطناعي؛ الطب المخبري؛ الكيمياء الحيوية السريرية؛ التفسير التشخيصي؛ دعم القرار السريري.

1. Introduction
Artificial intelligence (AI) is transforming clinical biochemistry laboratories by automating analytical processes, enhancing accuracy, and improving the interpretation of results(1). As these technologies evolve, assessing the readiness of laboratory technicians (in clinical biochemistry laboratories) to apply AI-based tools has become essential. Understanding current knowledge, attitudes, and proficiency provides valuable insight into educational gaps and the competencies required for safe AI adoption(2).

1.1 Definition of Artificial Intelligence in Medicine and Public Health
AI in healthcare refers to computer systems capable of performing tasks that typically require human intelligence—learning, reasoning, and decision-making(3). In laboratory medicine, AI algorithms analyze large datasets using machine-learning techniques to detect diagnostic patterns that may escape human interpretation(1, 4).

1.2 Importance of AI in Laboratory Medicine
AI has revolutionized laboratory result interpretation and quality control. Algorithms can process complex biochemical and imaging data, recognize anomalies, and assist clinicians in accurate diagnosis(5, 6). When integrated with electronic health record systems, AI also supports clinical decision-making by providing real-time, evidence-based recommendations(7, 8). Moreover, by simulating human cognition, AI can mine diagnostic and genomic databases to identify new biomarkers and precision-medicine targets(9).

1.3 Use of AI in Laboratory Medicine
AI's analytical capacity enhances diagnostic efficiency by identifying patterns and deviations in laboratory data(10, 11). Through automation, algorithms monitor equipment performance, detect analytical errors, and issue alerts for corrective actions(12). Predictive analytics modules use cumulative biochemical data to forecast disease progression and patient outcomes(13). By complementing human expertise, AI shortens turnaround time and improves overall laboratory productivity(14).

1.4 Literature Review
Recent studies highlight the rapid growth of AI applications in laboratory medicine, emphasizing its role in operational decision-making, workflow optimization, and personalized diagnostics(15-18). Machine-learning and deep-learning techniques have been widely adopted for pattern recognition and data classification in biochemical assays(4). Clinical laboratories now utilize AI to automate result validation, detect instrument errors, and support quality assurance(13). Despite these advances, published surveys consistently reveal heterogeneous knowledge and limited hands-on experience among laboratory professionals(16, 19).

1.5 Theoretical Frameworks in AI-Assisted Laboratory Interpretation
The integration of AI into laboratory interpretation is guided by several computational frameworks. Supervised learning uses labeled datasets—such as biochemical parameters linked to diagnoses—to train models that predict disease states(1, 20). Deep learning, employing multilayer neural networks, automatically extracts features from raw data and has proven effective in image analysis, genomics, and biochemical profiling(21). Reinforcement learning enables incremental improvement of diagnostic or operational decisions by rewarding correct outputs and penalizing errors, improving laboratory workflow optimization over time(22).

1.6 Gaps in Laboratory Technicians' AI Knowledge and Skills

Although AI adoption in clinical biochemistry has accelerated, multiple studies report significant gaps in both theoretical understanding and practical application(23). Many technicians lack formal training in AI fundamentals such as algorithm selection, data preprocessing, and model validation(6). Limited exposure to computational tools further impedes their confidence in integrating AI into routine workflows(24). Insufficient interdisciplinary collaboration between laboratory scientists and computer engineers also impedes customized system development(25). Data-management deficiencies including inconsistent sample records and inadequate awareness of ethical and regulatory issues further restrict reliable AI implementation(26). Addressing these limitations through targeted professional education and standardized data-governance practices is essential to realize AI's full potential in laboratory medicine.

2. Material and methods

2.1 Research Design

This study employed a qualitative, descriptive, cross-sectional design to explore the attitudes, knowledge, and proficiency of Libyan laboratory technicians in employing artificial intelligence (AI) tools for the interpretation of laboratory results in clinical biochemistry laboratories across both governmental and private sectors. A descriptive cross-sectional survey supplemented with semi-structured interview approaches was conducted to obtain rich, in-depth insights into participants' experiences, perceptions, and expectations regarding the application of AI in clinical laboratory practice. The primary objectives were to:

1. Assess the willingness of laboratory technicians to adopt AI-based technologies in daily practice.
2. Identify perceived barriers to AI implementation, including technical, ethical, and trust-related concerns.
3. Generate data that could inform future strategies for professional training and AI integration within laboratory workflows.

This design allowed for comprehensive exploration of both individual and collective viewpoints, yielding multifaceted data that reflect real-world professional contexts.

2.2 Sampling and Study Population

Participants were recruited from governmental and private clinical biochemistry labs across Al Khums city, Libya. A random sampling method was applied to ensure inclusion of a diverse range of laboratory professionals. Eligible participants met the following criteria:

1. Laboratory technicians with at least one year of professional experience in their current roles.
2. Technicians involved in laboratory results interpretation or diagnostic processes.
3. Individuals who had interacted with or received training in AI-based systems relevant to laboratory medicine.

The final sample consisted of 105 laboratory technicians who work in clinical biochemistry labs, representing a balance of governmental and private sector professionals. This sample size was considered appropriate for qualitative research, providing sufficient diversity while maintaining analytical depth.

All participants were informed of the study's purpose, assured of the confidentiality and anonymity of their responses, and granted full independence to withdraw at any point without penalty.

2.3 Data Collection Procedure

Data were collected through semi-structured, in-depth interviews conducted between April and August 2024. An interview guide comprising open-ended questions explored awareness of AI, perceived benefits, challenges and barriers, training needs, ethical considerations, and attitudes toward adoption. This flexible approach allowed for probing and follow-up questions while maintaining consistency across interviews. Interviews were conducted in person at participants' workplaces and lasted approximately 15 to 20 minutes, enabling comprehensive exploration without causing fatigue, ensuring coverage of all relevant dimensions while allowing respondents to elaborate freely. The Interview sessions were conducted in Arabic and later transcribed and back-translated into English for analysis, ensuring linguistic accuracy and retention of meaning. Verbatim notes and transcripts were compiled for subsequent thematic analysis.

This flexible approach allowed for probing and follow-up questions while maintaining consistency across interviews.

3. Results

1.1 Cross-tabulation statistics

This section presents the quantitative findings derived from survey responses collected from 105 participants. The analysis aimed to explore participants' educational backgrounds, professional experience, and their perceptions, familiarity, and openness toward artificial intelligence (AI) in healthcare, particularly in the context of interpreting laboratory results. Descriptive statistics were used to summarize demographic variables and key

response distributions. In contrast, inferential statistics were applied to examine potential associations between familiarity with AI and attitudes toward its use in clinical decision-making.
The results are organized into thematic tables that reflect participants' confidence in interpreting lab results, perceived importance of understanding diagnostic data, prior exposure to AI technologies, and their willingness to adopt AI-assisted interpretation. Additional tables highlight concerns related to accuracy, privacy, and ethical implications. Correlation analyses were conducted to assess whether prior experience or familiarity with AI influenced trust, openness, or perceived reliability of AI in healthcare settings.
A total of 105 participants completed the survey. The sample was predominantly composed of individuals holding a higher diploma (n=51,48.6%) or a bachelor's degree (n=46,43.8%), with a smaller proportion reporting a master's degree (n=8, 7.6%). No participants held doctoral degrees or specified alternative qualifications (Figure 1).

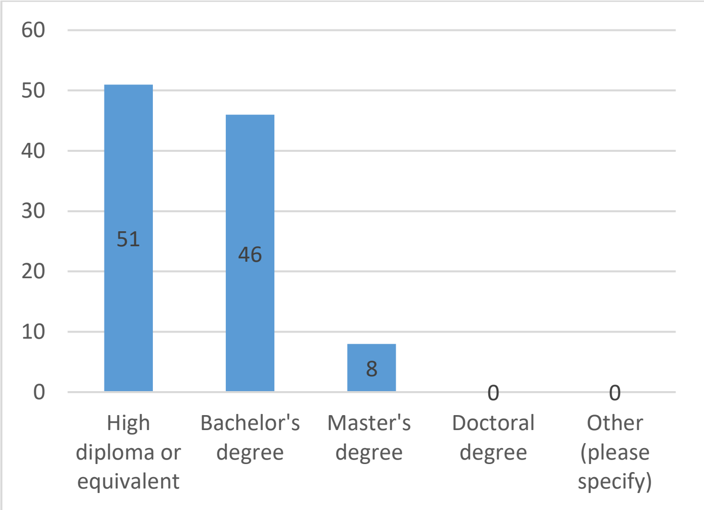

Figure 1: Level of education of participants

Regarding professional experience, the largest subgroup had 1–3 years of experience (35.2%), followed by those with 4–6 years (20.0%) and more than 10 years (18.1%) (Figure 2).

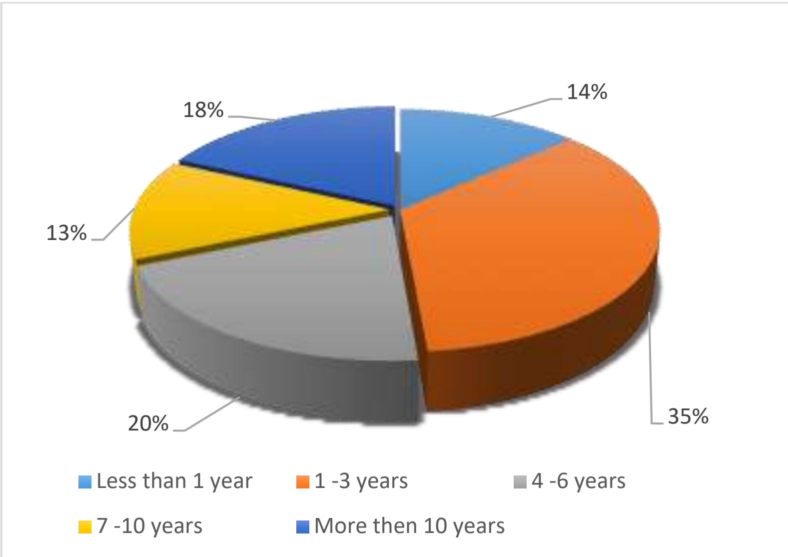

Figure 2: Professional experience of participants

Confidence in interpreting laboratory results varied: 51.4% reported occasional confidence, while 41.9% consistently felt confident; only 3.8% indicated no confidence (Table 1). Notably, 85.7% of respondents considered understanding lab results to be very important; others responded differently (Table 2).

Table 1: Confidence in interpreting lab results

Response	Frequency	Percent
Yes	44	41.9%
No	4	3.8%
Sometimes	54	51.4%
I am unsure	3	2.9%
Total	105	100%

Table 2: Importance of understanding lab results

Response	Frequency	Percent
Very important	90	85.7%
Somewhat important	8	7.6%
Neutral	3	2.9%
Not very important	1	1.0%
Not important at all	3	2.9%
Total	105	100%

Nearly half (n=48, 45.7%) had previously received a medical diagnosis they were uncertain about (Figure 3), suggesting a potential gap in diagnostic communication.

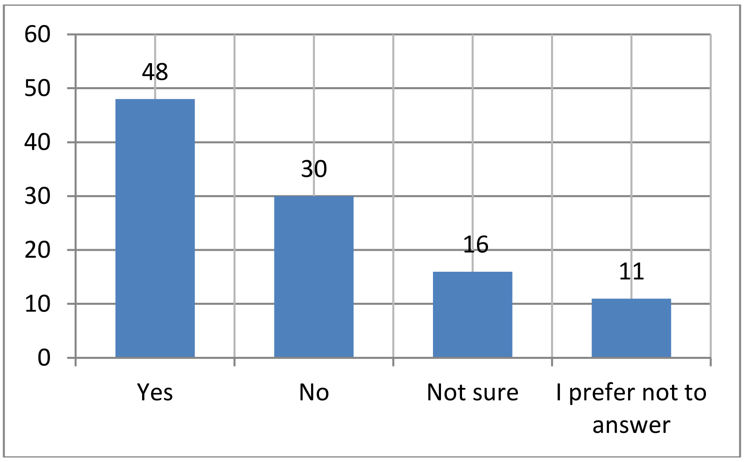

Figure 3: Experience of receiving an uncertain medical diagnosis

Awareness of artificial intelligence (AI) in healthcare was mixed: 22.9% were very familiar, 27.6% somewhat familiar, and 26.7% not familiar at all, with an additional 22.9% reporting no prior knowledge (Table 3).

Table 3. Familiarity with AI in healthcare

Response	Frequency	Percent
Very familiar	24	22.9%
Somewhat	29	27.6%
Not familiar at all	28	26.7%
I have no prior knowledge of AI in healthcare	24	22.9%
Total	105	100%

When asked about AI's potential to improve diagnostic accuracy, 35.2% believed AI could assist but should not replace human experts, while 27.6% remained uncertain (Table 4).

Table 4. Belief that AI can improve accuracy

Response	Frequency	Percent
Yes, I trust AI technology for lab results	13	12.4%
No, I do not trust AI's accuracy in lab results	17	16.2%
I'm unsure; more research is needed	29	27.6%
I would be open to trying AI for lab results	7	6.7%
I have concerns about the reliability and bias of AI	2	1.9%
AI can help in interpreting results, but should not replace human experts	37	35.2%
Total	105	100%

Participants' perceptions of AI's ability to catch errors in laboratory result interpretation indicate diverse opinions. About one-third (n=35, 33.3%) believed AI could identify potential errors, while 22.9% (n=24) were unsure. Notably, 21.0% (n=22) expressed skepticism about AI's capacity to interpret complex data, and 16.2% (n=17) doubted its accuracy, reflecting a cautious but generally optimistic attitude toward AI-assisted error detection (Figure 4). Confidence in AI's ability to interpret complex data was generally low: only 10.5% were very confident, while 28.6% were neutral and 40.0% expressed low confidence (Figure 5). Regarding future adoption, 26.7% were somewhat likely to recommend AI for interpretation, while 24.8% remained neutral and 6.7% were very unlikely to do so (Table 5).

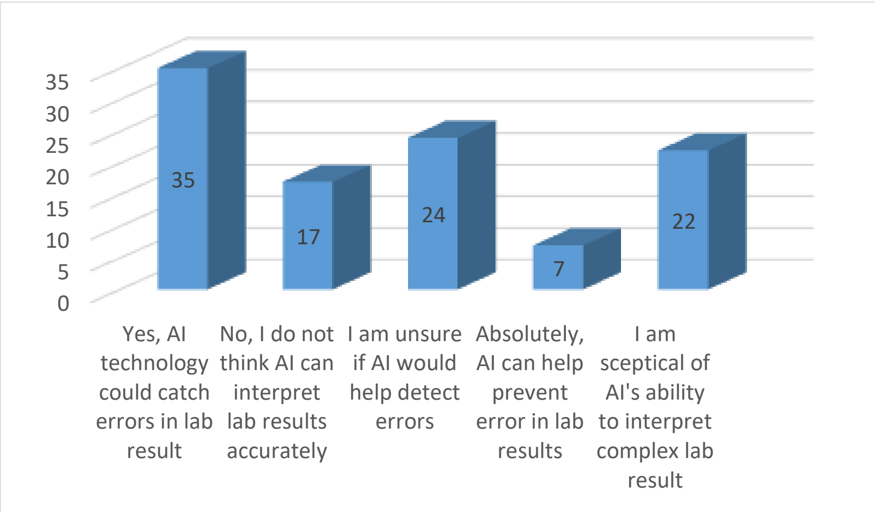

Figure 4: Can AI catch errors

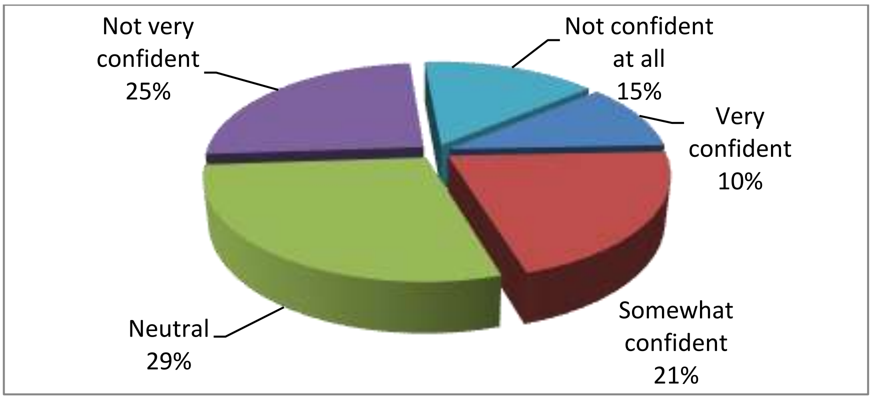

Figure 5: Confidence in AI for interpreting complex data

Table 5. Likelihood to recommend AI for interpretation

Response	Frequency	Percent
Extremely likely	13	12.4%
Very likely	15	14.3%
Somewhat	28	26.7%
Neutral/undecided	26	24.8%
Somewhat unlikely	2	1.9%
Very unlikely	3	2.9%
Extremely unlikely	7	6.7%
Don't know/not applicable	11	10.5%
Total	105	100%

3.2 Inferential Statistics

Correlation analyses were conducted to explore relationships between familiarity with AI and attitudes toward its use in healthcare. A weak positive correlation was observed between familiarity with AI and belief in its ability to improve interpretation accuracy ($r = 0.208$), suggesting that increased exposure may slightly enhance trust. Similarly, prior use of AI was weakly associated with openness to a doctor using AI ($r = 0.134$). The relationship between openness to doctor-led AI interpretation and concerns about AI yielded a negligible correlation ($r = 0.042$), indicating that concerns may not strongly deter openness. Overall, these findings suggest that while familiarity and prior use may influence attitudes, their impact remains limited.

4. Discussion

The rapid integration of AI into clinical biochemistry laboratories has ushered in new diagnostic capabilities and operational efficiencies.

This study explored the knowledge, attitudes, and perceptions of laboratory technicians toward Artificial Intelligence (AI) integration in laboratory medicine, particularly for interpreting biochemical results. The findings reveal a generally positive but cautious stance toward AI, characterized by moderate awareness, variable confidence, and concerns regarding accuracy, reliability, and ethical implications.

The educational background of participants was largely at the diploma and bachelor's levels, suggesting that most respondents possess technical training rather than advanced academic experience. This factor may partially explain the limited confidence observed in understanding and applying AI-based tools. Consistent with prior studies in clinical laboratory sciences, professional exposure and educational level are key determinants of digital competency and technology acceptance in healthcare settings(27-30).

While more than one-third of participants recognized AI's potential to enhance diagnostic accuracy, the belief that AI should *complement* rather than *replace* human expertise was strongly emphasized. This aligns with the international consensus that AI should function as a decision-support tool rather than an autonomous diagnostic system(31-33). The ambivalence reflected in the survey—where over 27% remained uncertain about AI's effectiveness—indicates that while curiosity exists, full confidence requires further evidence of reliability, transparency, and ethical safeguards.

The observed low confidence levels regarding AI interpretation of complex data (with nearly 40% expressing low trust) are consistent with findings from Haymond & McCudden (18) and Paranjape et al. (20), who reported that healthcare professionals often hesitate to rely on algorithmic predictions without adequate understanding of the underlying mechanisms(34). Such skepticism is not entirely negative; it reflects a prudent approach toward new technologies that demand validation, quality assurance, and regulatory oversight before large-scale clinical adoption.

Interestingly, correlation analyses revealed only weak positive associations between familiarity with AI and trust in its diagnostic value, implying that awareness alone may not translate into acceptance. This finding underscores the importance of structured education, experiential learning, and interdisciplinary collaboration between laboratory professionals, clinicians, and data scientists. Practical exposure to AI applications in laboratory workflows—supported by clear evidence of improved accuracy and efficiency—may be more effective than theoretical instruction alone in fostering genuine trust and competency(35-37).

Overall, the findings suggest a transitional phase in which laboratory technicians in clinical biochemistry labs recognize the potential benefits of AI yet remain cautious due to limited exposure, insufficient training, and ethical uncertainties. The results advocate for targeted educational interventions, institutional support, and a gradual integration strategy that emphasizes human–AI collaboration rather than replacement.

5. Conclusion

Artificial Intelligence represents a transformative opportunity for interdisciplinary laboratory medicine, capable of improving diagnostic precision, streamlining workflows, and enhancing decision support. However, this study highlights significant gaps in knowledge, confidence, and readiness among laboratory technicians to fully embrace AI-assisted result interpretation.

Bridging these gaps requires a multifaceted approach: incorporating AI and data literacy into laboratory science curricula, providing continuous professional development focused on ethical and practical applications, and fostering collaboration between laboratory professionals and AI developers. Building transparent, explainable AI systems that uphold data security and patient privacy will further strengthen confidence and acceptance.

In conclusion, while Libyan laboratory technicians in the governmental and private sectors demonstrate openness toward AI adoption, cautious optimism prevails. Ensuring successful integration will depend on sustained education, ethical governance, and institutional strategies that empower professionals to leverage AI responsibly—enhancing rather than replacing human expertise in laboratory medicine.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to the conduct or authorship of this study. The research was carried out independently, without any financial or personal relationships that could inappropriately influence its outcomes.

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