Rapid Communication

A Present Where AI is Enhancing Laboratory Medicine, A Future Where It Redefines Healthcare

Damien Gruson[1,2,3*]

[1]*Department of Laboratory Medicine, Cliniques Universitaires St-Luc and Université Catholique de Louvain, Brussels, Belgium.*
[2]*Pôle de recherche en Endocrinologie, Diabète et Nutrition, Institut de Recherche Expérimentale et Clinique, Cliniques Universitaires St-Luc and Université Catholique de Louvain, Brussels, Belgium.*
[3]*IFCC Division on Emerging Technologies*

Article Info

[*]***Corresponding Author:***
Prof. Damien Gruson
Department of Laboratory Medicine,
Cliniques Universitaires St-Luc and Université Catholique de Louvain
10 Avenue Hippocrate, B-1200 Brussels, Belgium
Phone +32-(0)2-7646747
fax +32-(0)2-7646930
E-mail: damien.gruson@uclouvain.be
ORCID: 0000-0001-5987-4376

Abstract

Artificial Intelligence (AI) has transitioned from a technological concept to a foundational component of healthcare innovation. In laboratory medicine, it is no longer a question of whether AI will play a role, but rather how it will be responsibly integrated to amplify clinical value, operational efficiency, and equitable patient care. This article explores the current and future impact of AI across diagnostic workflows, clinical decision-making, personalized prevention strategies, and hospital governance. It also highlights the ethical, legal, and sustainability considerations critical to ensuring AI supports a smarter, fairer, and more sustainable healthcare system.

Keywords

Artificial intelligence, automation, sustainability, clinical decision support system, workflow, equity

Introduction

Laboratory medicine stands at a transformative crossroads. Just as Moore's Law once defined computational growth, Huang's Law now marks the explosive evolution of AI processing power, driving unprecedented breakthroughs in healthcare. Between 2016 and 2024, AI computing power surged by over 1000x - an acceleration that is reshaping how we screen, diagnose, and manage diseases [1,2]. In this context, laboratory professionals are uniquely positioned to integrate AI to transform diagnostics, patient pathways, and population health. This short article presents a comprehensive view of how AI is currently enhancing laboratory medicine and outlines a vision of how it will redefine healthcare in the future. It draws on multidisciplinary insights to propose a collaborative and ethical path forward for laboratories worldwide.

The Evolution of AI in Healthcare

AI in healthcare now encompasses machine learning, generative AI, natural language processing, and multimodal models capable of integrating text, images, sensor data, and audio signals. Applications range from triaging patients in resource-limited settings to early detection of cardiovascular deterioration through smart wearables and remote sensors [2–4].

Recent studies show that generative AI can improve communication by offering culturally sensitive, emotionally aware support for patients, helping close gaps in health literacy and engagement [2,5]. AI also enables behavioral health interventions, such as using personalized avatars and visuals to enhance emotional regulation in pediatric or chronic care settings [6].

The Patient-Centered AI Landscape

AI holds promise in making healthcare more personalized and responsive. For patients with chronic diseases such as heart failure (HF) - particularly in those with diabetes, where HF may be the first sign of cardiovascular disease - AI can enhance follow-up and monitoring [2,7]. By integrating real-time data from wearables and digital health records, AI facilitates early intervention and dynamic care plans tailored to individual risk profiles [2,8]. AI can also act as a "health literacy bridge" by translating complex medical terminology into understandable, personalized insights, thus ensuring that patients are not only monitored but also empowered [2,9].

Empowering Clinicians with AI Tools

From the perspective of general practitioners (GPs), AI is reshaping the clinical workflow. Speech-based AI tools detect subtle cardiovascular changes, while language models help synthesize patient histories and suggest differential diagnoses [5]. Physicians increasingly rely on AI for administrative efficiency - automating documentation and reducing cognitive burden - thereby allowing more time for patient care [5,10]. AI also enhances medical education by standardizing case evaluations and promoting adaptive learning. As a decision-support system, it fosters earlier disease recognition, augments diagnostic accuracy, and bolsters continuity of care.

AI in Laboratory Operations

AI is revolutionizing every phase of the laboratory process [3,11,12]:

- **Pre-analytical**: Predictive AI detects potential sample anomalies before testing.
- **Analytical**: AI-powered instruments optimize calibration, reduce errors, and accelerate interpretation through pattern recognition.
- **Post-analytical**: AI assists in generating actionable insights and interpreting complex datasets, including omics-level information.

Laboratory automation is evolving toward hyperautomation where integrated AI systems orchestrate tasks, monitor quality in real-time, and anticipate resource demands [3,11]. Personalized proficiency testing is emerging, enabling labs to receive tailored assessments based on their test portfolios, improving targeted quality improvement [3].

Hospital Leadership and AI Strategy

AI is not just a clinical tool - it's a strategic asset for hospital directors. Predictive analytics help optimize bed management, staffing, and supply chain logistics. Hospitals that integrate AI report not only reduced operational costs but also improved patient throughput and satisfaction [13]. At the governance level, however, AI implementation must navigate challenges of interoperability with legacy systems, regulatory constraints, and the "hype vs. reality" gap. Successful strategies depend on interdisciplinary alignment - where clinicians, IT professionals, and administrators co-design AI integration [2,7].

Integrating Environmental and Social Determinants: The Role of Exposomics

AI is also enabling "precision exposomics" by merging environmental data (e.g., air quality, urbanization, socioeconomic factors) with health records to predict disease patterns and outcomes. For example, convolutional neural networks analyzing over 500000 Google Street View images in U.S. cities successfully predicted coronary heart disease (CHD) prevalence and explained 63% of variation across geographic areas [14].

This reinforces the importance of integrating environmental data in cardiovascular prevention and health policy planning. Exposomics, coupled with metabolomics and AI, represents a frontier in personalized risk assessment [15,16].

Ethical, Legal, and Environmental Challenges

The widespread use of AI in healthcare raises critical ethical and legal questions [12,17]:

- **Accountability**: Who is liable if AI makes a diagnostic error? The developer, the clinician, or the institution?
- **Transparency**: AI systems can produce "hallucinations"

or misleading outputs. Ensuring interpretability is key.
- **Bias and Equity**: Algorithms must be trained on diverse datasets to avoid reinforcing disparities.
- **Privacy**: Data governance must protect patient confidentiality while enabling secure AI training.

AI training models also consume substantial energy. The environmental impact of large-scale models has prompted calls for sustainable AI development, with best practices including model efficiency, transparent reporting, and carbon offsetting [17,18].

A Framework for Responsible Innovation

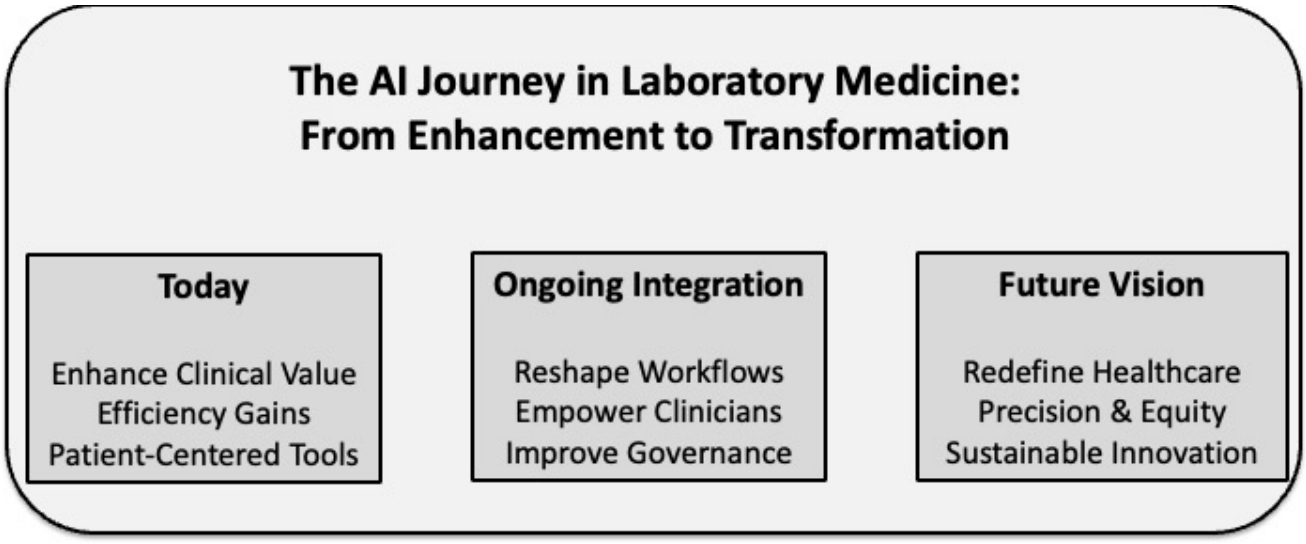
To fully realize AI's potential in laboratory medicine, we must align innovation with responsibility. A proposed action plan includes:

1. **Embrace Innovation Responsibly**
   Leverage AI to enhance diagnostics and precision medicine, while maintaining human oversight.
2. **Commit to Sustainable AI**
   Advocate for transparent reporting of AI energy consumption and develop energy-efficient algorithms.
3. **Navigate Ethical and Legal Frontiers**
   Support international consensus on AI liability, data standards, and patient autonomy.
4. **Foster Multidisciplinary Collaboration**
   Bring together clinicians, data scientists, policymakers, and patients to shape inclusive AI use cases.
5. **Act Now**
   Start piloting AI innovations in laboratory workflows to gain experience and refine governance strategies.

Conclusion

AI is already enhancing laboratory medicine - from diagnostics to workflow automation. Its future lies not just in innovation, but in responsible transformation. Developed and governed with care, AI will not only make laboratories smarter and more efficient, but also more sustainable, ethical, and aligned with the needs of patients and healthcare professionals (Figure 1). As laboratory medicine evolves, it must not merely adopt AI - it must shape it. With great computational power comes the responsibility to guide AI toward meaningful, equitable, and human-centered healthcare.

Figure 1: AI's evolving role in laboratory medicine: from current impact to future transformation.



Funding Statement

The authors received no specific funding for this work.

Declaration of Conflicts of Interest

The authors declare no conflicts of interest related to this publication.

Ethical Approval Statement

This article does not contain any studies with human participants or animals performed by any of the authors. Therefore, ethical approval was not required. The article is in compliance with the ethical principles for medical research involving human subjects, in accordance with the Declaration of Helsinki.

Author Contributions

Damien Gruson conceived, wrote, and reviewed the manuscript.

Credit Author Statement

Damien Gruson: Conceptualization, Writing - original draft, Writing - review & editing, Supervision.

Data Availability Statement

No datasets were generated or analyzed during the current study.

References

1. Video Shows How Engineers Fuel Huang's Law | NVIDIA Blogs [Internet]. [ci. Available from: https://blogs.nvidia.com/blog/huangs-law-dally-hot-chips/ (Accessed: 15/07/2025)
2. Lüscher TF, Wenzl FA, Ascenzo FD, Friedman PA, Antoniades C. Artificial intelligence in cardiovascular medicine: clinical applications. Eur Heart J. 2024;45(40):4291–4304.
3. Kim S, Min WK. Toward High-Quality Real-World Laboratory Data in the Era of Healthcare Big Data. Ann Lab Med. 2025;45(1):1–11.
4. Gruson D, Kemaloğlu Öz T. Trends in Healthcare and Laboratory Medicine: A Forward Look into 2025. Balkan Med J. 2025 Mar 24
5. Elvas LB, Almeida A, Ferreira JC. The Role of AI in Cardiovascular Event Monitoring and Early Detection: Scoping Literature Review. JMIR Med Inform. 2025;13.
6. Mansoor M, Hamide A, Tran T. Conversational AI in Pediatric Mental Health: A Narrative Review. Children. 2025;12(3):359.
7. Thangaraj PM, Benson SH, Oikonomou EK, Asselbergs FW, Khera R. Cardiovascular care with digital twin technology in the era of generative artificial intelligence. Eur Heart J. 2024;45(45):4808–4821.
8. Monzo L, Bresso E, Dickstein K, Pitt B, Cleland JGF, Anker SD, et al. Machine learning approach to identify phenotypes in patients with ischaemic heart failure with reduced ejection fraction. Eur J Heart Fail. 2024
9. Johnson KB, Horn IB, Horvitz E. Pursuing Equity with Artificial Intelligence in Health Care. JAMA Health Forum. 2025;6(1):e245031–e245031.
10. Vrdoljak J, Boban Z, Vilović M, Kumrić M, Božić J. A Review of Large Language Models in Medical Education, Clinical Decision Support, and Healthcare Administration. Healthcare. 2025;13(6):603.
11. Gruson D, Magalhaes T, Ruszanov A, Granaldi C, Bernardini S, Buttigieg SC. Hyperautomation in Healthcare: Perspectives from a Joint IFCC – EHMA Session. EJIFCC. 2023;34(4):284.
12. Gruson D, Gruson D, Macq B. The Next Clinical Decision Frontier: How to Efficiently and Safely Combine Machine Learning and Human Expertise. Clin Chem. 2023; Nov 29
13. Maleki Varnosfaderani S, Forouzanfar M. The Role of AI in Hospitals and Clinics: Transforming Healthcare in the 21st Century. Bioengineering. 2024;11(4):337.
14. Chen Z, Dazard JE, Khalifa Y, Motairek I, Al-Kindi S, Rajagopalan S. Artificial intelligence-based assessment of built environment from Google Street View and coronary artery disease prevalence. Eur Heart J. 2024;45(17):1540–1549.
15. Gruson D, Fux E, Kemaloğlu Öz T, Gouget B, Lee W, Shah S, et al. Contribution of laboratory medicine and emerging technologies to cardiovascular risk reduction via exposome analysis: An opinion of the IFCC Division on Emerging Technologies. Clin Chem Lab Med. 2024 Sep 2
16. Khera R. Artificial intelligence-enhanced exposomics: novel insights into cardiovascular health. Eur Heart J. 2024;45(17):1550–1552.
17. Gonzalez A, Crowell T, Lin SYT. AI Code of Conduct - Safety, Inclusivity, and Sustainability. JAMA Intern Med. 2025;185(1):12–13.
18. COLLECTIVE ACTION FOR RESPONSIBLE AI IN HEALTH. 2024 ; Available from: http://www.oecd.org/termsandconditions. (Accessed: 15/07/2025)