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Research Article

Automation in Microbiology to Reduce Turnaround Time for Patients Better Outcome: Narrative Review

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ABSTRACT
Automation has revolutionized and changed clinical and diagnostic microbiology by improving laboratory reporting, reducing turnaround time, enhancing diagnostic accuracy and minimizing human error. Modern microbiology laboratories has increasingly employed automated systems for specimen processing and culturing, microbial and organism identification. Automated blood cultures and antimicrobial susceptibility testing (AST), molecular diagnostics and gene detection has become easier and rapid. Technologies such as total laboratory automation (TLA), matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS) and artificial intelligence (AI) have transformed traditional workflows. Despite these advances challenges includes high implementation costs, infrastructure requirements. Workforce training remain significant barriers, particularly in low- and middle-income countries. This narrative review discusses the evolution, applications, advantages, limitations and future perspectives of automation in microbiology.

Keywords: Clinical and Diagnostic Microbiology, Total Laboratory Automation, MALDI-TOF MS, Artificial Intelligence, Antimicrobial Susceptibility Testing.

INTRODUCTION

Clinical and diagnostic microbiology laboratories play an essential role in diagnosing infectious diseases, guiding appropriate antimicrobial therapy and supporting infection prevention and control programs. Conventional microbiological laboratory methods are depend heavily on manual specimen processing, culture reading and interpreting, biochemical testing and antimicrobial susceptibility testing. These methods are generally labour-intensive, requires man power and are time-consuming with more chances of human errors.[1] Increasing specimen numbers, initiation of early empirical therapy has increased hospital antimicrobial resistance, thereby demanding for rapid diagnostics and identification methods to accelerate the adoption of automation in microbiology.

Automation encompasses technologies that perform laboratory procedures with minimal human intervention while ensuring reproducibility, quality and efficiency.[2] Modern automated systems integrate specimen inoculation, incubation, digital imaging, organism identification, susceptibility testing and laboratory information systems (LIS), significantly improving laboratory workflow and reducing turnaround time (TAT).

Evolution of Automation in Microbiology

Automation in microbiology began with automated blood culture systems in the 1970s. Subsequent developments introduced automated identification and antimicrobial susceptibility testing platforms. [3] The introduction of MALDI-TOF MS during the early 2000s revolutionized microbial identification by reducing identification time from days to minutes. The matrix assisted laser desorption method is unique in identifying organism on basis of proteomics.

Recent advances include total laboratory automation (TLA), which integrates specimen processing, automated transport, incubation, digital plate reading and result reporting into a continuous workflow.[4] Artificial intelligence and machine learning algorithms are now being developed to assist in interpreting culture images and predicting antimicrobial resistance.

Components of Automation in Microbiology

Automated Specimen Processing
Automated specimen processors standardize inoculation techniques, ensuring consistent streaking patterns on media and reducing person variability among laboratory personnel. Automated inoculation also decreases contamination rates and improves well separated colony isolation and reducing man power requirement.

Examples of Few Automated Laboratory Includes:
BD Kiestra™
Copan WASPLab®
These systems integrate barcode tracking of samples received, automated plate labelling and specimen transport and culture processing and result interpretation. [5]

Automated Incubation and Digital Imaging
Automated incubators maintain optimal environmental conditions while continuously monitoring culture plates. Digital imaging systems capture high-resolution images at scheduled intervals, allowing remote interpretation by microbiologists.

Benefits Include:
Reduced manual handling, Continuous monitoring, earlier identification and detection of microbial growth. Improved traceability and Automated Microbial Identification.
Matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS) has become the gold standard for rapid microbial identification. The technology identifies microorganisms by analysing unique protein spectra and comparing them with extensive databases.[6] Bacterial species are matched with in built data system and analysed. It helps in earlier reporting and improves patient treatment and health outcome

Advantages Include:
Rapid identification within minutes, High accuracy, reduced reagent costs, Broad organism coverage. Limitations include difficulty identifying closely related species and dependence on comprehensive databases. Pure and fresh cultures are required for identification.

Automated Antimicrobial Susceptibility Testing
Automated AST systems provide standardized susceptibility results while reducing manual interpretation errors.[7] Common systems include: VITEK 2, BD Phoenix , Micro Scan Walk Away. These platforms determine minimum inhibitory concentrations (MICs) and interpret susceptibility according to CLSI or EUCAST guidelines. Benefits include: Faster reporting, Improved reproducibility, Integration with laboratory information systems.[8] Automated Blood Culture Systems. Automated blood culture instruments continuously monitor microbial growth through detection of carbon dioxide production.

Common Platforms Include: BACTEC, BacT/ALERT- Of the primary drivers for this change, standardization of identification methods with MALDI–TOF–MS and the adoption of liquid microbiology specimen transport created a workflow pattern that could be optimized with automation. These systems shorten pathogen detection time and improve the diagnosis of bloodstream infections. [9] Versa-trek is another automated blood identification system providing automatic loading and unloading of blood culture bottles.

Molecular Automation
Automation has expanded into molecular microbiology through automated nucleic acid extraction, real-time PCR, multiplex PCR, and next-generation sequencing. Examples include: Gene-Xpert, Film Array, Cobas systems [10] these technologies enable rapid diagnosis of respiratory infections, tuberculosis, bloodstream infections, and emerging pathogens. Various panels of infectious diseases can be diagnosed by it.

Artificial Intelligence in Microbiology
Artificial intelligence represents the next generation of laboratory automation. AI algorithms analyse digital culture images, identify colony morphology, detect contamination and prioritize positive cultures. [11] Machine learning has also shown promise in: Predicting antimicrobial resistance strains like multidrug and pan drug resistance, Outbreak surveillance, Quality control. Laboratory workflow optimization although promising, AI requires extensive validation before widespread implementation.

Benefits of Automation
Automation offers numerous advantages: Reduced turnaround time, improved diagnostic accuracy, Standardization of laboratory procedures and reduced manual workload. Enhanced biosafety, better traceability, improved quality assurance, increased laboratory productivity. Rapid identification and

susceptibility testing enable earlier targeted antimicrobial therapy, improving patient outcomes and supporting antimicrobial stewardship. [12]

Challenges and Limitations

Despite significant advantages, automation has several limitations. High Cost in
Installation and maintenance of automated systems require substantial financial investment.

Infrastructure Requirements

Automation demands uninterrupted electricity, laboratory space, information technology support, and maintenance services. Training Requirements with laboratory personnel require specialized training for operation, troubleshooting, and quality management.
Limited flexibility with certain rare organisms and unusual specimens still require conventional manual methods.

Data Management

Large volumes of digital information require secure and safe storage, cybersecurity and password protection measures and integration with hospital information systems. [13]
Automation in Developing Countries
Implementation of automation remains limited in resource-constrained settings because of financial, infrastructural, and maintenance challenges. Nevertheless, gradual adoption of modular automation, especially MALDI-TOF MS and automated blood culture systems, has improved laboratory capacity in many tertiary-care hospitals. [14,15]
Cost-effective implementation strategies include phased automation, centralized laboratories, and public-private partnerships. In clinical microbiology culture, however, "full laboratory automation" refers to automation of the diagnostic workflow including all steps from inoculation of culture to final report generation. Therefore, a laboratory automation system can potentially contribute to all analytical steps from inoculation, incubation, plate reading and identification, or even antibiotic susceptibility testing. [16,17]

Future Perspectives

Future microbiology laboratories are going to integrate: Artificial intelligence, Machine learning, Robotics, Digital microbiology, Whole genome sequencing, Predictive analytics, Cloud-based laboratory information systems and hospital data integration system to enhance patient timely reporting and improve health outcome. The concept of "smart and digital laboratories" combines automation with AI-driven decision support to achieve faster, correct diagnosis and precision in medicine prescription. Automation with AI assisted is also expected to play a critical role in pandemic preparedness, outbreak management, antimicrobial resistance surveillance and infectious disease control. [18]
Laboratory automation has gained much interest during the past decade with a growing number of publications evaluating the potential impact in the clinical microbiology laboratory.

The Benefits the Most Well Studied in Recent Publications Represent:

- improved standardization (enhanced quality and re- producibility of bacterial cultures)
- increased laboratory efficiency (reduced turnaround times) and higher productivity
- increased workplace safety
- reduced long-term costs and early patient management

CONCLUSION

Automation has drastically transformed clinical and diagnostic microbiology by enhancing efficiency, accuracy and standardization while reducing turnaround time and manual workload. Technologies including MALDI-TOF MS, automated susceptibility testing VITEK 2 compact, total laboratory automation and molecular diagnostic platforms with gene sequencing and resistant marker detection have become integral components of modern laboratories. Although implementation remains challenging in resource-limited settings. Continued technological advances and decreasing costs are likely to expand global adoption. Future integration of artificial intelligence and digital microbiology promises further improvements in diagnostic capability and improves patient care and health outcome.

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REFERENCES

1. Croxatto A, Prod'hom G, Greub G. Applications of MALDI-TOF mass spectrometry in clinical diagnostic

microbiology. FEMS Microbiol Rev. 2012;36(2):380-407.
2. Bizzini A, Greub G. Matrix-assisted laser desorption ionization time-of-flight mass spectrometry, a revolution in clinical microbial identification. Clin Microbiol Infect. 2010;16(11):1614-9.
3. Baron EJ, Miller JM, Weinstein MP, Richter SS, Gilligan PH, Thomson RB Jr, et al. A guide to utilization of the microbiology laboratory for diagnosis of infectious diseases. Clin Infect Dis. 2013;57(4):e22-e121.
4. Bourbeau PP, Ledeboer NA. Automation in clinical microbiology. J Clin Microbiol. 2013;51(6):1658-65.
5. Clerc O, Greub G. Routine use of MALDI-TOF mass spectrometry in clinical microbiology. Clin Microbiol Infect. 2010;16(11):1614-9.
6. Patel R. MALDI-TOF MS for the diagnosis of infectious diseases. Clin Chem. 2015;61(1):100-11.
7. Doern GV. Modern clinical microbiology. J Clin Microbiol. 2014;52(9):3128-32.
8. Van Belkum A, Dunne WM Jr. Next-generation antimicrobial susceptibility testing. J Clin Microbiol. 2013;51(7):2018-24.
9. Bact/alert- Bourbeau PP, Ledeboer NA. Automation in clinical microbiology. J Clin Microbiol 2013;51:1658-65.
10. Miller JM, Binnicker MJ, Campbell S, Carroll KC, Chapin KC, Gilligan PH, et al. Guide to utilization of the microbiology laboratory for diagnosis of infectious diseases: 2018 update. Clin Infect Dis. 2018;67(6):e1-e94.
11. Smith KP, Kirby JE. The future of clinical microbiology laboratories: automation, artificial intelligence, and machine learning. J Clin Microbiol. 2020;58(9):e01520-19.
12. Humphries RM, Hindler JA. Emerging resistance, new antimicrobial agents and antimicrobial susceptibility testing. J Clin Microbiol. 2016;54(5):1148-57.
13. JiangY.LuoJ.HuangD.LiuY.LiD. D.. Machine learning advances in microbiology: a review of methods and applications. *Front. Microbiol.* 2020;13. doi: 10.3389/fmicb. 2022.925454.
14. WindeckerD.BajG.ShiriI.KazajP. M.KaesmacherJ.GraniC.et al. Generalizability of FDA-approved AI-enabled medical devices for clinical use. *JAMA Netw. Open*8, 2025; e258052.doi:10.1001/jamanetworkopen ..8052.
15. WalterC.WeissertC.GizewskiE.Burckhar dtI.MannspergerH.HanselmannS.et al. Performance evaluation of machine-assisted interpretation of Gram stains from positive blood cultures. *J. Clin. Microbiol.* 2024; 62, e0087623. doi: 10.1128/jcm.00876-23.
16. Dauwalder O, Michel A, Eymard C, Santos K, Chanel L, Luzzati A, et al. Use of artificial intelligence for tailored routine urine analyses. Clin Microbiol Infect 2021;27: 1168.e1–6.
17. Van TT, Mata K, Dien Bard J. Automated detection of Streptococcus pyogenes pharyngitis by use of Colorex Strep A CHROMagar and WASPLab artificial intelligence chromogenic detection module software. J Clin Microbiol 2019;57:e00811–9.
18. VanstokstraetenR.Van HonackerE.EmmerechtsK.JanssenZ.Mich elC.Van Der KelenG.et al. Validation of automated bacterial suspension preparation by Colibri((R)) and plate streaking by WASP((R)) for antibiotic disk diffusion susceptibility testing. *Antibiotics (Basel)* 2025; 14. Doi: 10.3390/antibiotics14121178.