EAS Journal of Pharmacy and Pharmacology
Abbreviated Key Title: EAS J Pharm Pharmacol
ISSN: 2663-0990 (Print) & ISSN: 2663-6719 (Online)
Published By East African Scholars Publisher, Kenya

Volume-5 | Issue-4 | Jul-Aug- 2023 | DOI: 10.36349/easjpp.2023.v05i04.005

OPEN ACCESS

Review Article

Emerging Landscape of Medical Laboratory Science in India: Promises and Opportunities

Saurabh Chaturvedi, PhD[1#], Rashi Gupta, PhD[1#], Harshit Singh, PhD[2], Sachin Kumar, PhD[1*]

[1]Department of Medical Laboratory Technology, School of Allied Health Sciences, Delhi Pharmaceutical Sciences and Research University, New Delhi, India
[2]Immuno Biology Lab, Translational Health Science and Technology Institute, Faridabad- Haryana, India

Article History
Received: 05.07.2023
Accepted: 11.08.2023
Published: 17.08.2023

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: Medical Laboratory Science (MLS) is a vital component of the health care system that provides diagnostic services and contributes to medical research. In India, MLS has been evolving rapidly in terms of technology, education, regulation, and quality. This paper aims to provide a comprehensive overview of the current status and future prospects of MLS in India, with a focus on the challenges and opportunities faced by the professionals and stakeholders involved in this field. The historical development and scope of MLS in India is described, highlighting the various roles and responsibilities of MLS professionals in different settings. Further, the current trends and innovations in MLS, such as molecular diagnostics, point-of-care testing, automation, and role of artificial intelligence are discussed. The major challenges and gaps are highlighted that need to be addressed to improve the quality, accessibility, affordability, and sustainability of MLS services and infrastructure in India, such as the lack of standardization, regulation, accreditation, recognition, training, and research. Moreover, the opportunities and initiatives that can enhance the capacity and contribution of MLS services in India are mentioned, such as the adoption of new technologies, innovations, and best practices; the strengthening of human resources, education, and collaboration; the development of ethical and legal frameworks; and the creation of an enabling environment for MLS innovation and adoption. The paper intends to provide a comprehensive overview of the emerging landscape of MLS in India and to inspire further research and discussion on this topic.

Keywords: Challenges and Opportunities, Health Care System, Medical Laboratory Science, Professional Development, Quality and Sustainability, Trends and Innovations.

INTRODUCTION

Medical Laboratory Science (MLS) is the branch of medical science that deals with performing laboratory investigations relating to the diagnosis, treatment, and prevention of disease [1]. MLS curriculum involves the analysis of body fluids, tissues, and cells using laboratory techniques and instruments in the clinical laboratories, such as, pathology, bio chemistry, microbiology, haematology, immunology, molecular biology, and cytogenetics [2].

Professionals working in the field of MLS are recognized as MLS professionals which play a crucial role as healthcare detectives, providing crucial laboratory information derived from various analyses that aid physicians in patient care[3]. MLS professionals use a variety of sophisticated biomedical instruments, advanced technology, and their skills to analyze clinical specimens in a laboratory setting. The specimens of an individual include blood, urine, feces, nasal or vaginal swabs, semen, aspirates etc [4, 5]. MLS professionals also contribute to the better development of country's health outcomes, quality and approachability of health care, establishment of upgraded health systems, and promotion of economic and social development.

MLS personnel play a vital role by working tirelessly to help in the detection as well as in the support of management of various diseases, such as infectious, acute and chronic diseases, malignancies, genetic and blood disorders. Also, they help us stay well and safe during endemic, epidemic or pandemic

***Corresponding Author:** Sachin Kumar
Department of Medical Laboratory Technology, School of Allied Health Sciences, Delhi Pharmaceutical Sciences and Research University, New Delhi, India

# Dr. Saurabh Chaturvedi and Dr Rashi Gupta have contributed equally and share First Authorship

circumstances [2]. MLS workforce also are involved in progression of medical research and innovation in India. They provide precise and accurate clinical laboratory data that is crucial for developing innovative medical technologies and treatments that can improve the health care system and health of people in India [2].

However, MLS professionals also face various inimitable challenges and further come across opportunities that provide innovative solutions taking in consideration the development and regulation of health care in India. From standardization of their training and accreditation to human resources and infrastructure, there are many gaps and barriers that hinder the optimal performance and utilization of their manual skills in India. Moreover, with the right support, guidance and appropriate resources, MLS professionals can play a vital role in refining healthcare conclusions for millions of people across the country.

This narrative review aims to give an in-depth and expressive analysis of the present and forthcoming scenarios of MLS and its impression on the MLS professionals in India. We will explore the following aspects of MLS in India: the current state and advances, main areas which needs to be focused and their usages, the possible advantages and effects, and the upcoming challenges and recommendations. We hope that this review will be useful for policy makers, health professionals, researchers, educators, students, industry partners, and the general public who are interested in the promises and opportunities of MLS in India.

Current Status and Trends of Medical Laboratory Science in India: History, Development, Challenges, and Opportunities

The first medical laboratories in India were set up by the British during the colonial period, to study diseases that were common in the tropics, such as malaria, cholera, plague, and leprosy [6]. Some of the early pioneers of MLS in India were Sir Ronald Ross, who found the malaria parasite in 1897; Sir Leonard Rogers, who invented the cure for kala-azar in 1919; and Sir Upendranath Brahmachari, who made urea stibamine for kala-azar in 1922 [7].

By conducting research, offering education, setting standards, and providing accreditation, the Indian Council of Medical Research (ICMR), All India Institute of Medical Sciences (AIIMS), Postgraduate Institute of Medical Education and Research (PGIMER), and National Accreditation Board for Testing and Calibration Laboratories (NABL) have all helped to advance MLS in India. These organizations have played a significant role in the expansion and diversification of the MLS in India.

MLS is a dynamic and developing field that spans numerous applications and disciplines in India. These comprise clinical pathology, haematology, immunology, molecular biology, cytogenetics, and clinical microbiology in addition to clinical biochemistry. From The National AIDS Control Programme (NACP) to the Revised National Tuberculosis Control Programme (RNTCP), from the Integrated Disease Surveillance Programme (IDSP) to the National Vector Borne Disease Control Programme (NVBDCP), the MLS workforce is at the forefront of many public health initiatives and programmes in India [8].

In India, MLS is a field that is expanding quickly. Good Clinical Laboratory Practices (GCLP) guidelines have been published by the ICMR, which will guarantee quick and correct processing of biological samples, early and accurate diagnosis, patient safety, and desired clinical outcomes [6].

To highlight the significance of MLS services and ensure their quality and regulation, the National Commission for Allied and Healthcare Professions Act 2021 was enacted that aims to improve the quality and accessibility of health services in India. It recognizes the vital role of allied and healthcare professionals, who are trained to support the diagnosis, treatment and prevention of diseases, and to promote health and wellness of the population. This act empowers the Commission to prescribe minimum standards of education, infrastructure, faculty, examination, ethics and grievance redressal for allied and healthcare institutions. Further, it promotes interdisciplinary collaboration and integration among different categories of health professionals, as well as with the medical, dental, nursing and pharmacy councils. It also creates opportunities for career advancement and professional development for allied and healthcare professionals. Added to the above key features and benefits, it enhances the availability, accessibility, affordability and quality of health services for the people of India [9]. Further, uniting all the MLS associations and professionals under a single organization was a tough but necessary challenge for the overall improvement of MLS field and professionals. Therefore, the Indian Confederation of Medical Laboratory Science (ICMLS) was formed in 2016 as a national registered body for MLS Associations, Academic bodies, industry partners and individual members. For the smooth functioning of the organization, the ICMLS got registered in 2022 as a national confederation of medical laboratory science at New Delhi under Indian Trust Act-1882 [8]. The ICMLS has been dedicating itself to the standardization, recognition, growth and excellence of medical lab education & services since its creation. The ICMLS experts have contributed to various professional development initiatives implemented by the Indian Government such as establishing uniformity and revision of the designation, pay scales, entry level qualification/ recruitment rules by carrying out cadre review of MLS personnel, designing curriculum, defining job roles, and devising career pathway for

MLS professionals [8]. Also, ICMLS launched the National Medical Laboratory Professional Week (NMLPW) in India, which has now turned into a national celebration for medical laboratory professionals throughout the nation. ICMLS also conducts its Scientific Conferences annually for the scientific advancement of its members.

Over time, MLS personnel in India have seen a change in their roles and have developed into an essential part of the healthcare system, helping with patient diagnosis and treatment. In the past, their main job was to do simple tests on blood and other specimens, but because to advancements in medical laboratory technology, they are now able to carry out more complex tests.

The need for MLS experts has grown dramatically, and more skilled people are required to carry out various diagnostic procedures due to the development in hospitals and clinics in India, particularly in metropolitan areas. This has led to a significant demand for MLS programmes, which provide scientific students with a profitable employment alternative. In addition, there is a dire need for additional qualified specialists. The expansion of India's healthcare system and requirement of the need for more qualified specialists, has led to the making of MLS programme very sought-after (Table 1). In the past, their primary responsibility involved conducting basic tests on blood and other specimens. Personnel trained in the field of MLS in India have a promising future as they can now perform more complicated tests due to the advancement of in this field. This will enable them to have a greater impact on patient care and treatment. However, with the advancements in medical technology, they now have the capability to perform more sophisticated examinations.

MLS field in India faces several challenges such as the lack of courses that expose students to new trends in the profession. The clinical laboratory market should follow the example set by other sectors, which is one of networks, integration, outsourcing, and a focus on core competences. It should also add value by offering knowledge services pertaining to in vitro diagnostic services [10]. Efficiency-boosting business models, such as horizontal and/or vertical integration, have been proposed.

Table 1: Opportunities and possibilities for India's Medical Laboratory Science development across four categories

Category	Possibilities	Opportunities
Infrastructure	Upgradation of existing infrastructure and creation of new infrastructure	Public-private partnerships for infrastructure development
Workforce	Training and development of existing workforce and recruitment of new workforce	Collaboration with academic institutions for training and development
Education	Development of new courses and curricula and upgradation of existing courses and curricula	Collaboration with industry for curriculum development
Policy	Development of new policies and upgradation of existing policies to support the growth of medical laboratory science in India	Collaboration with government for policy development

How the COVID 19 highlighted the opportunity of Medical Laboratory Technologists

The Coronavirus Disease–2019 (COVID-19) has had a devastating impact worldwide, infecting over one million people and resulting in more than 50,000 deaths [11]. The global health system has faced overwhelming challenges, with many countries losing a significant number of healthcare professionals in their efforts to combat the virus. The importance of medical laboratories in public health matters cannot be overstated, especially during pandemics like COVID-19. The doctors and nurses are the visible warriors in the battle against the diseases, but the MLS professionals are the secret allies who empower them with their skills and knowledge [12].

MLS is the basis of clinical medicine, and the role of experts in pandemic like COVID-19 is of foremost importance. Trained professionals play a vital role in the forefront of this effort by testing clinical specimens from infected and recovered patients, serving as disease detectives in the fight against the COVID-19 pandemic The responsibilities of MLS workforce in combating COVID-19 were far-reaching and thus comprehend various critical tasks, including but not restricted to diagnosis, intensive care, validation of recovery, safety and efficacy testing of antiviral agents, vaccine finding and development, and corroboration of testing protocols and kits.

The noteworthy contributions of MLS professionals shed light on their expertise and dedication that are invaluable in the battle against COVID-19. Recognition and support for these professionals are vital to strengthen the healthcare system's response and ultimately save lives during this challenging and unprecedented time.

The importance of MLS workforce in the healthcare industry has come to light as a result of the COVID-19 pandemic, and this has raised awareness of their significance on a global level. Their role in the

fight against the COVID-19 pandemic is multifaceted and goes beyond just diagnosis. Some of the crucial responsibilities of MLTs in combating the COVID-19 pandemic included:

- **Diagnosis:** Performing diagnostic tests to identify SARS-CoV-2, the virus causing COVID-19, in patients.
- **Monitoring:** Monitoring the disease progression in COVID-19 patients through repeated testing and analysis of laboratory data.
- **Confirmation of Recovery:** They are the ones who confirm whether a patient has beaten COVID-19 or not, by examining their test results.
- **Safety and Efficacy Testing of Antiviral Agents**: They contributed to the testing and evaluation of broad-spectrum antiviral agents to assess their safety and efficacy in treating COVID-19.
- **Vaccine Discovery and Development:** They were involved in the testing phase during development of vaccine, thus helping to measure the efficacy of possible COVID-19 vaccine candidates.
- **Validation of Testing Protocols and Kits:** They validated testing protocols and RT-PCR kits to ensure the precision and trustworthiness of COVID-19 testing.
- **Health Encouragement:** They actively engage in health encouragement efforts at various levels to promote public awareness and understanding of COVID-19 and preventive measures.

The contributions of MLS experts in these areas are crucial for effectively handling and battling the COVID-19 pandemic, ensuring precise diagnoses, monitoring patient's improvement, and supporting the progress in treatments and preemptive measures. Their expertise was essential in the overall effort to regulate and control the SARS-CoV2 spread and safeguard public health. In dealing with the pandemics like COVID-19, a multidisciplinary approach is essential and the full integration of MLS into the multidisciplinary team is crucial for effective containment.

Key Domains and Applications of Medical Laboratory Science in India

MLS is a field that helps to improve health care and health systems in India by performing laboratory tests for disease diagnosis, treatment, and prevention. It is also a rewarding and fulfilling career choice for those who are into science and medicine. There are various courses available for those who want to pursue a career in MLS in India, at different levels of education, such as diploma (DMLT), bachelors (BSc in MLT), masters (MSc in MLT), and doctorate (PhD) in the relevant field. The course details, such as eligibility, duration, curriculum, fees, faculty, infrastructure, and job prospects, may differ depending on the course and institution.

MLS is a healthcare course that trains students to become competent lab technologists capable of collecting and analyzing blood and other body fluids that are vital in both the diagnosis and treatment of patients [13]. They are the proficient experts who work in assorted fields of clinical laboratory, such as blood banking, clinical biochemistry, haematology, immunology, histopathology, and medical microbiology.

They conduct basic prenatal blood tests to advanced examinations that assist in detecting and diagnosing severe ailments like cancer, HIV/AIDS, and diabetes, they perform a broad spectrum of laboratory tests [14]. It is the duty of laboratory professionals to guarantee the precision of test outcomes and communicate the laboratory findings to doctors, who use this information to make decisions about the medical care of their patients. Costly sophisticated electronic equipment, computers, and instruments are used by laboratory professionals in their work [15].

They are the multi-talented professionals who examine samples in the clinical laboratory using a variety of procedures such as manual white blood cell differential count, bone marrow counts, microscopic analysis, and advanced analytical technology. Moreover, they aid physicians in choosing suitable laboratory tests and ensuring appropriate specimen collection methods, thereby providing crucial support to healthcare providers [16].

Also, they have the responsibility to identify deviations in their test outcomes and possess the ability to rectify issues with the instruments. They oversee the functioning of advanced analyzers available in the market and troubleshoot any problems that arise during the process. They carry out equipment validations, calibrations, and quality controls. In laboratory medicine, quality assurance pertains to verifying the accuracy of every stage of testing process, which is critical for dependable medical decision-making and efficient patient care [17].

The analytical error rate has fallen significantly over the last few decades, owing primarily to improvements in the reliability and standardization of analytical techniques, reagents, and apparatus. Furthermore, developments in information technology, quality control, and quality assurance procedures have aided in this improvement [18].

Fields in Medical Laboratory Science

Laboratory testing comprises a wide range of disciplines, including clinical biochemistry, medical microbiology (involving bacteriology mycology and virology), haematology/blood group serology, human anatomy and physiology, immunology, histopathology and cytology, parasitology, and molecular biology (Figure 1). Within these areas, MLTs play a vital role in

generating accurate laboratory data that is essential for detecting various conditions such as infectious pathogens like bacteria or viruses, cancer, heart attacks, diabetes, and drug poisoning. Their work goes beyond just identifying diseases; they also monitor the quality of testing and collaborate with other healthcare team members to achieve better health outcomes for patients [19, 20].

The unsung heroes of the health care system are MLS professionals. By conducting tests on blood, tissue, and other biological fluids, they assist doctors and nurses in diagnosing and treating patients. Medical technologists, clinical laboratory scientists, medical laboratory scientists, clinical laboratory technicians, and medical laboratory assistants are a few of the occupations in this sector.

In essence, these multi-talented professionals can be likened to a "disease detective" as they help identify the root cause of diseases through the examination and analysis of blood, tissue, and other body fluids. Moreover, MLS professionals working in the field of clinical medicine contribute in monitoring disease progression and treatment effectiveness, highlighting their indispensable role in the healthcare system. Undeniably, it is essential to distinguish that behind every accurate and consistent laboratory result, there is a skilled and expert MLS professional.

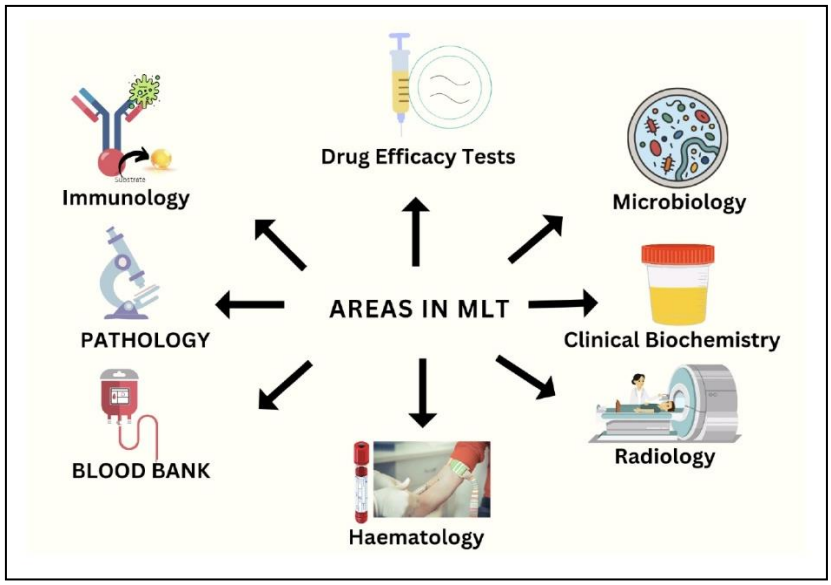

Figure 1: Areas in Medical Laboratory Science or Medical Laboratory Technology

Medical Laboratory Technology (MLT) or Medical Laboratory Science (MLS) is a fascinating field that explores the secrets of life at the molecular level. MLS professionals use cutting-edge techniques and instruments to analyze biological samples and reveal the causes and cures of diseases. MLS is divided into several areas, each with its own focus and challenges. Areas are Immunology, Drug Efficacy Tests, Microbiology, Radiology, Clinical Biochemistry, Haematology, Blood Bank, Pathology.

Medical Laboratory Science in India: A Catalyst for Health Care Development

MLS is the cornerstone of India's healthcare system. It gives medical professionals the diagnostic data they need to choose the best course of treatment for their patients. MLS improves the standard and accessibility of healthcare by guaranteeing that laboratory services are accessible to all patients, regardless of their location or socioeconomic position. In addition, it encourages cooperation and knowledge sharing among politicians, academics, and healthcare practitioners, which may result in more effective and efficient healthcare delivery. Finally, through promoting research and innovation and creating jobs, MLS encourages economic progress and social development [6].

By providing data for patient care and treatment, illness prevention and control, and the creation of public health policy, MLS is a crucial component that supports healthcare systems. It's like a bridge that fosters collaboration between healthcare professionals, researchers, and policymakers. This collaboration leads to more effective and efficient healthcare delivery. They monitors disease trends and outbreaks, identifies emerging health threats, and evaluates the effectiveness of public health interventions. MLS is like a critical component of quality health care that creates direct enhancements within the lives of patients and within the effectiveness of individual health care workers [21].

MLS is an important driver of the Indian economy that promotes economic growth and social development by creating jobs and supporting research

and innovation. It is a critical component of quality health care that creates direct enhancements within the lives of patients and within the effectiveness of individual health care workers. MLS provides data for patient care and treatment, disease prevention and control, and public health policy development. It fosters collaboration and knowledge exchange between healthcare professionals, researchers, and policymakers, which can lead to more effective and efficient healthcare delivery [7].

India's Medical Laboratory Science: A look into the future

MLS is a substantial field in health care system of India that plays a key role in the investigation and treatment of diseases. There are several breaches and blocks that need to be conversed in order to enhance the capacity and quality of MLS personnel and infrastructure in India.

Addressing the gaps and barriers

There is a need to recognize and sermon the gaps and barriers that hamper the ideal functioning of MLS services in India, such as lack of standardization, certification, accreditation, guidelines, and acknowledgement of MLS professionals and institutions; scarcity of qualified and skilled MLS personnel; meagre infrastructure, equipment, resources and supplies; little cognizance and utilization of MLS services among the public and health care workers; and ethical issues such as confidentiality, discretion, consent, excellence, and quality assurance [5]. Some prospective solutions include emerging and instigating national policies, guidelines, and integrity for proper utilization of professionals assistance; consolidating the education, training, documentation, and career development of MLS professionals; enhancing the infrastructure, technology, and resources for MLS workforce; promoting the cognizance, mandate, and utilization of MLS services; and ensuring the ethical and legal aspects of MLS personnel practice.

Boosting the competencies and quality of MLS professionals and infrastructure

There is an urgent need to augment the capacity and eminence of MLS personnel and infrastructure to capacitate the increasing demand and intricacy of MLS services in India. This can be accomplished by escalating and intensifying the MLS curriculum, education and training courses to contain various corrections, levels, and modes of learning; refining the recruitment process, retention policies, enthusiasm, and performance of MLS professionals through enticements, acknowledgement, appreciation, and their feedback; implementing innovative and advanced technologies such as automation, point-of-care testing, and molecular diagnostics (Table 2). to improve the competence, accuracy, precision, and cost-effectiveness of MLS services; and establishing a vigorous quality management system for MLS services that includes quality control, quality assurance, accreditation, and quality assessment.

Table 2: Upsides and Downsides of Point-of-Care Testing, Automation and Molecular Diagnostics in Medical Laboratory Science

	Point-of-care testing [25-27]		**Automation [28, 29]**		**Molecular diagnostics [30, 31]**	
Category	**Advantages**	**Limitations**	**Advantages**	**Limitations**	**Advantages**	**Limitations**
Precision	Faster turnaround time for results compared with testing sent to a central laboratory	Less precise, accurate, specific, or sensitive than testing performed in a clinical laboratory setting	Improved accuracy and precision of test results	Higher initial costs, enhanced expenditure for supplies, space requirements and infrastructure constraints	Increased sensitivity and specificity of test results	Higher cost compared with traditional methodologies
Staffing	Can be used by clinical staff to obtain test results for more efficient diagnosis or treatment decisions	Usually performed by staff who are untrained in laboratory medicine	Reduced workload for laboratory staff and increased efficiency of laboratory operations	Staff overcrowding, increased generation of noise and heat, higher risk of downtime	Reduced workload for laboratory staff and increased efficiency of laboratory operations	Equipment and reagent costs could be prohibitive to some laboratories
Cost	Lower cost compared with testing sent to a central laboratory	Higher reagent costs per test than laboratory-based assays	Reduced test costs and increased return on investment on the long-term	Enhanced expenditure for supplies	Lower cost compared with traditional methodologies in some cases	Higher cost compared with traditional methodologies in some cases
Patient care	Near-patient testing that is performed near or at the site of a patient, with the result leading to possible change in the care of the patient	Jeopardizes the quality of the test results	Improved turnaround time for test results and faster diagnosis or treatment decisions	Jeopardizes the quality of the test results	Faster turnaround time for test results and faster diagnosis or treatment decisions	Jeopardizes the quality of the test results

Fostering ethical and regulatory principles and standards for MLS

There is a need to uphold and promote norms and guidelines for MLS that protect the rights and interests of patients, health care workforce, MLS professionals, institutions, and society. This can be achieved by evolving and implementing a code of ethics for MLS experts that sets the morals, ideals, obligations, criteria, and benchmarks of professional practice; forming a legal structure for MLS that manages the scope of work, licensure, enrollment, qualification, endorsement, etc. of MLS personnel and organizations; devising a protocol for reporting, examining, settling, and precluding errors, complaints, malpractice, and negligence in MLS; safeguarding the privacy, consent, and confidentiality of patients and their test findings; and advancing the social commitment and accountability of MLS personnel and establishments towards the public health and well-being.

Developing a conducing environment for MLS innovation and utilization

There is a need to create an enabling environment for MLS innovation and adoption that fosters the generation, dissemination, and utilization of new knowledge, skills, technologies, and practices in MLS. This can be facilitated by encouraging and supporting the research, development, and evaluation of new methods, tools, products, and services in MLS that address the unmet needs and challenges of the health care system ; creating a platform for collaboration, communication, and exchange of information, ideas, experiences, and best practices among various stakeholders involved in MLS, such as researchers, educators, practitioners, policymakers, industry partners, etc. ; building the capacity and competency of MLS professionals and institutions to adopt and implement the innovations in MLS through training, guidance, support, and feedback; and evaluating the impact and outcomes of the innovations in MLS on the quality, accessibility, efficiency, effectiveness, safety, and satisfaction of MLS services.

Integration of Artificial Intelligence (AI): Vital component in Modern Laboratory Technology

AI can be useful in medical laboratories for various purposes, such as:

Diagnostics: AI can help diagnose diseases and conditions by analyzing laboratory results, medical images, patient records, and other data sources. AI can also suggest possible treatments or preventive measures based on the diagnosis [22].

Reviewing risk profiles of patients: AI can help identify patients who are at high risk of developing certain diseases or complications, such as sepsis, cancer, or heart failure. AI can also monitor the vital signs of patients and alert clinicians if there are any changes or anomalies.

Laboratory results: AI can help improve the quality and efficiency of laboratory testing by automating tasks, reducing errors, optimizing workflows, and providing feedback. AI can also help interpret and visualize laboratory data in a meaningful way [22-24].

Financial analytics: AI can help optimize the use of resources and reduce costs in medical laboratories by analyzing data on inventory, demand, supply chain, billing, and reimbursement [22].

AI has the potential to transform the field of medical laboratory technology by providing faster, more accurate, and more personalized services to patients and clinicians. However, there are also some challenges and barriers to implementing AI in laboratory medicine, such as high investment costs, lack of proven clinical benefits, privacy concerns, ethical issues, and regulatory frameworks [2]. Therefore, it is important to educate the laboratory community on the value of AI and conduct research to prove its clinical utility and address its implementation challenges.

CONCLUSION

MLS is an essential and vibrant domain of health care system that aids in the recognition, avoidance, and remedy of various diseases. India, being a growing nation with a vast and diverse population, confronts many obstacles and chances in the area of MLS. This article has explored the present scenario, development, challenges and potentials of MLS in India, encompassing various dimensions such as education, training, regulation, accreditation, quality, innovation, research, and collaboration. Among the developments in field of MLS, The National Commission for Allied and Healthcare Professions Act 2021, ICMLS and NMLPW are breakthrough action to fortify India's health system. Commission will facilitate the production of a proficient health workforce that can satisfy the increasing demand, elevate the level of health care, overcome the health inequalities, and accomplish the mission of universal health coverage. ICMLS partners with global medical lab organizations for the synchronization and enhancement of medical laboratory science education and practices.

Also, emphasizes has been laid on some of the commendable practices and accomplishments of MLS in India, as well as the fields that demand development and engagement. The authors conclude that MLS in India has a lot of potential and promise to improve the health outcomes and well-being of the people, as well as to contribute to the global advancement of MLS. However, this requires a cooperative and coordinated attempt from all the concerned entities, including the government, academia, industry, professional bodies, health care providers, patients, and society overall. This review will serve as a valuable resource and guide for

anyone intrigued or involved with MLS field in India [8, 21].

Limitations and Challenges

The article acknowledges the limitations and challenges that exist in the field of MLS in India. The paucity of exhaustive and credible data on the scenario, directions, challenges, and possibilities of MLS in India, which hinders the evidence-based planning, monitoring, and evaluation of MLS policies and programs. The heterogenicity and complication of the health care system in India, which presents obstacles for the standardization, harmonization, and integration of MLS services across different regions, sectors, levels, and settings. The quick shifts and improvements in the field of MLS, which necessitate persistent update and enhancing of the knowledge, skills, technologies, and practices of MLS personnel and establishments. The voids and hindrances that impede the optimal operation of MLS in India, such as lack of awareness, recognition, demand, utilization, regulation, accreditation, quality assurance, ethical frameworks, etc. of MLS services among various stakeholders.

Prospective future directions and recommendations

In this review we have discussed and put forward some viable approaches and recommendations to increase the capacity, quality, and impact of MLS in India, such as solidifying the policy framework, streamlining the curriculum and certification, upgrading the infrastructure and technology, establishing ethical and legal frameworks, creating a facilitative environment for innovation and adoption, and facilitating collaboration and communication among various stakeholders. Authors recommends some fields for additional research and action to overcome these limitations and challenges and to augment the capacity, quality, and outcome of MLS in India. Carrying out more methodical and thorough research on the different facets of MLS in India such as needs analysis, situation review, impact assessment, best practices recognition etc. to generate more trustworthy and germane data and evidence for informed decision-making and policy-making in MLS. Designing and implementing national policies, guidelines, and standards for MLS that are congruent with the global and regional directions and regulations and that are flexible to the local needs and circumstances of different regions, sectors, levels, and settings in India. Advancing the innovation and utilization of new methods, tools, products, and services in MLS that resolve the unmet needs and challenges of the health care system in India and that augment the efficiency, accuracy, swiftness, cost-effectiveness, safety, and satisfaction of MLS services.

Disclosure: All the authors declared no competing interests.

Contributions

SC, RG, HS, and SK designed the study. All authors contributed to drafting of the manuscript, revising manuscript content, approval of the final version, and providing intellectual content of critical importance to the work described.

Source of Funding: No source and support of funding.

REFERENCES

1. Shahangian, S., & Snyder, S. R. (2009). Laboratory medicine quality indicators: a review of the literature. *American journal of clinical pathology*, *131*(3), 418-431.
2. Leber, A. L., Peterson, E., & Dien Bard, J. (2022). The hidden crisis in the times of COVID-19: critical shortages of medical laboratory professionals in clinical microbiology. *Journal of clinical microbiology*, *60*(8), e00241-22.
3. Uchejeso, O. M., Maduka, M. K., & Obiora, E. R. (2020). Medical laboratory science; the distortion of nomenclature across the globe. *New Zealand Journal of Medical Laboratory Science*, *74*(1), 52-53.
4. Akuyam, S. A. (2014). The role of medical laboratory diagnosis in quality healthcare delivery system and its problems, challenges and prospects in Nigeria. *J Med Lab Sci*, *23*, 7-16.
5. Obeta, M. U., Maduka, K. M., Ofor, I. B., & Ofojekwu, N. M. (2019). Improving quality and cost diminution in modern healthcare delivery: the role of the medical laboratory scientists in Nigeria. *International Journal of Business and Management Invention (IJBMI)*, *8*(03), 8-19.
6. Mushtaq, M. U. (2009). Public health in British India: A brief account of the history of medical services and disease prevention in colonial India. *Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine*, *34*(1), 6.
7. https://main.mohfw.gov.in/sites/default/files/Model%20Curriculum%20Handbook-Medical%20lab%20sciences.pdf (Accessed on 01 August 2023)
8. Sachdeva, K. S., Kumar, A., Dewan, P., Kumar, A., & Satyanarayana, S. (2012). New vision for Revised National Tuberculosis Control Programme (RNTCP): universal access-"reaching the un-reached". *The Indian journal of medical research*, *135*(5), 690.
9. a2021-14.pdf (indiacode.nic.in) (Accessed on 01 August 2023)
10. Bossuyt, X., Verweire, K., & Blanckaert, N. (2007). Laboratory medicine: challenges and opportunities. *Clinical chemistry*, *53*(10), 1730-1733.
11. Ibeh, I. N., Enitan, S. S., Akele, R. Y., & Isitua, C. C. (2020). A Review of the COVID-19 Pandemic and the Role of Medical Laboratory Scientists in containment. *J Med Lab Sci*, *30*(1), 68-89.

12. Fang, B., & Meng, Q. H. (2020). The laboratory's role in combating COVID-19. *Critical reviews in clinical laboratory sciences*, *57*(6), 400-414.
13. Teshima, D. Y., Yamaguchi, R., & Izutsu, S. (2018). Medical School Hotline: The Department of Medical Technology at the John A. Burns School of Medicine, University of Hawai 'i at Manoa. *Hawai'i Journal of Medicine & Public Health*, *77*(10), 259.
14. Leber, A. L., Peterson, E., & Dien Bard, J. (2022). The hidden crisis in the times of COVID-19: critical shortages of medical laboratory professionals in clinical microbiology. *Journal of clinical microbiology*, *60*(8), e00241-22.
15. Olver, P., Bohn, M. K., & Adeli, K. (2023). Central role of laboratory medicine in public health and patient care. *Clinical Chemistry and Laboratory Medicine (CCLM)*, *61*(4), 666-673.
16. Arneth, B. M., & Menschikowki, M. (2015). Technology and new fluorescence flow cytometry parameters in hematological analyzers. *Journal of clinical laboratory analysis*, *29*(3), 175-183.
17. Lundberg, G. D. (1981). Acting on significant laboratory results. *Jama*, *245*(17), 1762-1763.
18. Plebani, M. (2006). Errors in clinical laboratories or errors in laboratory medicine?. *Clinical Chemistry and Laboratory Medicine (CCLM)*, *44*(6), 750-759.
19. Olson, H., Ronayne, C., Anakin, M., Meldrum, A., & Rich, A. (2020). Working together in clinical pathology: An interprofessional education initiative for dentistry, oral health, and medical laboratory science teachers and students. *MedEdPublish*.
20. Nimer, R., Swedan, S., Kofahi, H., & Khabour, O. (2021). Increased adherence to infection control practices among medical laboratory technicians during the COVID-19 pandemic: a self-reported survey study. *Annals of global health*, *87*(1).
21. Kruk, M. E., Gage, A. D., Arsenault, C., Jordan, K., Leslie, H. H., Roder-DeWan, S., ... & Pate, M. (2018). High-quality health systems in the Sustainable Development Goals era: time for a revolution. *The Lancet global health*, *6*(11), e1196-e1252.
22. Paranjape, K., Schinkel, M., Hammer, R. D., Schouten, B., Nannan Panday, R. S., Elbers, P. W., ... & Nanayakkara, P. (2021). The value of artificial intelligence in laboratory medicine: current opinions and barriers to implementation. *American Journal of Clinical Pathology*, *155*(6), 823-831.
23. Bohr, A., & Memarzadeh, K. (2020). The rise of artificial intelligence in healthcare applications. In *Artificial Intelligence in healthcare* (pp. 25-60). Academic Press.
24. Xu, Y., Liu, X., Cao, X., Huang, C., Liu, E., Qian, S., ... & Zhang, J. (2021). Artificial intelligence: A powerful paradigm for scientific research. *The Innovation*, *2*(4).
25. https://ascls.org/wp-content/uploads/2012/11/Brochure_POCT_Use_Limitations_Providers_2019.pdf(Accessed on 01 August 2023)
26. Shaw, J. L. (2021). Point-of-care testing: the good, the bad, and the laboratory oversight. *The Journal of Applied Laboratory Medicine*, *6*(4), 1090-1093.
27. Wool, G. D. (2019). Benefits and pitfalls of point-of-care coagulation testing for anticoagulation management: an ACLPS critical review. *American journal of clinical pathology*, *151*(1), 1-17.
28. Advances in Clinical Laboratory Automation. AACC.org. https://www.aacc.org/cln/articles/2014/december/lab-automation (Accessed on 01 August 2023)
29. Kumar, V., & Gill, K. D. (2018). *Basic concepts in clinical biochemistry: a practical guide*. Springer Singapore.
30. Molecular Diagnostics in the Medical Laboratory in Real Time (asm.org). https://asm.org/Articles/2021/July/Molecular-Diagnostics-in-the-Medical-Laboratory-in (Accessed on 01 August 2023)
31. Is it Time to Substitute Culture With Molecular Diagnostics for Infectious Diseases? AACC.org. https://www.aacc.org/cln/cln-industry-insights/2022/is-it-time-to-substitute-culture-with-molecular-diagnostics-for-infectious-diseases (Accessed on 01 August 2023)

Cite This Article: Saurabh Chaturvedi, Rashi Gupta, Harshit Singh, Sachin Kumar (2023). Emerging Landscape of Medical Laboratory Science in India: Promises and Opportunities. *EAS J Pharm Pharmacol, 5*(4), 113-121.