



Point of Care Testing in Modern Medical Laboratory Practices: Advances and Clinical Applications

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ABSTRACT

Point of care testing is a way of doing things in medical laboratory sciences. It lets doctors do tests right where the patient is or really close by. This is different from the way of doing lab tests, where they have to send the samples somewhere else and wait a long time for the results. With point of care testing doctors can get the results faster which helps them make decisions right away. New machines like analyzers and biosensors are being made, which makes point of care testing better and more accurate. These machines are used in lots of places like emergency rooms, operating rooms and even in ambulances. Point of care testing helps doctors check things like blood sugar levels, blood gases and if someone is having a heart attack. It also helps them figure out if someone has an infection or if a woman is pregnant. Using machines like nucleic acid amplification and electrochemical biosensors makes point of care testing even better and faster. All these new machines and methods help doctors find out what is wrong with someone sooner start treatment away and keep an eye on the patient all the time. This is really important for people who're very sick or have long-term health problems. To make sure point of care testing works properly doctors and nurses need to be trained and the machines need to be checked regularly. They also need to make sure the results are accurate and recorded correctly. There are some problems with point of care testing like the machines can be expensive and the results might not always be the same. If they can figure out these problems, point of care testing can be really helpful. In the future point of care testing might get even better with automation, artificial intelligence and special sensors that people can wear. It could even be possible to do tests from away which would be really helpful for people who live in remote areas. In all point of care testing is a big change, in the way medical labs work and it can really help patients get better care. It can make healthcare more efficient help people get faster and save time. They need to keep working on making the machines better and making sure everything is done correctly.

Keywords: Point-of-Care Testing (POCT); Rapid Diagnostic Testing; Biosensors; Nucleic Acid Amplification; Electrochemical Sensors;.



GRAPHICAL ABSTRACT

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1. INTRODUCTION

POCT has gained more and more prominence in contemporary medical laboratory practice due to the possibility of conducting diagnostic procedures either at the point of care itself or at nearby locations. In contrast to the traditional laboratory tests in which samples of body fluids or tissues are taken from patients and sent to specialized laboratories for analysis, POCT offers faster results that can aid in making clinical decisions (Akceoglu et al,2021). The primary objective of POCT is to minimize the time span between specimen collection and results obtained by patients that is known as turn-around-time (TAT). Fast access to laboratory data may be especially helpful when physicians have to make urgent decisions related to the diagnosis, treatment, monitoring of patients' health state or their referral to other medical institutions. In the era of health care that focuses on prompt, convenient, patient-oriented and cost-effective solutions, POCT has evolved from rather primitive bedside tests to advanced diagnostic procedures (Alter,D.N et al,2021). POCT development has been largely attributed to technological advancements in fields of analytical chemistry, miniaturization, electronics, biosensors, microfluidics, information technology, and molecular diagnostics (Badrack,T. et al,2021). The first

generation POCTs were mainly used for performing simple tests, for example, urinary pregnancy tests and glucose tests in blood samples. Modern POCTs have advanced from being able to carry out simple tests to conducting complex analyses of small amounts of whole blood, plasma, serum, urine, saliva, or other bodily fluids. The current POCTs are portable, battery-powered, automated, and easy-to-use due to the reduced need for specimen manipulation. Biosensors have contributed to the development of POCTs through their ability to transduce the biological or chemical interactions to electrical signals. This has enabled electrochemical, optical, immunological, and molecular detection systems to be incorporated in POCTs to allow the analysis of a variety of analytes and biomarkers. In addition, microfluidics have advanced the technology through integration of specimen manipulation, reagent mixing, reaction, and detection in cartridge-based systems or lab-on-a-chip formats (Brun, T. et al, 2021). POCT finds extensive applications in the clinical setting. One of the oldest applications of POCT involves testing of blood glucose levels, which are commonly applied in patients with diabetes and glucose abnormalities in hospitals. Blood gas and electrolyte analysis is especially suitable in the ED, ICU, operating theater, and other critical care environments where fast results on the patient's oxygenation, ventilation, acid-base balance, and electrolytes may be needed. Testing of cardiac markers including troponin level can help in evaluating the patients with suspected acute coronary syndrome together with clinical features and other diagnostic tests. Testing for coagulation parameters like PT/INR can help monitor patients undergoing some anticoagulants. There are also POCTs used in pregnancy testing, haemoglobin estimation, infectious disease screening, urinalysis, lactate, ketones, and other tests (Illiescu, F.S et al, 2021). This significance of point-of-care testing is especially prominent in the field of emergency and critical-care medicine. The shortened turnaround times in this type of medicine help increase the speed with which doctors receive necessary information for the proper patient treatment. The rapid assessment of blood gases, for instance, may help assess critically ill patients, while rapid measurement of glucose and electrolytes may help recognize metabolic disorders. The point-of-care testing in emergency situations may also be helpful in quicker triaging and decisions on treatment. Likewise, in the case of ambulances and other out-of-hospital settings, portable diagnostics may help obtain laboratory data before the arrival of the patient to the hospital (Bhati D et al, 2023).

2. EVOLUTION OF POINT-OF-CARE TESTING TECHNOLOGIES IN MODERN MEDICAL LABORATORY PRACTICE

Point of care testing instruments have developed since the early stages of basic bedside diagnostics into becoming an important constituent of laboratory equipment. At first, most of the diagnostic tests were done in laboratories with the help of high-quality instrumentation, and in many cases, the test results were obtained within hours or days (Park & H.D, 2021). The development of the first simple diagnostic instruments such as the urine test strips, the blood glucose meters, and the pregnancy tests showed that some diagnostic tests could be conducted close to the patient. Using the achievements in biotechnology, electronics, microfluidic, biosensors, and molecular diagnostics, the POCT instruments have become smaller, faster, portable, and easier to use. The examples of the modern POCT are glucose meters, blood gas and electrolytes analysers, haemoglobin meters, coagulation testing devices, cardiac marker tests, infectious disease tests, and portable molecular diagnostics. POCT technologies can provide the results of diagnostics tests within several minutes (Alhan O et al, 2023). The evolution of the POCT is associated with the implementation of computerization, wireless communication, quality control automation, and connections with the laboratory information system and electronic health record system. The connectivity became an important aspect of POCT, as it allows transferring the test results into the electronic form (Dang A, 2023).

Therefore, POCT can be performed not only in the laboratory but also in emergency departments, intensive care units, ambulatory facilities, ambulances, rural clinics, and community health facilities. Thus, POCT has improved the availability and rapidity of diagnosis and is especially important for fast clinical decision making (Velasco-Hernandez et al, 2021). At the same time, the accurate analysis, quality assurance, proper training of the operators, biosafety, and correct handling of the results are still important for the reliability of POCT. Overall, the evolution of POCT can be considered as the transition from the laboratory-based tests to the fast decentralized patient-based diagnostics thanks to the achievements in microfluidic, biosensors, miniaturization, and molecular technologies (Hayden, O. et al, 2022).

3. CLINICAL APPLICATIONS IN LABORATORY MEDICINE

Point-of-care testing (POCT) has become a part of modern laboratory medicine because POCT can carry out diagnostic tests right where the patient is cared for and because POCT delivers results quickly enough to help doctors make decisions immediately (Kalia, R. Et al 2022). I have seen how POCT saves time in wards. In practice POCT is widely used to check blood glucose levels in people with diabetes. POCT also checks blood gases and electrolyte levels in patients who're very ill. In cases where a heart attack is suspected POCT measures biomarkers such as troponin. When patients take blood thinners, POCT tests clotting for example PT/INR. Other important places for POCT are emergency departments, care units, operating theatres, outpatient clinics, ambulances and rural or low resource hospitals. In these settings POCT gives data that can be especially useful (Salgado Fernandez & Gomes, K.B, 2022). Infectious disease care can also gain from POCT and from tests, for malaria, HIV, COVID 19, influenza and other infections depending on the technology available and the setting (Teebagy, S. Et al 2022). Pregnancy tests haemoglobin checks, lactate readings, ketone tests and urinalysis are common POCT studies. By measuring blood gases, pH, electrolytes, glucose and lactate POCT helps doctors evaluate a patient's condition and decide on treatment right away especially in emergencies and critical care. POCT becomes more important when regular laboratory tests need the sample to be sent, processed and then waited for which takes longer (Zhang et al., 2022). Contemporary POCT instruments are increasingly portable, automated, and digitally connected, allowing test results to be transferred to laboratory information systems and electronic health records, thereby improving documentation, result management, and clinical communication (Yang, S-M, et al, 2022). However, reliable POCT requires appropriate patient identification, specimen collection and handling, instrument operation, internal quality control, calibration or verification, operator training and competency assessment, documentation, and appropriate laboratory oversight. POCT must not be seen as an alternative to the central laboratory but must instead complement existing laboratory practices as it gives immediate and convenient results but still upholds the need for the laboratory in ensuring quality assurance and standardization of results (Zhang, Y & Liu, Y, 2022).

4. QUALITY CONTROL, STANDARDIZATION, AND ACCREDITATION IN POINT-OF-CARE TESTING IN MODERN MEDICAL PRACTICES

Quality control, standardization, and accreditation are key elements of effective POCT in the current healthcare setting since the results obtained through POCT may be utilized for making quick diagnoses, providing treatment, and making decisions on further care. Quality control (QC) is referred to a series of measures designed to make sure that POCT produces accurate and reliable results. QC includes the

correct storage and handling of reagents, calibration or verification of equipment, usage of appropriate internal quality control materials, instrument maintenance, documentation, and corrections of the results that exceed allowed limits (Crapnell et al., 2022). Being aware of the fact that POCT is usually conducted not only within the lab but also by medical professionals outside the lab setting, regular training and proficiency assessments of POCT operators should be viewed as quality assurance measures as well. Standardization consists of conducting tests using standardized methods, procedures, SOPs, using appropriate reference materials and quality criteria. Thus, standardization minimizes the variability between operators and testing sites and increases the comparability of patient results. Standardization also includes correct sampling, labeling, handling, testing, recording, and reporting of results (Xie et al., 2022). Accreditation stands for formal recognition of the healthcare or laboratory services being competent and following specific quality and technical criteria. The standard covers aspects of quality and competence in medical laboratories and applies to entities responsible for medical laboratory testing, including those performing POCT. Accreditation includes assessment of competencies of staff members, equipment, processes, quality-management systems, documents, and performance. Thus, together with QC, standardization, and accreditation form the system of quality management for POCT (Buno et al., 2021).



Fig. 1: Integrating quality control, standardization, accreditation and Competency accurate, reliable, safe and clinically valuable POCT results.

It enables minimization of errors that can occur both on analytical and preanalytical stages, provides safety for patients, increases confidence in results of quick tests, and enables improvements. The application of these measures is especially important in modern healthcare settings because the advantages provided by POCT in terms of convenience and speed have to be combined with the same standards of precision and reliability that are usually required from traditional laboratory tests (Serder et al., 2021). Efficient management of POCT demands strong collaboration among laboratory specialists, clinicians, nurses, administrators, and IT specialists. Quality control, standardization, and accreditation

enable POCT to supplement services of laboratory facilities and provide quick, reliable, and clinically valuable results (Xing et al., 2024).

5. CHALLENGES AND IMPLEMENTATION OF POINT-OF-CARE TESTING IN HEALTHCARE SETTINGS IN MODERN MEDICAL PRACTICE

Point-of-Care Testing (POCT) is now a part of how we take care of people because Point-of-Care Testing (POCT) gives fast results right by the patients side. I have seen that just buying the testing machines is not enough to make it work well. Hospitals and clinics often run into trouble with things, like how accurate the tests are how to keep quality high and how to train the staff. They also have to worry about keeping the machines running storing the test liquids managing costs and following all the rules. Before you start using Point-of-Care Testing (POCT) you really need to plan and see what the doctors actually need. Healthcare workers need to have steps to follow and get enough training to do the job right. It is also vital to check the results.

Table: Challenges and Implementation of Point-of-Care Testing in Healthcare Settings

SL No.	Point	Challenges/Implementation	References
1.	It & data connectivity	Connect POCT devices with laboratory/hospital information system to reduce manual transcription errors and improve result reporting, monitoring, and record keeping.	(Yared et al., 2023)
2.	Regulatory compliance & management	Follow national regulation, accreditation standards, manufacturer instructions, and institutional policies. Clearly define responsibilities among laboratory staff, clinicians, administrators, and the POCT committee.	(Bradley et al., 2023)
3.	Continuous performance monitoring	Regularly monitor turnaround time, error rates, QC failures, operator competency, device utilization, costs, and clinical outcomes to support continuous quality improvement.	(Shang et al., 2023)
4.	Clinical need assessment	Identify which tests rapid results and determine where POCT will provide the greatest clinical benefit.	(Khan et al., 2023)
5.	Technology selection & validation	Select suitable POCT devices based on accuracy, reliability, clinical usefulness, ease of use, maintenance requirements. Validate the device before routine patient testing.	(Shaw et al., 2023)
6.	Quality control & accuracy	Maintain reliable results through internal QC, external quality assessment, calibration, verification, and regular performance checks.	(Otto et al., 2024)
7.	Staff training & competency	Operators must receive proper training in specimen collection, testing, result interpretation, troubleshooting, and safety, followed by competency assessment.	(Banfi et al., 2024)
8.	Standardization	Different departments may use different instruments, reagents, methods. Standardized SOPs and testing procedures are therefore essential.	(Plebani et al., 2025)
9.	Logistics & Inventory management	Ensure proper procurement, stock monitoring, stock monitoring, and expiry-date management of reagents and consumables.	(Sacks et al., 2024)

6. FUTURE DIRECTIONS IN POINT-OF-CARE TESTING IN MODERN MEDICAL PRACTICES

Point-of-care testing is predicted to become a crucial element in the future of modern medical practice due to the emphasis of healthcare systems on fast diagnosis, individualized treatment, accessibility, and patient-centered care (Stavelin et al., 2024). Some areas of improvement in POCT in the future will include improved analytical accuracy, shorter testing time, greater variety of analytes, increased portability, digitalization, and better accessibility of diagnostic services at hospitals, primary care centers, in homes, rural areas, and resource-poor settings (Zhang et al., 2024). Future developments in biosensing, microfluidics, nanotechnology, molecular diagnostics, artificial intelligence, wearable technologies, and interconnected healthcare systems will bring about a change in POCT from simple bedside testing into the new digital diagnostics system. One of the areas of POCT development is the creation of smaller, faster, and more sensitive diagnostic devices. New developments in microelectronics and microfluidics allow for integration of various analytical procedures in one platform (Palomeque et al., 2024). Future lab-on-a-chip systems may have the ability to prepare, conduct, detect, and analyze results in one disposable cartridge. Such systems may use very little amounts of samples and give a result fast. The development in miniaturization will also make the diagnostic devices portable and easy-to-use in such locations as ambulances, community clinics, rural health centers, and other places where there are no conventional laboratories (Kost et al., 2024).



Fig. 2: Future of care testing (POCT): Emerging Technologies and digital integration advances in AI, nanotechnology, microfluidics, wearables, multiplex diagnostics, and cloud connectivity enabling faster, personalized, accessible, and integrated healthcare with reliable diagnostic outcomes.

Multiplex testing can also be viewed as a key field of future development. Modern POC testing devices typically analyze one target or a small set of targets (parameters). Future POC testing devices are expected to perform analysis of multiple biomarkers, pathogens or biochemical parameters using

one single specimen (Ahmadsaidulu et al., 2024). Multiplex molecular or immunoassays may provide healthcare specialists with additional diagnostic data without performing a large number of independent tests. Thus, in the case of infectious diseases treatment, for instance, a multiplex platform may be used to distinguish multiple pathogens or identify multiple targets during testing procedure. In other cases, measurement of several biomarkers at once may give a more comprehensive image of the condition of the patient (Shi et al., 2025). Artificial intelligence (AI) and machine learning are also supposed to play an important role in the future of POC testing. The use of AI-based system may allow healthcare specialists to interpret complex test results and patterns, identify abnormal results, evaluate trends and support decision-making. The mobile devices might become the platform for connected diagnostic tests. The results of POCT will be able to be safely sent to the electronic health records, laboratory information systems, clinicians, and healthcare providers. The use of cloud computing might make possible the centralized monitoring of the POCT test activity, quality control performance, inventory, operator competency, and the status of devices. This possibility could be particularly useful in case of healthcare organizations providing POCT services at several hospitals or community facilities (Augustine et al., 2025).

Another area of significant future application for POCT technology includes its development for remote, rural, and resource-limited settings. Traditional lab diagnostics can be hard to implement in regions with insufficient infrastructure, trained personnel, transport, energy supply, or facilities. POCT portable platforms demanding low infrastructural requirements could provide necessary diagnostic capabilities to the regions closer to the patients in need. In the future, such POCT devices are expected to feature low-power demands, ease of use, durability, low maintenance requirements, long shelf life of reagents, and resistance to environmental factors (Pillay et al., 2025). All of those developments might contribute to increased accessibility of diagnostics and earlier disease recognition. The further development of POCT will also call for higher quality management, standardization, and regulation. As POCT devices become more complex and testing more decentralized, the issue of providing a consistent performance of these devices will still remain relevant. The future programs of POCT should have an effective internal quality control, external quality assessment, operators' competency assessment, devices' validation, standardization, connectivity, documentation, and performance monitoring (Rahim et al., 2025). To conclude, the future of POCT is expected to be characterized by high rates of technological development and integration with the digital healthcare system. Such innovative technologies as miniaturized lab-on-a-chip platforms, multiplex assays, biosensors, molecular diagnostics, artificial intelligence, wearables, smart phone connectivity, and cloud computing will likely bring great benefits to the sphere of POCT (Shaw et al., 2025). These innovations will increase the speed of POCT and make it more accessible, personalized and incorporated into everyday healthcare. However, at the same time, the innovations in POCT should be carefully validated, standardized, regulated, and professionally implemented. With the proper approach, POCT may become an important part of laboratory medicine and healthcare in general (Vaubourdolle et al., 2025).

7. CONCLUSION OF POINT OF CARE TESTING IN MODERN MEDICAL PRACTICES

The concept of POCT has been identified as one of the most valuable advancements in modern medicine laboratory practices through proximity of diagnostic testing to patients as well as fast availability of clinically meaningful information. In contrast to the conventional laboratory testing which usually involves specimen collection, transportation, preparation, analysis and reporting in the centralized laboratory (Kalantar et al., 2025), POCT allows for obtaining the results on-site or in close proximity

to patient care location. Such reduction of the turnaround time is expected to assist in prompt clinical decision making, timely diagnosis, commencement of the treatment, patient monitoring, and referral. The progress of POCT, therefore, led to gradual change in the delivery of laboratory services, especially in emergency departments, outpatient clinics, operating theatres, ambulances, primary healthcare centers, community and remote locations (Wat et al., 2025). The progress of POCT technology led to expansion of the scope of its clinical applications. Initially POCT was mainly linked with laboratory tests such, as glucose and pregnancy testing. Today POCT has grown into a field that uses biosensors, immunoassays, electrochemical detection, molecular diagnostics, microfluidics, lab on a chip technology and automated portable instruments (Fan et al. 2025). Because of these advances POCT now lets a range of haematological, coagulation, cardiac, infectious disease and molecular studies be carried out outside the traditional laboratory. Blood glucose testing, blood gases and electrolytes testing, cardiac biomarkers testing, coagulation testing, haemoglobin testing, infectious diseases testing, pregnancy testing, lactate testing, and some molecular tests are some examples of applications demonstrating the increasing significance of POCT (Haghighy et al., 2025).

One of the greatest advantages of POCT is its capacity to deliver quickly obtainable results to assist in patient management. In situations of emergency or critical care, the significance of laboratory data may be increased by the rapidly changing clinical situation (Thai et al., 2025). Rapidly obtained data on glucose levels, blood gases, electrolyte content, lactate concentration, or cardiac biomarkers can contribute to assessing the patient and choosing a strategy of patient management. POCT in primary care and community practice may improve access to selected laboratory investigations and decrease the need for distant centralized laboratories. But at the same time, the effectiveness of POCT highly depends on the quality of results that it produces (Sautter et al., 2024). Only quickly obtainable but inaccurate results do not provide any benefit. Hence, quality control, standardization, training of operators, assessment of competence, equipment maintenance, reagents' supply and storage, and proper documentation should become parts of a good POCT program. Some pre-analytical factors like patient identification, specimen collection, sample handling, and environmental conditions can affect results, as well as some analytical and post-analytical errors. That is why, POCT should become part of a quality management system (Lan et al., 2025).

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