The Review Of
DIABETIC
STUDIES OPEN ACCESS

A Comprehensive Review Of Blood Tests To Monitor Chronic Disease

Abdulrahman Qalil Badi Alanazi[1], Nasser Dafas Aldafas[2], Riyadh Moaber Omar Manni[3], Ruqayyah Mohammed Aljurayan[4], Kholod Awayd S Alenezi[5], Samiyah Fahis A Alanazi[6], Abdullah Mohammed, Al-Aidan[7], Ahmed Omar Alhussain[8], Faleh Ibrahim Alrashdi[9], Fahad Sattan Alrashdi[10], Majed Atallah Almutairi[11], Khalid Munawir Alharbi[12], Nasser Mohammed[13]

[1.] Laboratory Technology Specialist, AlNakheel Medical Complex, General Directorate of Medical Services, Riyadh, Kingdom of Saudi Arabia. abanzi1990@gmail.com
[2.] Laboratory Specialist, Alzulfi General Hospital, Ministry of Health, Kingdom of Saudi Arabia. naseraldafas@gmail.com
[3.] Laboratories Technician, Jazan health cluster, Kingdom of Saudi Arabia. Rmanni@moh.gov.sa
[4.] Specialist laboratory, Prince Salman Bin Mohammed in Al-Dilam Hospital, First Health Cluster, Riyadh Region, Kingdom of Saudi Arabia.
[5.] clinical laboratory sciences (specialist), Prince Abdulaziz Bin Musaed Hospital, Arar, Kingdom of SaudiArabia.
[6.] clinical laboratory sciences (specialist) - Forensic Toxicology unit in Arar Forensic Medical ServicesCenter, Kingdom of Saudi Arabia.
[7.] Assistant Epidemiologist, Majmaah University, College of Applied Medical Sciences, Kingdom of SaudiArabia.
[8]Senior Medical Laboratory Specialist, Department of Medical Laboratories - College of Applied Medical Sciences - Majmaah University, Kingdom of Saudi Arabia.
[9]Department of Medical Equipment Technology, College of Applied Medical Sciences, Majmaah University, Kingdom of Saudi Arabia.
[10]Outpatient Clinic, College of Dental, Majmaah University, Kingdom of Saudi Arabia.
[11]Department of Medical Equipment Technology, College of Applied Medical Sciences, Majmaah University, Kingdom of Saudi Arabia
[12]Outpatient Clinic, College of Dental, Majmaah University, Kingdom of Saudi Arabia.
[13]Biomedical Equipment Technician, College of Applied Medical Sciences, Kingdom of Saudi Arabia

Abstract

Chronic diseases are a major global health challenge, accounting for the majority of deaths and disabilities worldwide. Blood tests play a crucial role in the early detection, ongoing monitoring, and effective management of these conditions. This comprehensive review synthesizes current evidence on the utility of blood tests in monitoring chronic diseases, focusing on their role in early detection, disease progression tracking, treatment optimization, and complication prevention. The scope encompasses major chronic conditions, including cardiovascular diseases, diabetes, chronic kidney disease, cancer, and respiratory disorders, and examines key biomarkers used in clinical practice. The review evaluates the frequency, interpretation, and clinical impact of routine blood testing while addressing challenges such as test variability, patient adherence, and accessibility. Emerging trends, including the integration of artificial intelligence, point-of-care testing, and remote monitoring platforms, are explored as they transform the landscape of chronic disease management. The review also discusses the pathophysiological basis for blood test use, limitations and challenges in biomarker application, and the significance of reference ranges and clinical decision-making algorithms. Future perspectives, such as personalized medicine based on biomarker profiles, integration with wearable biosensors, big data applications for predictive modeling, and international guidelines harmonization, are highlighted. By analyzing the latest guidelines, technological innovations, and economic implications, this review provides a thorough understanding of how blood-based diagnostics contribute to improved patient outcomes and sustainable healthcare systems in the context of the rising global burden of chronic diseases.

Keywords Chronic disease, biomarkers, blood tests, diagnostics, laboratory monitoring, clinical outcomes.

INTRODUCTION:

Chronic diseases constitute a major global burden with significant impact on health systems, economies, and quality of life. Chronic diseases include a broad range of diseases that can be communicable or non-communicable. Chronic diseases are often associated with modifications of normal physiological levels of various analytes that are routinely measured in serum and other body fluids, as well as pathological findings, such as chronic inflammation, oxidative stress, and mitochondrial dysfunction. Identification of at-risk populations, early diagnosis, and prediction of prognosis play a major role in preventing or reducing the burden of chronic diseases. Biomarkers are tools that are used by health professionals to aid in the identification and management of chronic diseases. Biomarkers can be diagnostic, predictive, or prognostic. Several individual or grouped biomarkers have been used successfully in the diagnosis and prediction of certain chronic diseases, however, it is generally accepted that a more sophisticated approach to link and interpret various biomarkers involved in chronic disease is necessary to improve our current procedures. In order to ensure a comprehensive and unbiased coverage of the literature, first a primary frame of the manuscript (title, headings and subheadings) was drafted by the authors working on this paper. Second, based on the components drafted in the preliminary skeleton a comprehensive search of the literature was performed using the PubMed and Google Scholar search engines. Multiple keywords related to the topic were used. Out of screened papers, only 190 papers, which are the most relevant, and recent articles were selected to cover the topic in relation to etiological mechanisms of different chronic diseases, the most recently used biomarkers of chronic diseases and finally the advances in the applications of multivariate biomarkers of chronic diseases as statistical and clinically applied tool for the early diagnosis of chronic diseases was discussed. Recently, multivariate biomarkers analysis approach has been employed with promising prospect. A brief discussion of the multivariate approach for the early diagnosis of the most common chronic diseases was highlighted in this review. The use of diagnostic algorithms might show the way for novel criteria and enhanced diagnostic effectiveness inpatients with one or numerous noncommunicable chronic diseases. The search for new relevant biomarkers for the better diagnosis of patients with non-communicable chronic diseases according to the risk of progression, sickness, and fatality is ongoing. It is important to determine whether the newly identified biomarkers are purely associations or real biomarkers of underlying pathophysiological processes. Use of multivariate analysis could be of great importance in this regard (GBD 2015 Risk Factors Collaborators, 2016).

Blood tests are essential for the prevention, diagnosis, and management of chronic diseases, but related studies are often fragmented, making it difficult for primary care physicians to follow best practices. This review highlights the importance and recommendations of blood testing in common chronic conditions such as cardiovascular diseases, diabetes, chronic kidney disease, vitamin D deficiency, iron deficiency, and rheumatoid arthritis. It emphasizes the need for further research to enhance physicians' awareness of clinical guidelines and improve patient access to blood testing (Cabalar et al., 2024).

1.1 Global Epidemiology of Chronic Diseases

Noncommunicable diseases (NCDs) are the leading cause of mortality globally, accounting for at least 43 million deaths in 2021, which represents 75% of all non-pandemic-related deaths. Cardiovascular diseases (CVDs) are the primary contributors, causing approximately 19 million deaths annually, followed by cancers (10 million), chronic respiratory diseases (4 million), and diabetes (over 2 million, including kidney disease deaths). These four disease groups collectively account for 80% of all premature NCD deaths, with 18 million occurring before age 70, 82% of which occur in low- and middle-income countries. The global burden has been steadily increasing, with chronic diseases responsible for 74% of all deaths in 2019, up from 67% in 2010. In the United States, chronic diseases are responsible for 8 of the 10 leading causes of death, with heart disease and cancer alone accounting for nearly 40% of all deaths in 2022. The prevalence of multiple chronic conditions is also rising, with 27% of U.S. adults affected in 2018. The economic impact is staggering, with global chronic disease costs projected to reach $47 trillion by 2030. The aging global population and persistent risk factors such as tobacco use, physical inactivity, unhealthy

diets, and air pollution continue to drive this epidemiological transition from infectious to chronic diseases (Thomas et al., 2023).

1.2 Importance of Early Detection and Ongoing Monitoring

Early detection of chronic diseases is critical for improving treatment outcomes, reducing complications, and lowering healthcare costs. Identifying conditions such as diabetes, cardiovascular disease, or cancer at an early stage allows for timely intervention, often before irreversible damage occurs. For example, detecting prediabetes enables lifestyle modifications that can prevent progression to type 2 diabetes, while early diagnosis of hypertension reduces stroke risk. Early intervention not only improves survival rates but also enhances quality of life by preventing disability and maintaining functional independence. From an economic perspective, treating diseases early is significantly more cost-effective than managing advanced stages; for instance, treating hypertension is less expensive than post-stroke rehabilitation. Ongoing monitoring is equally vital, as it allows healthcare providers to track disease progression, assess treatment efficacy, and adjust therapies proactively. Regular screening and longitudinal biomarker assessment help identify subtle changes such as rising HbA1c or worsening kidney function before they lead to severe complications like neuropathy, dialysis, or myocardial infarction. Moreover, early detection of risk factors such as high cholesterol, obesity, or inflammation enables preventive strategies that reduce the overall burden on healthcare systems (He et al., 2019).

1.3 Significance of Blood Tests in Disease Management

Blood tests are indispensable tools in the prevention, diagnosis, and management of chronic diseases, providing objective, quantifiable data on physiological status and disease activity. They enable the measurement of key biomarkers that reflect metabolic, cardiovascular, renal, and immune function. For diabetes, glycated hemoglobin (HbA1c) and fasting glucose levels are used to assess long-term glycemic control and guide insulin or oral hypoglycemic therapy. In cardiovascular disease, lipid panels measure total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides, which inform statin use and lifestyle recommendations. Inflammatory markers such as C-reactive protein (CRP) and homocysteine provide additional risk stratification for atherosclerosis and thrombosis. For chronic kidney disease (CKD), serum creatinine and estimated glomerular filtration rate (eGFR) are essential for staging and monitoring renal function, while blood urea nitrogen (BUN) reflects nitrogen waste clearance. Blood tests also detect nutritional deficiencies, such as vitamin D or iron, that can exacerbate chronic conditions and require supplementation. Beyond monitoring, blood tests facilitate early diagnosis through screening programs, such as detecting elevated prostate-specific antigen (PSA) for prostate cancer or abnormal liver enzymes for non-alcoholic fatty liver disease. The integration of blood testing with digital health platforms and artificial intelligence enables personalized, data-driven care, improving adherence and clinical decision-making (Cabalar et al., 2024).

1.4 Aim and Scope of the Review

This comprehensive review aims to synthesize current evidence on the role of blood tests in monitoring chronic diseases, with a focus on their utility in early detection, disease progression tracking, treatment optimization, and complication prevention. The scope encompasses major chronic conditions, including cardiovascular diseases, diabetes, chronic kidney disease, cancer, and respiratory disorders, and examines key biomarkers used in clinical practice. It evaluates the frequency, interpretation, and clinical impact of routine blood testing, while addressing challenges such as test variability, patient adherence, and accessibility. The review also explores emerging trends, including the integration of artificial intelligence, point-of-care testing, and remote monitoring platforms, which are transforming the landscape of chronic disease management. By analyzing the latest guidelines, technological innovations, and economic implications, this review seeks to provide a thorough understanding of how blood-based diagnostics contribute to improved patient outcomes and sustainable healthcare systems.

2. Background: Role of Blood Tests

2.1 Concept of Biomarkers and Their Diagnostic/Prognostic Value

Biomarkers are measurable indicators of biological states or conditions that have gained pivotal importance in medical science for diagnosing, monitoring, and prognosticating chronic diseases. They are quantifiable substances or characteristics in the blood that reflect normal biological processes, pathogenic processes, or responses to therapeutic interventions. Blood tests assess biomarkers such as glucose, cholesterol, inflammatory proteins (e.g., C-reactive protein), hormones, and organ function indicators, providing a window into the internal milieu of the body (Chen et al., 2019).

The diagnostic value of biomarkers lies in their ability to detect early pathological changes before clinical symptoms manifest. For example, elevated HbA1c levels serve as a diagnostic and monitoring biomarker for diabetes mellitus, reflecting average blood glucose over months, which guides long-term glycemic control. Similarly, cardiac troponins are sensitive and specific biomarkers for myocardial injury and are central to diagnosing acute and chronic cardiac conditions (D'Costa et al., 2016).

Prognostically, biomarkers help predict disease progression and outcomes. Studies have documented that elevations in biomarkers such as CRP, HbA1c, troponin, and others correlate strongly with adverse events like cardiovascular complications, respiratory exacerbations, and diabetic complications. The combined use of multiple biomarkers can enhance predictive accuracy for clinical outcomes, facilitating personalized medicine approaches by tailoring treatment plans based on individual biomarker profiles (Shaik et al., 2024).

2.2 Pathophysiological Basis for Blood Test Use in Chronic Conditions

Chronic diseases often involve sustained or progressive pathophysiological changes, such as inflammation, tissue damage, metabolic dysregulation, or impaired organ function. Blood tests provide quantitative assessments that reflect these underlying changes. For instance, in chronic kidney disease, serum creatinine and estimated glomerular filtration rate (eGFR) measurements reflect renal filtration capacity and are essential for staging disease severity and managing therapy. Inflammation is a common pathway in many chronic conditions, including cardiovascular diseases, autoimmune disorders, and chronic respiratory diseases. Measuring inflammatory biomarkers like CRP or erythrocyte sedimentation rate (ESR) offers insight into disease activity and guides treatment strategies. Hormonal biomarkers assist in diagnosing and monitoring endocrine disorders, such as thyroid dysfunction in hypothyroidism or hyperthyroidism. At a molecular level, advanced proteomic and genomic biomarkers detected in blood are increasingly used to stratify patients based on molecular disease mechanisms, which helps in earlier diagnosis, risk stratification, and monitoring treatment efficacy. This pathophysiological linkage reinforces the critical role that blood biomarkers play across the spectrum of chronic disease management (Al-hadlaq et al., 2022).

2.3 Limitations and Challenges in Biomarker Application

Despite the numerous advantages, biomarker use in clinical practice faces significant limitations and challenges. One major challenge is the variability among individuals, including biological differences, comorbid conditions, and lifestyle factors that can affect biomarker levels, leading to diagnostic ambiguity. Analytical variability also exists due to differences in sample handling, assay techniques, and laboratory standards, which can compromise reliability and reproducibility of results (Bhawal et al., 2020).

Another limitation is the lack of universally validated biomarkers with high sensitivity and specificity for many chronic diseases. For instance, identifying low-abundance proteins in blood requires highly sensitiv(Schöll et al., 2024)e proteomic technologies, which can be costly and technologically demanding. Integrating biomarker data into clinical decision-making also requires robust evidence from large, diverse cohorts with longitudinal follow-up to establish clinical utility and cost-effectiveness (Schöll et al., 2024).

Regulatory and practical challenges further hinder widespread implementation. Approval processes for new biomarker assays can be lengthy, and access may be restricted by cost and availability. Additionally, the interpretation of biomarker panels requires specialized expertise,

and there is a need to develop standardized clinical guidelines for their use to avoid overtesting and misinterpretation (Schöll et al., 2024).

Emerging research aims to overcome these challenges through improved assay technologies, large-scale validation studies, and integrative approaches combining multiple biomarkers with clinical parameters to enhance diagnostic and prognostic capabilities. However, until these hurdles are fully addressed, cautious and evidence-based application of biomarkers remains essential in managing chronic diseases (Sturmey & Malaspina, 2022).

3. Classification of Blood Tests for Chronic Disease

Blood tests play a fundamental role in the management of chronic diseases by helping diagnose conditions, monitor progression, evaluate treatment response, and assess prognosis. The classification of these blood tests can be approached from two major perspectives: based on the disease category and based on the test's functional role in patient care (Cabalar et al., 2024).

3.1 Based on Disease Category

Blood tests are often grouped by the chronic disease conditions they help to monitor and manage. This facilitates targeted diagnostic pathways and disease-specific monitoring strategies.

Cardiovascular Diseases: Blood tests for cardiovascular conditions typically assess lipid profiles (total cholesterol, LDL, HDL, triglycerides), inflammatory markers such as high-sensitivity C-reactive protein (hs-CRP), homocysteine levels, lipoprotein(a), and cardiac biomarkers like troponin. These tests aid in risk stratification, diagnosis of acute events, and monitoring of therapy efficacy (Kumakura et al., 2015).

Endocrine and Metabolic Disorders: This category includes tests for diabetes mellitus such as fasting plasma glucose, HbA1c, oral glucose tolerance test, C-peptide, and insulin levels. Thyroid function tests encompass thyroid-stimulating hormone (TSH), free T4, free T3, and antibodies such as thyroid peroxidase and thyroglobulin antibodies. Other metabolic tests include calcium, phosphate, parathyroid hormone, vitamin D, cortisol, and adrenal hormone panels (Babić Leko et al., 2023).

Chronic Kidney Disease (CKD): Blood tests focus on renal function markers including serum creatinine, estimated glomerular filtration rate (eGFR), urea, and electrolyte levels. Hematological parameters such as hemoglobin, white blood cell count, platelets, and albumin are also monitored due to their relevance in CKD-associated complications (Gounden et al., 2024).

Liver Disease: Monitoring liver disease involves assessing enzymes like alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), gamma-glutamyl transferase (GGT), bilirubin levels, albumin, and coagulation markers such as prothrombin time and INR. Scores like ChildPugh and MELD incorporate these tests to assess liver disease severity and prognosis (Kalas et al., 2021).

Autoimmune Disorders: Blood tests help detect autoantibodies like antinuclear antibodies (ANA), rheumatoid factor, and disease-specific markers aiding in diagnosis and monitoring autoimmune diseases such as lupus, rheumatoid arthritis, and Sjögren's syndrome. Inflammatory markers such as ESR and CRP are also valuable for assessing disease activity (Castro & Gourley, 2010a).

Hematological Disorders: These include complete blood counts with differential, coagulation profiles, bone marrow examinations, and advanced molecular diagnostics. They are crucial for diagnosing anemia, clotting disorders, leukemias, lymphomas, myelomas, and inherited hematological conditions (National Academies of Sciences et al., 2023).

Cancer Surveillance: Blood-based cancer tests include complete blood counts, tumor markers, circulating tumor cell detection, and circulating free DNA analysis (liquid biopsy). These non-invasive blood tests aid in early detection, diagnosis, monitoring therapeutic response, and guiding personalized treatment strategies (Haber & Velculescu, 2014).

3.2 Based on Test Function

Apart from disease categories, blood tests can be classified based on their clinical roles:

• **Diagnostic Tests:** These identify the presence of disease or condition, e.g., HbA1c for diabetes, troponin for myocardial infarction, or ANA for autoimmune diseases.

• **Monitoring/Progression Indicators:** These track disease activity or progression over time, such as lipid profiles in cardiovascular disease, creatinine in CKD, or liver function tests in cirrhosis.
• **Therapeutic Response Evaluation:** Tests assess how well a patient is responding to treatment, like viral load tests in hepatitis, tumor markers in oncology, or inflammatory markers in autoimmune disease.
• **Prognostic Risk Assessment:** Blood tests help estimate the risk of future complications or disease outcomes, e.g., high hs-CRP levels predicting cardiovascular events or MELD score components predicting liver transplant urgency.
This classification aids clinicians in selecting appropriate blood tests not only according to the disease but also depending on the clinical question.

4. Blood Tests in Specific Chronic Diseases

4.1 Cardiovascular Diseases

Blood tests play a pivotal role in diagnosing and monitoring cardiovascular diseases (CVD), aiding in risk stratification and assessment of disease progression. The lipid profile, including total cholesterol, lowdensity lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides, remains fundamental for evaluating atherosclerotic risk and guiding lipid-lowering therapy. Elevated LDL and triglycerides with low HDL are associated with coronary artery disease risk (Cabalar et al., 2024).
High-sensitivity C-reactive protein (hs-CRP) serves as a sensitive biomarker of systemic inflammation, predictive of cardiovascular events. Elevated hs-CRP levels correlate with increased risk independent of traditional lipid measures. Cardiac-specific troponins, primarily used in acute myocardial infarction diagnosis, also hold prognostic value in chronic ischemic heart disease by indicating ongoing myocardial injury (Madjid & Fatemi, 2013).
Natriuretic peptides, including B-type natriuretic peptide (BNP) and N-terminal pro BNP (NT-proBNP), are essential markers of myocardial strain and heart failure severity. They guide therapeutic decisions and provide prognostic information in chronic heart failure management (King et al., 2025).

4.2 Diabetes Mellitus and Metabolic Syndrome

For diabetes mellitus and metabolic syndrome, fasting plasma glucose and glycated hemoglobin (HbA1c) are cornerstone diagnostic and monitoring tests. HbA1c provides an integrated measure of glycemic control over the previous 2-3 months and predicts microvascular and macrovascular complications (Nelson & Dungan, 2025).
Serum insulin and C-peptide levels assess endogenous insulin production, differentiating type 1 from type 2 diabetes and identifying insulin resistance. Lipid profiles are crucial in metabolic syndrome for assessing cardiovascular risk related to dyslipidemia—a common comorbidity characterized by elevated triglycerides and low HDL (Swarup et al., 2024).
Oral glucose tolerance tests remain important for diagnosing glucose intolerance and gestational diabetes (Jeha & Haymond, 2007).

4.3 Chronic Kidney Disease (CKD)

In chronic kidney disease, serum creatinine is the primary marker for renal function, used to estimate the glomerular filtration rate (eGFR), which stages CKD severity. The eGFR, calculated using creatinine-based equations, may be supplemented by cystatin C for accuracy in certain populations (Chouhan et al., 2023).
Blood urea nitrogen (BUN) levels reflect renal clearance function and protein metabolism but are less specific than creatinine. Electrolyte disturbances, including sodium, potassium, calcium, and phosphate imbalances, are common in CKD and monitored to prevent complications such as hyperkalemia and mineral bone disease (Lopez-Giacoman & Madero, 2015).
Novel biomarkers like kidney injury molecule-1 and neutrophil gelatinase-associated lipocalin are emerging as tools to detect early kidney damage beyond conventional tests.

4.4 Chronic Liver Disease

Liver function tests (LFTs) including alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and bilirubin are central to diagnosing liver inflammation,

cholestasis, and hepatocellular injury. Parameters like albumin and prothrombin time (PT)/international normalized ratio (INR) evaluate the liver's synthetic capability and coagulation status, indicating the severity of liver dysfunction (Patel et al., 2025).

Alpha-fetoprotein (AFP) is utilized as a tumor marker in hepatocellular carcinoma (HCC) surveillance among patients with chronic liver disease. Elevated AFP levels warrant imaging studies for early cancer detection. Noninvasive fibrosis markers and composite scores (such as FIB-4) enhance the assessment of fibrosis severity and risk stratification (Iwasa et al., 2021).

4.5 Autoimmune Disorders

Autoimmune diseases frequently require laboratory evaluation with inflammatory markers like erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) to assess systemic inflammation and disease activity (Moore & Dalrymple, 2016).

Autoantibody panels are diagnostic cornerstones, including antinuclear antibodies (ANA) for systemic lupus erythematosus and other connective tissue diseases, anti-double-stranded DNA (anti-dsDNA) antibodies specific for lupus nephritis, and rheumatoid factor (RF) for rheumatoid arthritis. These autoantibodies aid diagnosis, monitor disease progression, and guide immunosuppressive therapy (Castro & Gourley, 2010b).

4.6 Hematological Disorders

Complete blood count (CBC) parameters provide critical insights into hematological disorders by evaluating red blood cells, white blood cells, and platelets, assisting in the diagnosis of anemia, infections, and hematological malignancies (Madjid & Fatemi, 2013).

Iron studies encompassing ferritin, transferrin, and serum iron measure iron status, guiding evaluation of iron deficiency or overload states. Vitamin B12 and folate concentrations are essential for diagnosing megaloblastic anemias and nutritional deficiencies affecting hematopoiesis (Varon, 2016).

4.7 Oncology Surveillance

In oncology, blood tests include tumor markers such as prostate-specific antigen (PSA) for prostate cancer, cancer antigen 125 (CA-125) for ovarian cancer, carcinoembryonic antigen (CEA) for colorectal and other cancers, and cancer antigen 19-9 (CA 19-9) for pancreatic and gastrointestinal malignancies. These markers assist in cancer detection, monitoring treatment response, and detecting recurrence (Le et al., 2025).

Circulating tumor DNA (ctDNA) represents an innovative liquid biopsy method enabling tumor genetic profiling and early detection of minimal residual disease, showing promise for personalized oncology surveillance (Virdee et al., 2025).

5. 1Interpretation and Clinical Decision Making

5.1 Reference Ranges and Their Variability

Reference ranges, often specified as normal ranges or intervals, are foundational benchmarks used to interpret blood test results. These ranges represent the spectrum of values expected in a healthy population and serve as guides to distinguish normal physiology from potential pathology. However, reference ranges are not absolute thresholds but rather statistically derived intervals that carry inherent variability based on several factors. These include the laboratory methodology, population demographics such as age, sex, ethnicity, and geographic location, as well as pre-analytical variables like sample handling and timing of collection. The concept of biological variation further complicates interpretation; intra-individual fluctuations occur due to intrinsic biological rhythms and external influences such as diet, exercise, or hydration status. Additionally, analytical variability arises from differences in reagents, instruments, and calibration procedures between laboratories. Therefore, clinicians must assess blood test results within the context of these variabilities rather than relying solely on rigid cutoffs. Understanding the extent of normal physiological variation aids in avoiding misclassification of results, reducing false positives or negatives in chronic disease monitoring (Cabalar et al., 2024).

5.2 Effect of Comorbidities on Test Results

Comorbidities critically influence the interpretation of blood tests by altering normal physiological markers and disease-related parameters. Chronic diseases rarely exist in isolation, and coexisting conditions can mask or mimic laboratory abnormalities, potentially confounding

disease monitoring. For example, inflammatory markers such as C-reactive protein (CRP), ferritin, and erythrocyte sedimentation rate (ESR) may be elevated not only due to acute exacerbations of a chronic inflammatory disease but also by concurrent infections or autoimmune diseases. Renal impairment affects electrolyte balance and hemoglobin levels, influencing the interpretation of tests monitoring anemia or metabolic status. Similarly, liver diseases may skew liver function tests and impact protein synthesis markers like albumin. In patients with cardiovascular comorbidities, biomarkers such as troponins or natriuretic peptides require cautious interpretation, as they may be persistently elevated due to underlying cardiac stress unrelated to acute events. Moreover, comorbidities can modify baseline reference ranges, necessitating personalized interpretation frameworks. This complexity underscores the need for comprehensive clinical evaluation alongside laboratory data, ensuring that the presence of additional chronic illnesses is factored into clinical decision-making to prevent diagnostic errors and inappropriate management strategies (Rahman et al., 2021).

5.3 Clinical Algorithms Integrating Blood Test Data

To optimize decision making in chronic disease management, clinical algorithms and predictive models increasingly incorporate blood test data alongside clinical parameters. These algorithms range from simple rule-based pathways to sophisticated machine learning models that leverage large datasets to detect patterns imperceptible to human analysis. For instance, in diabetes management, algorithms integrate glycated hemoglobin (HbA1c), fasting glucose levels, and lipid profiles along with patient demographics to stratify risk and guide therapeutic adjustments. In chronic kidney disease, composite scores of creatinine, estimated glomerular filtration rate (eGFR), and electrolyte panels inform staging and progression risk, facilitating timely intervention. Advances in artificial intelligence (AI) have augmented these approaches by combining routine blood test results with multi-omics data, imaging, and electronic health records (EHRs) to predict disease trajectories with higher accuracy. Such integrative models support personalized medicine by tailoring monitoring intervals and therapies. Importantly, these algorithms aid in early detection of disease exacerbations, prognosis estimation, and therapeutic response evaluation. Clinical decision support systems embedding these tools help healthcare providers navigate the complexity of chronic diseases, improving outcomes through data-driven insight and standardized protocols (Afrifa-Yamoah et al., 2024).

6. Emerging Biomarkers and Novel Tests in Chronic Disease Monitoring

The landscape of chronic disease monitoring has been transformed by the advent of emerging biomarkers and innovative testing methodologies. These new tools provide unprecedented sensitivity, precision, and the potential for earlier detection and personalized treatment strategies, surpassing the capabilities of traditional blood tests (de Franciscis et al., 2016).

6.1 Genomic and Proteomic Markers in Chronic Disease Monitoring

Genomic and proteomic markers have become critical in understanding and monitoring chronic diseases at a molecular level. Genomic biomarkers involve specific gene variants, transcriptomic profiles, and noncoding RNAs that correlate with disease susceptibility, progression, and therapeutic response. For instance, transcriptomic markers such as long non-coding RNAs (lncRNA) have been linked to cardiovascular diseases, while gene polymorphisms are instrumental in prognostic predictions across various chronic conditions like hypertension and peripheral vascular disease (de Franciscis et al., 2016).

Proteomic biomarkers, which analyze the protein expression profiles in biological samples, offer dynamic insights into the pathophysiological state of diseases. Proteins such as matrix metalloproteinases (MMPs), inflammatory cytokines, and oxidative stress-related enzymes serve as indicators of disease processes ranging from vascular inflammation to neurodegeneration. Notably, proteomic analyses have revealed altered levels of glial fibrillary acidic protein (GFAP) and superoxide dismutase (SOD1) in Alzheimer's disease, linking oxidative stress and inflammation to disease progression (Robeson et al., 2008).

Multi-omics approaches integrating genomic, proteomic, and metabolomic data amplify the precision of chronic disease detection and monitoring. Studies leveraging large cohorts demonstrate that specific proteins consistently show greater predictive capability for disease

incidence and prevalence compared to genetic variants or metabolites alone, suggesting their utility as clinically actionable biomarkers (Smelik et al., 2024).

6.2 MicroRNAs as Dynamic Regulators and Biomarkers

MicroRNAs (miRNAs), small non-coding RNAs that regulate gene expression post-transcriptionally, have emerged as versatile biomarkers in various chronic illnesses, especially chronic respiratory diseases, cardiovascular conditions, and pediatric chronic diseases. Altered miRNA expression impacts inflammation, cell proliferation, apoptosis, and immune responses, processes central to chronic disease pathophysiology (Stolzenburg & Harris, 2018).

For example, miR-126 suppresses vascular inflammation by inhibiting vascular cell adhesion molecule-1 (VCAM-1), thereby reducing leukocyte adherence. Other miRNAs like miR-155 are involved in immune cell activation and regulation, influencing chronic inflammatory responses crucial in diseases such as COPD and asthma. Circulating miRNAs in blood provide minimally invasive windows into disease activity and response to therapy, supporting their role as both diagnostic and prognostic biomarkers (Zhang & Han, 2024).

6.3 Metabolomics-Based Assays

Metabolomics, the comprehensive study of metabolites in biological samples, offers sensitive and holistic assessments of biochemical and metabolic dysfunctions underlying chronic diseases. By measuring small molecules such as amino acids, lipids, and carbohydrates, metabolomic assays can detect metabolic alterations preceding overt clinical symptoms in diseases like diabetes, cardiovascular disorders, autoimmune diseases, and thyroid dysfunction (Tsoukalas et al., 2024).

Metabolomic profiling enables identification of metabolic pathways involved in disease onset and progression, guiding personalized interventions including dietary modifications, lifestyle changes, and targeted pharmacotherapy. These assays provide a dynamic reflection of both genetic and environmental influences on chronic disease states, improving early diagnosis, monitoring therapeutic efficacy, and potentially reversing disease mechanisms (Tsoukalas et al., 2024).

6.4 Liquid Biopsy Innovations in Cancer Monitoring

Liquid biopsy represents a cutting-edge, minimally invasive approach for cancer detection and monitoring through analysis of circulating tumor DNA (ctDNA), RNA, exosomes, and circulating tumor cells (CTCs) in bodily fluids such as blood, saliva, or urine. This technique facilitates early cancer detection, real-time therapy monitoring, and detection of minimal residual disease or relapse, offering advantages over traditional tissue biopsies in terms of safety, feasibility for repeated sampling, and capturing tumor heterogeneity (Pandey & Yadav, 2025).

Liquid biopsies have shown promise in screening multiple cancer types at early stages, often before clinical symptoms arise, thus enabling timely and potentially life-saving interventions. The molecular information gleaned from liquid biopsies supports precision oncology by informing treatment selection and monitoring resistance mechanisms, thereby enhancing patient outcomes in chronic cancer management (Pandey & Yadav, 2025).

7. Technological Advances in Blood Testing

Technological advances continue to revolutionize blood testing, significantly enhancing the ability to monitor chronic diseases more accurately, rapidly, and conveniently. These innovations encompass pointof-care testing developments, lab automation augmented with artificial intelligence (AI), and telemedicine applications for remote monitoring, collectively facilitating a more proactive, patient-centered approach to chronic disease management (Whiting et al., 2019).

7.1 Point-of-Care Testing Developments

Point-of-care testing (POCT) has undergone remarkable advancements, enabling rapid diagnostics directly at or near the site of patient care rather than relying solely on centralized laboratories. Emerging technologies such as microfluidics and lab-on-a-chip devices allow multiple assays to be performed on a single small blood sample, significantly reducing turnaround time and patient discomfort. These devices integrate sample handling, reagent mixing, and detection into compact, portable platforms, delivering nearinstant results that are critical for timely clinical decision-making in chronic disease management (Khan et al., 2023).

Innovations include solid-based staining techniques and disposable cartridge systems, which simplify the sample preparation process, such as staining and washing, to single-step operations. Notably, POCT devices are increasingly incorporating AI algorithms for automated analysis, which enhances precision and consistency by reducing human error. For instance, advanced blood analyzers can simultaneously assess complete blood count (CBC) and morphology with AI-driven interpretation, optimizing diagnostic accuracy at the point of care. These developments address traditional barriers by improving usability, speed, and diagnostic depth, allowing health providers to offer personalized, immediate care and reduce overall healthcare costs (Han et al., 2025).

7.2 Lab Automation and AI-Assisted Interpretation

Laboratory automation integrated with AI represents a paradigm shift in the interpretation of blood test results, especially for complex analyses like hematology. AI-driven systems, including machine learning and deep learning models, are now employed to analyze large, multi-parametric datasets generated by technologies such as flow cytometry. These models excel at identifying intricate cellular patterns and classifying diseases with high accuracy, which is invaluable in diagnosing hematological malignancies and other chronic conditions (Liao et al., 2025).

Automated AI tools translate raw laboratory data into actionable clinical insights with greater speed and reliability than traditional manual methods. Natural language processing (NLP) and large language models (LLMs) assist in contextualizing lab values for clinicians and patients alike, demystifying complex medical terminology and enabling clearer communication of health status. Furthermore, AI algorithms can detect subtle early changes in blood biomarkers, facilitating preemptive interventions and personalized monitoring plans. The use of AI-powered platforms not only enhances diagnostic accuracy but also improves operational efficiency and mitigates diagnostic delays in chronic disease management (Santos-Silva et al., 2024).

7.3 Telemedicine and Remote Monitoring Using Blood Test Results

Telemedicine has increasingly embraced blood testing as a vital component of remote patient monitoring, particularly for chronic disease management. Advances in telehealth facilitate home-based blood sample collection through user-friendly kits with clear instructions, enabling patients to perform sample collection at their convenience without visiting clinical facilities. These samples are securely transported to accredited laboratories where advanced automated systems ensure precise analysis (Ezeamii et al., 2024).

The integration of telemedicine with digital platforms allows test results to be rapidly transmitted to both patients and healthcare providers, enabling timely interpretation and clinical decision-making via virtual consultations. This remote feedback loop enhances patient engagement, supports ongoing treatment adjustments, and fosters continuity of care. The ability to conduct frequent, minimally invasive monitoring optimizes management of chronic conditions such as diabetes, cardiovascular diseases, and renal disorders by providing real-time information on disease progression and therapeutic response. Telemedicine blood testing thus represents a transformative step toward accessible, efficient, and personalized healthcare delivery, especially in underserved or geographically remote populations (Greenwood et al., 2014).

8. Challenges and Limitations

8.1 Biological Variability and Pre-Analytical Errors

Biological variability refers to the natural fluctuations in analyte concentrations within and between individuals. These variations arise from genetic, physiological, and environmental factors and pose a major challenge in accurately interpreting blood test results for chronic disease monitoring. Within-subject biological variation often necessitates personalized reference ranges or the use of reference change values (RCVs) to distinguish true clinical changes from normal fluctuations. Studies report that many commonly tested analytes such as blood sugar, creatinine, and electrolytes have significant biological variation, influencing the reliability of standard reference intervals and complicating the monitoring of disease progression or treatment response (Ali et al., 2023).

Pre-analytical errors represent another critical limitation that can significantly affect test accuracy and reliability. These errors occur before the actual analysis, during patient preparation, sample collection, handling, transport, and storage. They constitute approximately 60-70% of all

laboratory errors and include hemolysis, inadequate sample volume, improper tube usage, labeling errors, and clot formation. The prevalence of such errors varies across clinical departments, with inpatient and critical care settings experiencing higher rates. These errors can lead to misdiagnosis, inappropriate treatment decisions, and increased healthcare costs (Nordin et al., 2024).

8.2 Cost-Effectiveness Considerations

While blood tests are integral to chronic disease management, their cost-effectiveness must be carefully evaluated, especially given healthcare budget constraints. Advanced and frequent testing can improve clinical outcomes but often at the expense of increased healthcare spending. Economic evaluations, including cost-utility analyses, have demonstrated that information and communications technology (ICT)based tailored management interventions that include regular blood monitoring are cost-effective for diseases like hypertension and diabetes, with incremental cost-effectiveness ratios (ICERs) well within acceptable thresholds. However, unnecessary or overly frequent testing may lead to over-diagnosis and inefficient resource utilization. Therefore, optimizing testing frequency and strategies based on clinical need and outcome evidence is essential to balance clinical benefit with economic sustainability (Mohiuddin et al., 2024).

8.3 Patient Compliance with Regular Testing

Effective chronic disease monitoring depends not only on test availability but also on patient adherence to recommended testing schedules. Compliance rates vary widely due to factors such as asymptomatic nature of many chronic conditions, patient understanding, socioeconomic status, and health system barriers. Studies have shown varying compliance, with significant portions of patients demonstrating partial or poor adherence to prescribed blood testing regimens. Non-compliance delays diagnosis, hampers treatment adjustments, and negatively impacts disease outcomes. Methods to enhance compliance include patient education, simplified testing procedures, use of reminders, and integration of testing with routine care visits (Rafii et al., 2014).

8.4 Equity in Access to Laboratory Services Globally

Global disparities in laboratory service access represent a profound limitation in chronic disease monitoring. In low- and middle-income countries (LMICs), weak laboratory infrastructure, shortage of skilled personnel, and underfunding result in only a minority having access to essential diagnostic services. Estimates show that in some LMICs, only about 18% of the population have access to basic diagnostics, leading to delayed or missed diagnoses and exacerbating health inequities. Strengthening laboratory systems globally through investment, training, and partnerships is a critical priority to ensure equitable access to timely, accurate, and affordable diagnostics as part of comprehensive chronic disease care (Larkin et al., 2024).

9. Future Perspectives

9.1 Personalized Medicine Based on Biomarker Profiles

The future of chronic disease monitoring increasingly hinges on personalized medicine driven by biomarker profiles. Biomarkers, measurable indicators of biological processes, enable precise characterization and stratification of patients beyond traditional diagnostics. Personalized medicine tailors interventions based on genetic, biochemical, and environmental factors unique to each individual. This approach improves treatment outcomes and minimizes adverse effects by aligning therapies with patient-specific disease mechanisms. Advances in biomarker discovery have notably impacted oncology, cardiovascular diseases, and diabetes, allowing targeted therapy choices informed by tumor genetic mutations or cardiac biomarkers. The dynamic profiling of biomarker panels facilitates early disease detection, risk prediction, and personalized prevention strategies, signaling a shift from one-size-fits-all models to precision healthcare (Plans-Beriso et al., 2024).

9.2 Integration with Wearable Biosensors

The integration of blood test biomarkers with wearable biosensor technology represents a transformative future development in chronic disease monitoring. Wearable biosensors provide continuous, real-time assessment of physiological and biochemical parameters through non-invasive means, such as transdermal glucose monitoring or sweat biomarker analysis. Coupled

with advances in miniaturized biosensing and enzyme immobilization technology, these devices promise constant health status tracking outside clinical settings. This continuous monitoring enhances early detection of disease exacerbations and facilitates responsive treatment adjustments. Artificial intelligence (AI) algorithms integrated with wearable biosensors allow pattern recognition and predictive analytics, enabling personalized disease management and alert generation for patients and healthcare providers. Despite challenges such as data accuracy and privacy, wearables are positioned to play a major role in patient-centered chronic disease care (Jafleh et al., 2024).

9.3 Big Data Applications for Predictive Modeling

The accumulation of vast amounts of biomedical and lifestyle data offers unprecedented opportunities through big data analytics and predictive modeling. By synthesizing disparate data sources, including electronic health records, genomics, wearable device outputs, and social determinants, models can identify hidden patterns to predict disease onset, progression, and therapeutic response. Machine learning algorithms such as gradient boosting and random forests have demonstrated accuracy exceeding 80% in predicting chronic diseases like diabetes, hypertension, and cardiovascular conditions. These predictive tools enable proactive interventions and precision health management by quantifying individual risk profiles and anticipating adverse events. Big data-driven insights not only enhance preventative care but also optimize resource allocation and patient education, promising to reshape chronic disease paradigms (Lee et al., 2022).

9.4 International Guidelines Harmonization

To maximize the clinical impact of blood tests and emerging technologies for chronic disease monitoring, international harmonization of clinical practice guidelines is vital. Diverse national guidelines currently exist with varying recommendations on biomarker use, screening intervals, and follow-up protocols. Collaborative efforts, such as those undertaken for cardiomyopathy surveillance and pediatric cancer survivor care, emphasize evidence-based, transparent processes, and multidisciplinary consensus to create unified, implementable guidelines suitable for global adoption. Harmonization not only facilitates standardized patient care but also promotes large-scale research collaborations necessary to fill knowledge gaps, validate biomarker utility, and assess cost-effectiveness. Future initiatives are expected to establish adaptable frameworks balancing consistent global standards with local healthcare system flexibility (Armenian et al., 2015).

Conclusion

Blood tests remain essential tools in the prevention, diagnosis, and management of chronic diseases, providing vital quantitative biomarkers that enable early detection, continuous monitoring, and treatment optimization. Their role spans major chronic conditions such as cardiovascular diseases, diabetes, chronic kidney disease, cancer, and respiratory disorders. Despite challenges including biological variability, test accessibility, patient adherence, and cost considerations, blood testing continues to evolve with advances in technology, including point-of-care devices, AI-assisted interpretation, and telemedicine integration. Emerging biomarkers from genomic, proteomic, and metabolomic research, along with novel approaches such as liquid biopsy and wearable biosensors, promise to enhance personalized medicine and proactive disease management. The future of chronic disease monitoring lies in harmonizing international guidelines, expanding equitable access, and leveraging big data analytics and predictive models to improve patient outcomes and healthcare sustainability. Ultimately, the integration of traditional and innovative blood tests into clinical practice offers a powerful approach to mitigating the global burden of chronic diseases and supporting precision healthcare delivery.

References

1. Afrifa-Yamoah, E., Adua, E., Peprah-Yamoah, E., Anto, E. O., Opoku-Yamoah, V., Acheampong, E., Macartney, M. J., & Hashmi, R. (2024). Pathways to chronic disease detection and prediction: Mapping the potential of machine learning to the pathophysiological processes

while navigating ethical challenges. Chronic Diseases and Translational Medicine, 11(1), 1–21. https://doi.org/10.1002/cdt3.137

2. Al-hadlaq, S. M., Balto, H. A., Hassan, W. M., Marraiki, N. A., & El-Ansary, A. K. (2022). Biomarkers of non-communicable chronic disease: An update on contemporary methods. PeerJ, 10, e12977. https://doi.org/10.7717/peerj.12977

3. Ali, Md. A., Hossain, Md. S., Juliana, F. M., & Reza, Md. S. (2023). Evaluation of Biological Variation of Different Clinical Laboratory Analytes in the Blood of Healthy Subjects. Cureus. https://doi.org/10.7759/cureus.36242

4. Armenian, S. H., Hudson, M. M., Mulder, R. L., Chen, M. H., Constine, L. S., Dwyer, M., Nathan, P. C., Tissing, W. J. E., Shankar, S., Sieswerda, E., Skinner, R., Steinberger, J., van Dalen, E. C., van der Pal, H., Wallace, W. H., Levitt, G., & Kremer, L. C. M. (2015). Recommendations for Cardiomyopathy Surveillance for Survivors of Childhood Cancer: A Report from the International Late Effects of Childhood Cancer Guideline Harmonization Group. The Lancet. Oncology, 16(3), e123–e136. https://doi.org/10.1016/S1470-2045(14)70409-7

5. Babić Leko, M., Jureško, I., Rozić, I., Pleić, N., Gunjača, I., & Zemunik, T. (2023). Vitamin D and the Thyroid: A Critical Review of the Current Evidence. International Journal of Molecular Sciences, 24(4), 3586. https://doi.org/10.3390/ijms24043586

6. Bhawal, R., Oberg, A. L., Zhang, S., & Kohli, M. (2020). Challenges and Opportunities in Clinical

7. Cabalar, I., Le, T. H., Silber, A., O'Hara, M., Abdallah, B., Parikh, M., & Busch, R. (2024). The role of blood testing in prevention, diagnosis, and management of chronic diseases: A review. The American Journal of the Medical Sciences, 368(4), 274–286.

8. https://doi.org/10.1016/j.amjms.2024.04.009

9. Castro, C., & Gourley, M. (2010a). Diagnostic Testing and Interpretation of Tests for Autoimmunity.

The Journal of Allergy and Clinical Immunology, 125(2 Suppl 2), S238–S247.
https://doi.org/10.1016/j.jaci.2009.09.041

10. Castro, C., & Gourley, M. (2010b). Diagnostic Testing and Interpretation of Tests for Autoimmunity.

The Journal of Allergy and Clinical Immunology, 125(2 Suppl 2),S238–S247.
https://doi.org/10.1016/j.jaci.2009.09.041

11. Chen, Y., Tao, Y., Zhang, L., Xu, W., & Zhou, X. (2019). Diagnostic and prognostic value of biomarkers in acute myocardial infarction. Postgraduate Medical Journal, 95(1122), 210–216. https://doi.org/10.1136/postgradmedj-2019-136409

12. Chouhan, A. S., Kaple, M., & Hingway, S. (2023). A Brief Review of Diagnostic Techniques and Clinical Management in Chronic Kidney Disease. Cureus.
https://doi.org/10.7759/cureus.49030

13. D'Costa, J. J., Goldsmith, J. C., Wilson, J. S., Bryan, R. T., & Ward, D. G. (2016). A Systematic Review of the Diagnostic and Prognostic Value of Urinary Protein Biomarkers in Urothelial Bladder Cancer. Bladder Cancer (Amsterdam, Netherlands), 2(3), 301–317. https://doi.org/10.3233/BLC-160054

14. de Franciscis, S., Metzinger, L., & Serra, R. (2016). The Discovery of Novel Genomic, Transcriptomic, and Proteomic Biomarkers in Cardiovascular and Peripheral Vascular Disease: The State of the Art.

BioMed Research International, 2016(1), 7829174. https://doi.org/10.1155/2016/7829174

15. Ezeamii, V. C., Okobi, O. E., Wambai-Sani, H., Perera, G. S., Zaynieva, S., Okonkwo, C. C., Ohaiba, M. M., William-Enemali, P. C., Obodo, O. R., & Obiefuna, N. G. (2024). Revolutionizing

Healthcare: How Telemedicine Is Improving Patient Outcomes and Expanding Access to Care. Cureus. https://doi.org/10.7759/cureus.63881
16. GBD 2015 Risk Factors Collaborators. (2016). Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: A systematic analysis for the Global Burden of Disease Study 2015. Lancet (London, England), 388(10053), 1659–1724. https://doi.org/10.1016/S0140-6736(16)31679-8
17. Gounden, V., Bhatt, H., & Jialal, I. (2024). Renal Function Tests. In StatPearls [Internet]. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK507821/
18. Greenwood, D. A., Young, H. M., & Quinn, C. C. (2014). Telehealth Remote Monitoring Systematic
Review. Journal of Diabetes Science and Technology, 8(2), 378–389. https://doi.org/10.1177/1932296813519311
19. Haber, D. A., & Velculescu, V. E. (2014). Blood-Based Analyses of Cancer: Circulating Tumor Cells and Circulating Tumor DNA. Cancer Discovery, 4(6), 650–661. https://doi.org/10.1158/21598290.CD-13-1014
20. Hacker, K. (2024). The Burden of Chronic Disease. Mayo Clinic Proceedings: Innovations, Quality &
Outcomes, 8(1), 112–119. https://doi.org/10.1016/j.mayocpiqo.2023.08.005
21. Han, G.-R., Goncharov, A., Eryilmaz, M., Ye, S., Palanisamy, B., Ghosh, R., Lisi, F., Rogers, E., Guzman, D., Yigci, D., Tasoglu, S., Di Carlo, D., Goda, K., McKendry, R. A., & Ozcan, A. (2025). Machine learning in point-of-care testing: Innovations, challenges, and opportunities. Nature Communications, 16(1), 3165. https://doi.org/10.1038/s41467-025-58527-6
22. He, K., Huang, S., & Qian, X. (2019). Early detection and risk assessment for chronic disease with irregular longitudinal data analysis. Journal of Biomedical Informatics, 96, 103231. https://doi.org/10.1016/j.jbi.2019.103231
23. Iwasa, M., Shigefuku, R., Eguchi, A., Tamai, Y., & Takei, Y. (2021). Update on blood-based biomarkers for chronic liver diseases prognosis: Literature review and institutional experience. JGH Open: An
Open Access Journal of Gastroenterology and Hepatology, 5(11), 1250–1256. https://doi.org/10.1002/jgh3.12667
24. Jafleh, E. A., Alnaqbi, F. A., Almaeeni, H. A., Faqeeh, S., Alzaabi, M. A., & Al Zaman, K. (2024). The Role of Wearable Devices in Chronic Disease Monitoring and Patient Care: A Comprehensive Review. Cureus. https://doi.org/10.7759/cureus.68921
25. Jeha, G. S., & Haymond, M. (2007). Understanding and interpreting laboratory test results in the clinical management of diabetes mellitus. Pediatric Endocrinology Reviews: PER, 5 Suppl 1, 608–628.
26. Kalas, M. A., Chavez, L., Leon, M., Taweesedt, P. T., & Surani, S. (2021). Abnormal liver enzymes: A review for clinicians. World Journal of Hepatology, 13(11), 1688–1698. https://doi.org/10.4254/wjh.v13.i11.1688
27. Khan, A. I., Khan, M., & Khan, R. (2023). Artificial Intelligence in Point-of-Care Testing. Annals of Laboratory Medicine, 43(5), 401–407. https://doi.org/10.3343/alm.2023.43.5.401
28. King, N., Smart, N. A., Bungon, T., Peacock, M., & Awan, S. A. (2025). Biomarkers in coronary artery disease: Systematic review and meta-analysis. Future Cardiology, 21(1), 39–46. https://doi.org/10.1080/14796678.2024.2442214
29. Kumakura, H., Fujita, K., Kanai, H., Araki, Y., Hojo, Y., Kasama, S., Iwasaki, T., Ichikawa, S., Nakashima, K., & Minami, K. (2015). High-sensitivity C-reactive Protein, Lipoprotein(a) and Homocysteine are Risk Factors for Coronary Artery Disease in Japanese Patients with Peripheral Arterial Disease. Journal of Atherosclerosis and Thrombosis, 22(4), 344–354.

30. https://doi.org/10.5551/jat.25478
31. Larkin, P. M. K., Theel, E. S., Culbreath, K., Garner, O. B., Vassell, S., Kim, W., She, R. C., Wesley Long, S., & Esther Babady, N. (2024). Diagnostic testing and laboratory equity in clinical microbiology. Microbiology Spectrum, 12(8), e01222-24.
https://doi.org/10.1128/spectrum.01222-24
32. Le, Q. A., Kiener, T., Johnson, H. A., Li, K. H., Limburg, P. J., Fendrick, A. M., Kisiel, J. B., & Ebner, D. W. (2025). Adherence to recommended blood-based screening tests for cancer and chronic diseases:
A systematic literature review. Preventive Medicine,191, 108213.
https://doi.org/10.1016/j.ypmed.2024.108213
33. Lee, C., Jo, B., Woo, H., Im, Y., Park, R. W., & Park, C. (2022). Chronic Disease Prediction Using the Common Data Model: Development Study. JMIR AI, 1(1), e41030.
https://doi.org/10.2196/41030
34. Liao, H., Zhang, F., Chen, F., Li, Y., Sun, Y., Sloboda, D. D., Zheng, Q., Ying, B., & Hu, T. (2025). Application of artificial intelligence in laboratory hematology: Advances, challenges, and prospects. Acta Pharmaceutica Sinica B. https://doi.org/10.1016/j.apsb.2025.05.036
35. Lopez-Giacoman, S., & Madero, M. (2015). Biomarkers in chronic kidney disease, from kidney function to kidney damage. World Journal of Nephrology, 4(1), 57–73. https://doi.org/10.5527/wjn.v4.i1.57
36. Madjid, M., & Fatemi, O. (2013). Components of the complete blood count as risk predictors for coronary heart disease: In-depth review and update. Texas Heart Institute Journal, 40(1), 17–29.
37. Mohiuddin, S. G., Ward, M. E., Hollingworth, W., Watson, J. C., Whiting, P. F., & Thom, H. H. Z. (2024). Cost-Effectiveness of Routine Monitoring of Long-Term Conditions in Primary Care: Informing Decision Modelling with a Systematic Review in Hypertension, Type 2 Diabetes and Chronic Kidney Disease. PharmacoEconomics Open, 8(3), 359–371.
https://doi.org/10.1007/s41669024-00473-y
38. Moore, T. L., & Dalrymple, A. M. (2016). Laboratory Studies in Autoimmune Diseases. Missouri Medicine, 113(2), 118–122.
39. National Academies of Sciences, E., Division, H. and M., Services, B. on H. C., & Techniques, C. on I. N. or I. D. or E. (2023). Techniques for Hematological Disorders. In Advances in the Diagnosis and Evaluation of Disabling Physical Health Conditions. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK593683/
40. Nelson, M., & Dungan, K. M. (2025). Diagnostic Tests for Diabetes Mellitus. In Endotext [Internet]. MDText.com, Inc. https://www.ncbi.nlm.nih.gov/books/NBK278985/
41. Nordin, N., Ab Rahim, S. N., Wan Omar, W. F. A., Zulkarnain, S., Sinha, S., Kumar, S., & Haque, M. (2024). Preanalytical Errors in Clinical Laboratory Testing at a Glance: Source and Control Measures. Cureus. https://doi.org/10.7759/cureus.57243
42. Pandey, S., & Yadav, P. (2025). Liquid biopsy in cancer management: Integrating diagnostics and clinical applications. Practical Laboratory Medicine, 43, e00446.
https://doi.org/10.1016/j.plabm.2024.e00446
43. Patel, K., Asrani, S. K., Fiel, M. I., Levine, D., Leung, D. H., Duarte-Rojo, A., Dranoff, J. A., Nayfeh, T., Hasan, B., Taddei, T. H., Alsawaf, Y., Saadi, S., Majzoub, A. M., Manolopoulos, A., Alzuabi, M., Ding, J., Sofiyeva, N., Murad, M. H., Alsawas, M., … Sterling, R. K. (2025). Accuracy of blood-based biomarkers for staging liver fibrosis in chronic liver disease: A systematic review supporting the
AASLD Practice Guideline. Hepatology (Baltimore, Md.), 81(1), 358–379.
https://doi.org/10.1097/HEP.0000000000000842

44. Plans-Beriso, E., Babb-de-Villiers, C., Petrova, D., Barahona-López, C., Diez-Echave, P., Hernández, O. R., Fernández-Martínez, N. F., Turner, H., García-Ovejero, E., Craciun, O., Fernández-Navarro, P.,
Fernández-Larrea, N., García-Esquinas, E., Kuhn, I., Jiménez-Planet, V., Moreno, V., RodríguezArtalejo, F., Sánchez, M. J., Pollan-Santamaria, M., … Pérez-Gómez, B. (2024). Biomarkers for personalised prevention of chronic diseases: A common protocol for three rapid scoping reviews. Systematic Reviews, 13, 147. https://doi.org/10.1186/s13643-024-02554-9
45. Rafii, F., Fatemi, N. S., Danielson, E., Johansson, C. M., & Modanloo, M. (2014). Compliance to treatment in patients with chronic illness: A concept exploration. Iranian Journal of Nursing and Midwifery Research, 19(2), 159–167.
46. Rahman, Md. A., Shanjana, Y., Tushar, Md. I., Mahmud, T., Rahman, G. M. S., Milan, Z. H., Sultana, T., Chowdhury, A. M. L. H., Bhuiyan, M. A., Islam, Md. R., & Reza, H. M. (2021). Hematological abnormalities and comorbidities are associated with COVID-19 severity among hospitalized patients: Experience from Bangladesh. PLoS ONE,16(7),e0255379.
https://doi.org/10.1371/journal.pone.0255379
47. Robeson, R. H., Siegel, A. M., & Dunckley, T. (2008). Genomic and Proteomic Biomarker Discovery in Neurological Disease. Biomarker Insights, 3, 73–86.
https://doi.org/10.4137/bmi.s596
48. Santos-Silva, M. A., Sousa, N., & Sousa, J. C. (2024). Artificial intelligence in routine blood tests. Frontiers in Medical Engineering, 2. https://doi.org/10.3389/fmede.2024.1369265
49. Schöll, M., Verberk, I. M. W., Campo, M. del, Delaby, C., Therriault, J., Chong, J. R., Palmqvist, S., & Alcolea, D. (2024). Challenges in the practical implementation of blood biomarkers for Alzheimer's disease. The Lancet Healthy Longevity, 5(10). https://doi.org/10.1016/j.lanhl.2024.07.013
50. Shaik, S. P., Karan, H. H., Singh, A., Attuluri, S. K., Khan, A. A. N., Zahid, F., & Patil, D. (2024). HFpEF: New biomarkers and their diagnostic and prognostic value. Current Problems in Cardiology, 49(1 Pt C), 102155. https://doi.org/10.1016/j.cpcardiol.2023.102155
51. Smelik, M., Zhao, Y., Li, X., Loscalzo, J., Sysoev, O., Mahmud, F., Mansour Aly, D., & Benson, M. (2024). An interactive atlas of genomic, proteomic, and metabolomic biomarkers promotes the potential of proteins to predict complex diseases. Scientific Reports, 14(1), 12710. https://doi.org/10.1038/s41598-024-63399-9
52. Stolzenburg, L. R., & Harris, A. (2018). The role of microRNAs in chronic respiratory disease: Recent insights. Biological Chemistry, 399(3), 219–234. https://doi.org/10.1515/hsz-2017-0249
53. Sturmey, E., & Malaspina, A. (2022). Blood biomarkers in ALS: Challenges, applications and novel frontiers. Acta Neurologica Scandinavica, 146(4), 375–388.
https://doi.org/10.1111/ane.13698
54. Swarup, S., Ahmed, I., Grigorova, Y., & Zeltser, R. (2024). Metabolic Syndrome. In StatPearls [Internet]. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK459248/
55. Thomas, S. A., Browning, C. J., Charchar, F. J., Klein, B., Ory, M. G., Bowden-Jones, H., & Chamberlain, S. R. (2023). Transforming global approaches to chronic disease prevention and management across the lifespan: Integrating genomics, behavior change, and digital health solutions. Frontiers in Public Health, 11, 1248254. https://doi.org/10.3389/fpubh.2023.1248254
56. Tsoukalas, D., Sarandi, E., Fragoulakis, V., Xenidis, S., Mhliopoulou, M., Charta, M., Paramera, E., Papakonstantinou, E., & Tsatsakis, A. (2024). Metabolomics-based treatment for chronic diseases: Results from a multidisciplinary clinical study. BMJ Nutrition, Prevention & Health, 7(2), e000883.
https://doi.org/10.1136/bmjnph-2024-000883

57. Varon, J. (2016). Hematologic Disorders. Handbook of Critical and Intensive Care Medicine, 159–180. https://doi.org/10.1007/978-3-319-31605-5_7
58. Virdee, P. S., Collins, K. K., Smith, C. F., Yang, X., Zhu, S., Roberts, N., Oke, J. L., Bankhead, C., Perera, R., Hobbs, F. R., & Nicholson, B. D. (2025). Clinical Prediction Models Incorporating Blood
Test Trend for Cancer Detection: Systematic Review, Meta-Analysis, and Critical Appraisal. JMIR Cancer, 11, e70275. https://doi.org/10.2196/70275
59. Whiting, D., Croker, R., Watson, J., Brogan, A., Walker, A. J., & Lewis, T. (2019). Optimising laboratory monitoring of chronic conditions in primary care: A quality improvement framework. BMJ
Open Quality, 8(1), e000349. https://doi.org/10.1136/bmjoq-2018-000349
60. Zhang, M., & Han, Y. (2024). MicroRNAs in chronic pediatric diseases (Review). Experimental and Therapeutic Medicine, 27(3), 1–8. https://doi.org/10.3892/etm.2024.12388