



An Overview on Interpretation of Laboratory Parameters

Syeda Zuleqaunnisa Begum*¹, Shireen Fatima², Ummul Khair Afifa Fatima²

1. Assistant Professor, Department of Pharmacy Practice, Deccan School of Pharmacy, Hyderabad, Telangana, India.

2. B. Pharmacy Students, Deccan School of Pharmacy, Hyderabad, Telangana, India.

*Corresponding author's E-mail: syedazuleqaunnisa@gmail.com

Received: 02-04-2024; Revised: 25-05-2024; Accepted: 04-06-2024; Published on: 15-06-2024.

ABSTRACT

Clinical and laboratory tests in clinical medicine include a range of measurements that may be categorized as "normal range" tests, positive or negative tests, or contextual tests. Laboratory services play an integral role in the healthcare system from primary through to tertiary level care since diagnostic tests can either confirm or exclude a tentative diagnosis, or screen for potential diseases. Clinical laboratory tests used in the evaluation of disease states involves CBP, sugar test, liver function test, Kidney function Test, Thyroid Function Test, lipid profile, cardiac biomarkers, Fluid and Electrolyte Test, microbiological Cultural Sensitivity test, pulmonary function tests. General understanding of lab data helps pharmacists to understand the patient's medical background and in order to separate that which is relevant to patient's drug therapy

Keywords: Laboratory services; Healthcare system; Laboratory test; Healthcare providers; Clinical context.

INTRODUCTION

Laboratory investigations play a pivotal role in diagnosing and management of diseases. The number of tests ordered daily rises with the number and complexity of diagnoses at discharge.

1. Complete Blood Count (CBC): Complete blood count (CBC) is one of the most common blood tests requested by clinicians and evaluates the total numbers and characteristics of cell components in the blood

- The most frequent type of WBC is neutrophils, accounting for 50–70% of the total WBC in blood circulation. Neutrophils are the primary immune cells that respond to infection and are controlled under homeostatic conditions.
- Lymphocytes are a critical population of WBCs and play an essential role in both innate and adaptive immunity.
- The primary function of Hb is to move O₂ to the tissue of the whole body.
- The primary function of the platelet is hemostasis. ⁽¹⁾
- Common terms in CBC and their normal values are as follows

Red Blood Cell (RBC) Count: The number of RBCs per volume of blood (normal value: 4.2 to 6.9 x 10⁹/mm³)

Hemoglobin (Hb): Amount of oxygen-carrying capacity of blood (normal value: 130 to 180 g/L in males, 120 to 160 g/L in females)

Hematocrit (Hct): Percentage of whole blood occupied by packed RBCs (normal value: 45% to 62% in males, 37% to 48% in females)

Mean Corpuscular Volume (MCV): The measure of RBC size (normal value: 80 to 100 micromillimeter)

Mean Corpuscular Hemoglobin (MCH): Amount of oxygen-carrying hemoglobin inside RBCs (normal value: 27 to 32 pg/cell)

Mean Corpuscular Hemoglobin Concentration (MCHC): Average concentration of Hb inside RBCs (normal value: 32% to 36%)

White Blood Cell (WBC) Count: The number of WBCs per volume of blood (normal value: 4.3 to 11 x 10⁹/mm³)

WBC differential:

- Neutrophils (normal value: 1.8 to 7.8 x 10³/mm³)
- Lymphocytes (normal value: 0.7 to 4.5 x 10³/mm³)
- Monocytes (normal value: 0.1 to 1.0 x 10³/mm³)
- Eosinophils (normal value: 0 to 0.4 x 10³/mm³)
- Basophils (normal value: 0 to 0.2 x 10³/mm³)

Platelet Count: The number of platelets per volume of blood (normal value: 150 to 400 x 10⁹/mm³).

Reticulocytes: The number of immature RBCs in circulating blood (normal value: 1% of total RBC count)

Peripheral Smear

Peripheral smear gives information regarding abnormality in size, shape, color, counts, and composition (inclusions) of cells compared to normal.

Coagulation Profile

Commonly used tests for hemostasis are as follows.

Platelet Count: it gives an account of the number of platelets in the volume of blood (normal value: 150 to 400 x 10⁹/L). Low platelet count occurs in thrombocytopenia. It



could be primary (isolated thrombocytopenia) without any other underlying cause, or it could be secondary with associated conditions such as HIV, HCV, SLE, CLL. Certain drugs cause drug-induced thrombocytopenia, e.g., aspirin, ethanol, and NSAIDs.

Prothrombin Time (PT): It is also reported along with laboratory control (normal range: 11 to 24s). It measures the extrinsic pathway (factor VII) and common pathway. It is prolonged in vitamin K deficiency, vitamin K antagonist therapy (warfarin), and factor VII deficiency.

International Normalized Ratio (INR): Normal range is 0.9 to 1.2. It is used to monitor warfarin therapy and for the assessment of hepatic function.

Activated Partial Thromboplastin Time (aPTT): It is reported against a normal control (normal range: 22 to 35s). It measures the activity of the common pathway and intrinsic pathway (factors VIII, IX, XI, XII). It is also used to monitor heparin therapy. It is prolonged in hemophilia A (Factor VIII deficiency) and B (Factor IX deficiency).

Other Tests

- Fibrinogen
- D-Dimers
- Specific factor assays (Factor VIII)
- Lupus anticoagulant
- Tests for thrombophilia (activated protein C resistance)
- Von Willebrand tests (vWF antigen, Ristocetin cofactor activity, factor VIII)

2. Sugar Tests

Diagnostic Tests in Diabetes Mellitus

- Fasting Blood Glucose (FBG): normal range is <126 mg/dL
- Random Blood Glucose (RBG): normal range is <200 mg/dL
- Glycosylated Hemoglobin (HbA1c): normal value is <6.5 %
- 2-hour 75 gm Oral Glucose Tolerance Test (OGTT): normal value is < 200 mg/dl

Approach to Suspected Diabetes Mellitus

Diabetes mellitus (DM) is a metabolic disorder characterized by hyperglycemia with disturbances in carbohydrate, protein, and fat metabolism resulting from defects in insulin secretion, its action, or both. Typical DM symptoms are polyuria, polydipsia, weight loss, polyphagia, blurred vision, and increased susceptibility to infections. There are two major types of DM.

1. Type 1 diabetes mellitus (immune-mediated, idiopathic)

2. Type 2 diabetes mellitus

Any one of the following is diagnostic

1. FBG \geq 126 gm/dL OR
2. 2 hr OGTT \geq 200 mg/dL OR
3. RBG \geq 200mg/dL along with classic symptoms of DM OR
4. HbA1c \geq 6.5 %

Impaired fasting glucose:

Patients who have FBG between 109 to 126 mg/dL are labeled to have impaired fasting glucose and are then subjected to 2 hr 75 gm OGTT to confirm DM²

3. Liver Function Tests:

The term "liver function tests" is a misnomer as many of the tests do not comment on the function of the liver but rather pinpoint the source of the damage. Elevations in ALT and AST in out of proportion to ALP, and bilirubin denotes a hepatocellular disease. An elevation in ALP and bilirubin in disproportion to ALT and AST would characterize a cholestatic pattern. A mixed injury pattern is defined as an elevation of alkaline phosphatase and AST/ALT levels. Isolated hyperbilirubinemia is defined as an elevation of bilirubin with normal alkaline phosphatase and AST/ALT levels.

Reference ranges for LFTs tend to vary depending on the laboratory. Further, normal reference ranges vary between males and females and may be higher for those with a higher body mass index. A patient's blood test values should be interpreted based on the reference value of the laboratory in which the test is done. It is recommended that each laboratory establish its own reference interval based on its methodology³

Alanine transaminase: 4 to 36 IU/L

Aspartate transaminase: 5 to 30 IU/L

Alkaline phosphatase: 30 to 120 IU/L

Gamma-glutamyltransferase: 6-50 IU/L

Bilirubin: 2 to 17 μ mol/L

Direct bilirubin: 0 to 6 μ mol/L

Prothrombin time: 10.9 to 12.5 seconds

Albumin: 35-50 g/L

Total protein: 60 to 80 g/L

Lactate dehydrogenase: 50 to 150 IU/L

4. Renal Function Test:

Glomerular Filtration Rate

The best overall indicator of the glomerular function is the glomerular filtration rate (GFR). GFR is the rate in milliliters per minute at which substances in plasma are filtered through the glomerulus; in other words, the clearance of a



substance from the blood. The normal GFR for an adult male is 90 to 120 mL per minute.

Creatinine

The most commonly used endogenous marker for the assessment of glomerular function is creatinine. The calculated clearance of creatinine is used to provide an indicator of GFR.

$$C = (U \times V) / P$$

C = clearance, U = urinary concentration, V = urinary flow rate (volume/time i.e. ml/min), and P = plasma concentration

Blood Urea Nitrogen (BUN): Urea or BUN is a nitrogen-containing compound formed in the liver as the end product of protein metabolism and the urea cycle. About 85% of urea is eliminated via kidneys; the rest is excreted via the gastrointestinal (GI) tract. The ratio of BUN: creatinine can be useful to differentiate pre-renal from renal causes when the BUN is increased. In pre-renal disease, the ratio is close to 20:1, while in intrinsic renal disease, it is closer to 10:1. Upper GI bleeding can be associated with a very high BUN to creatinine ratio (sometimes >30:1).⁴

5. Thyroid Gland

Thyroid function tests provide information at physiological, pathological and anatomical levels. The concentration of total T4 in adults ranges from 5 to 12 µg/dL (64 to 154 nmol/L). A normal serum TT3 concentration in adult range from 80-190 ng/dL. The normal values for FT4 in adults range from 1.0 to 3.0 ng/dL (13 to 39 pmol/L). Free Triiodothyronine (FT3) The normal adult reference value is 0.25-0.65 ng/dL (3.8-10 nmol/L).

Thyrotropin or Thyroid Stimulating Hormone (TSH): Normal range is approximately 0.5-4.5 mU/L.⁵

6. Electrolytes:

Electrolytes are essential for basic life functioning, such as maintaining electrical neutrality in cells and generating and conducting action potentials in the nerves and muscles. Significant electrolytes include sodium, potassium, chloride, magnesium, calcium, phosphate, and bicarbonates. Electrolytes come from our food and fluids.

These electrolytes can be imbalanced, leading to high or low levels. High or low levels of electrolytes disrupt normal bodily functions and can lead to life-threatening complications.

Sodium: Hyponatremia is diagnosed when the serum sodium level is less than 135 mmol/L. Hypernatremia occurs when serum sodium levels are greater than 145 mmol/L.

Potassium: Hypokalemia occurs when serum potassium levels are under 3.6 mmol/L. Hyperkalemia occurs when the serum potassium levels are above 5.5 mmol/L.

Calcium: Hypocalcemia is diagnosed when the corrected serum total calcium levels are less than 8.8 mg/dL. Hypercalcemia is when corrected serum total calcium levels exceed 10.7 mg/dL.

Magnesium: Hypomagnesemia occurs when the serum magnesium levels are less than 1.46 mg/dL.⁶

7. Tests Associated with Cardiac Disorders:

Lipid profile: a lipid profile or lipid panel consists of the following,

- Total cholesterol
- High-density lipoprotein (HDL) cholesterol
- Low-density lipoprotein (LDL) cholesterol
- Triglycerides
- Fasting triglyceride level:
 - Normal: less than 150 mg/dL
 - Mild hypertriglyceridemia: 150 to 499 mg/dL
 - Moderate hypertriglyceridemia: 500 to 886 mg/dL
 - Very high or severe hypertriglyceridemia: greater than 886 mg/dL
- LDL-C level:
 - Optimal: less than 100 mg/dL
 - Near optimal/above optimal: 100 to 129 mg/dL
 - Borderline high: 130 to 159 mg/dL
 - High: 160 to 189 mg/dL
 - Very high: greater than 190 mg/dL
- HDL level:
 - Low: less than 40
 - High: greater than or equal to 60.⁷

Cardiac biomarkers

Cardiac biomarkers are endogenous substances released into the bloodstream when the heart muscle is damaged or stressed. Measurement of these biomarkers is used to help diagnose, assess risk, and manage acute coronary syndrome (ACS), a potentially life-threatening condition characterized by the sudden onset of persistent pain in the chest, one or both arms, shoulders, stomach, or jaw, shortness of breath, nausea, sweating and dizziness.

AST: It increases in the blood 3 to 4 hours after an AMI, peaks at 15 to 28 hours. and returns to baseline within 5 days.

Myoglobin: It is a heme protein found in cardiac and skeletal muscle tissue. Due to its low molecular weight, myoglobin can be detected in the blood 1 hour after myocardial injury, peaks within 4 to 12 hours, and immediately returns to baseline levels. As a result,



myoglobin has some diagnostic value alongside CK-MB for faster detection of AMI.

Cardiac troponins: These are specific and sensitive biomarkers of cardiac ischemia and are the preferred biomarkers in evaluating patients suspected to have AMI. There are sensitive and highly sensitive assays to detect cardiac troponin levels in the blood. Although CK-MB has a high sensitivity for cardiac myocytes, testing for CK-MB should not be used as a first-line diagnostic measure if cardiac troponin assays are available. In the absence of cardiac troponin assays, CK-MB can be useful in evaluating AMI, but it is far less sensitive and specific than cardiac troponins. Since cardiac troponin levels remain elevated in the blood for multiple days after an AMI, they are not useful in evaluating for reinfarction of cardiac myocytes (another myocardial infarction).

CK-MB: CK-MB levels normalize 48 to 72 hours after an AMI, so a rising level in the blood after normalization can confirm that another myocardial infarction has occurred⁸

8. MICRO BIOLOGICAL CULTURE SENSITIVITY TESTS

Dilution methods (Eg-Broth and Agar dilution method):

Common dilution tests include broth dilution and agar dilution. In both tests, bacteria are placed onto multiple plates, tubes, or wells containing a specific concentration of antibiotic.

Broth dilution consists of microdilution and macrodilution. Although they are similar, the methods differ primarily by the modality that is used to perform susceptibility testing (wells or tubes). Broth microdilution is performed by placing different antibiotics with varying concentrations in wells that contain liquid media. Bacteria are added to each well, and the tray is incubated. The presence of bacterial growth is then identified through visual inspection of the plate. The MIC of the broth microdilution test is determined when no growth is observed with a particular antibiotic. An advantage of this test is that more than one antibiotic can be tested at a time. Disadvantages are that broth dilution is labor-intensive and time-consuming, and potential procedural errors may occur.

The agar dilution test is similar to the broth dilution test, the major difference being that it uses physical media as opposed to liquid media. Agar dilution is performed by placing standard concentrations of the organism on agar plates that vary in concentration of antibiotic. The MIC is determined in the first test tube that demonstrates no growth of the organism. This test is commonly used when testing multiple bacteria against a particular antibiotic. Agar dilution is also labor-intensive and time-consuming, and it cannot test more than one antibiotic at a time.

Disc-diffusion method

The disk diffusion, or Kirby-Bauer, method, is a common test used to determine antibiotic susceptibility. Diffusion testing works by placing an antibiotic disc onto an agar plate containing bacteria. The plate is incubated for up to

24 hours and during this time, the antibiotic diffuses throughout the plate, forming a concentration gradient surrounding the disc. As the antibiotic concentration decreases, bacteria are more likely to grow. The diameter of the area displaying no growth is measured to determine susceptibility as per CLSI guidelines. Larger zones indicate decreased bacterial growth with greater antibiotic susceptibility, whereas smaller zones show increased bacterial growth with less antibiotic susceptibility. If the antibiotic does not inhibit growth, there is no zone of inhibition—therefore, the bacteria are resistant.

Automated methods

Automated systems have the advantage of being less labor-intensive and of enabling quicker reporting of results. These systems primarily use dilution principles to determine antibiotic susceptibility. Fully automatic systems will introduce bacteria to a panel, incubate them, then read and interpret the susceptibility results. Automated tests determine MIC through the use of algorithms and allow rules that predict resistance to other antibiotics. Also, these systems can save results to be used in the creation of antibiograms along with other reports. The FDA sets standards for the approval of automated systems, which include a rate of false resistance of less than 3% and a false susceptibility of less than 1.5% on the lower end of the 95% confidence interval (CI) and less than 7.5% on the upper end of the 95% CI.⁹

9. PULMONARY FUNCTION TESTS

Pulmonary function tests (PFTs) allow physicians to evaluate the respiratory function of their patients in many clinical situations and when there are risk factors for lung disease, occupational exposures, and pulmonary toxicity.

Spirometry

Spirometry is a physiological test that measures the ability to inhale and exhale air relative to time. Spirometry is a diagnostic test of several common respiratory disorders such as asthma and chronic obstructive pulmonary disease (COPD). It is also instrumental in monitoring the progression of various respiratory disorders. The main results of spirometry are forced vital capacity (FVC), forced expiratory volume exhaled in the first second (FEV1), and the FEV1/FVC ratio. The procedure of spirometry has 3 phases: 1) maximal inspiration; 2) a “blast” of exhalation; 3) continued complete exhalation to the end of the test. There are within-maneuver acceptability and between-maneuver reproducibility criteria for spirometry.

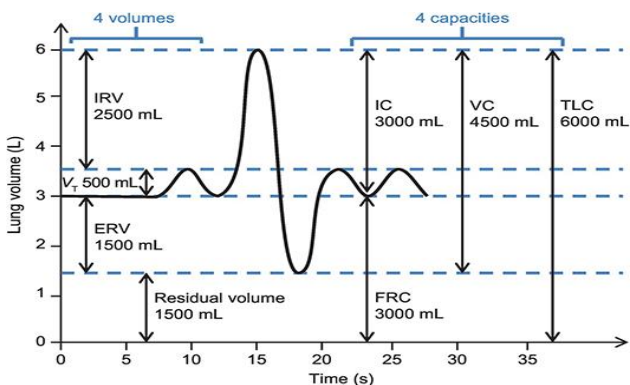
SPIROMETRY TEST	NORMAL	ABNORMAL	
		Mild	Severe
FVC and FEV1	Equal to or greater than 80%	Mild Moderate Severe	70-79% 60-69% less than 60%
FEV1/FVC	Equal to or greater than 70%	Mild Moderate Severe	60-69% 50-59% less than 50%



Static lung volume

The measurement of lung volumes includes several important variables, such as functional reserve capacity (FRC), vital capacity (VC), slow vital capacity (SVC), expiratory reserve volume (ERV), and residual volume (RV). The lung volume measurement is very important to detect changes in lung volume independent of effort, especially when FVC is reduced on spirometry.

There are two methods to measure lung volumes: body plethysmography and gas dilution methods (nitrogen washout and inert gas dilution). The gas dilution method uses an inert gas (poorly soluble in alveolar blood and lung tissues), either nitrogen or helium. The subject breathes a gas mixture until equilibrium is achieved. The volume and mixture of gas exhaled after the equilibrium has been achieved permit the calculation of FRC. In body plethysmography, the subject sits inside a body box and breathes against a shutter valve. FRC is calculated using Boyle Law (at a given temperature, the product of gas volume and pressure is constant). FRC calculated by body plethysmography is usually larger in subjects with obstructive lung disease and air trapping than FRC calculated using gas dilution methods. Body plethysmography is considered the gold standard for lung volume measurement, especially in heterogeneous airflow obstruction, such as in COPD or asthma, where plethysmography is more accurate than helium dilution.



Carbon monoxide diffusing capacity

Diffusion studies the diffusion of gases across the alveolar-capillary membranes. Its measurement uses carbon monoxide (CO) to calculate the pulmonary diffusion capacity. The most common method is the standard single-breath D. It is measured in milliliters per minute per mm Hg.

The factors affecting the D are volume and distribution of ventilation, mixing and diffusion, the composition of the gas, characteristics of the alveolar membrane and lung parenchyma, the volume of alveolar capillary plasma, concentration and binding properties of hemoglobin, and gas tensions in blood entering the alveolar capillaries. ⁽¹⁰⁾

Normal value:

- Normal DLCO: >75% of predicted, up to 140%

- Mild: 60% to LLN (lower limit of normal)
- Moderate: 40% to 60%
- Severe: <40%

Alveolar arterial oxygen gradient

- Alveolar oxygen tension is calculated & arterial oxygen tension measured by blood gas estimation.
- Difference between the two gives a measurement of alveolar to arterial oxygen gradient.

Normal value: 5-15 mm Hg.

Arterial blood gas

Arterial blood gas sampling provides important information on gas exchange and oxygen delivery to the tissues. Type 1 respiratory failure is defined as a partial pressure of oxygen (PaO₂) < 8 kPa with normal partial pressure of carbon dioxide (PaCO₂). Causes of type 1 respiratory failure include pneumonia and pulmonary embolism. Type 2 respiratory failure occurs when hypoxia is accompanied by hypercapnia (PaCO₂ > 6.5 kPa). This is seen in ventilatory failure and examples of causes include respiratory muscle weakness and COPD. Type 2 respiratory failure may also occur in patients with advanced type 1 respiratory failure as they tire and develop ventilatory failure. Such patients may require ventilatory support in the form of non-invasive or invasive ventilation.¹¹

An arterial blood gas test usually includes the following measurements:

ABG	Normal range
O ₂ CT	15-23%per 100mL of blood
pH	7.35-7.45
PaCO ₂	35-45mmHg
PaO ₂	80-100mmHg
HCO ₃	22-26mEq/L
O ₂ Sat	95-100%

CONCLUSION

In conclusion, Lab tests are used to detect disease, guide treatment, monitor response to treatment, and monitor disease progression. Interpreting laboratory results requires a systemic and comprehensive approach, taking into consideration reference ranges, clinical context, trends, limitations of tests, pre-analytical factors, expert consultation and patient communication.

Source of Support: The author(s) received no financial support for the research, authorship, and/or publication of this article

Conflict of Interest: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.



REFERENCES

1. Seo IH, Lee YJ. Usefulness of Complete Blood Count (CBC) to Assess Cardiovascular and Metabolic Diseases in Clinical Settings: A Comprehensive Literature Review. *Biomedicines*. 2022 Oct 25;10(11):2697. doi: 10.3390/biomedicines10112697. PMID: 36359216; PMCID: PMC9687310.
2. Khattak ZE, El Sharu H, Bhutta BS. Overview on Ordering and Evaluation of Laboratory Tests. [Updated 2023 Aug 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan.
3. Lala V, Zubair M, Minter DA. Liver Function Tests. [Updated 2023 Jul 30]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls.
4. Gounden V, Bhatt H, Jialal I. Renal Function Tests. [Updated 2023 Jul 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan.
5. G. Shivaraj, B. Desai Prakash, V. Sonal, K. Shruthi, H. Vinayak, M. Avinash *Thyroid function tests: a review*, *Eur Rev Med Pharmacol Sci*, 2009;13:341-349.
6. Shrimanker I, Bhattarai S. Electrolytes. 2023 Jul 24. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan. PMID: 31082167.
7. Lee Y, Siddiqui WJ. Cholesterol Levels. [Updated 2023 Jul 24]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan.
8. Patibandla S, Gupta K, Alsayouri K. Cardiac Biomarkers. [Updated 2023 Nov 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan.
9. Giuliano C, Patel CR, Kale-Pradhan PB. A Guide to Bacterial Culture Identification and Results Interpretation. *P T*. 2019 Apr;44(4):192-200. PMID: 30930604; PMCID: PMC6428495.
10. Ponce MC, Sankari A, Sharma S. Pulmonary Function Tests. [Updated 2023 Aug 28]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan.
11. Ranu H, Wilde M, Madden B. Pulmonary function tests. *Ulster Med J*. 2011 May;80(2):84-90. PMID: 22347750; PMCID: PMC3229853.

For any questions related to this article, please reach us at: globalresearchonline@rediffmail.com

New manuscripts for publication can be submitted at: submit@globalresearchonline.net and submit_ijpsrr@rediffmail.com

