Lab Test Interpretation Table

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Antigen, tumour marker and diagnostic tests are not comprehensively included in this guide.

*NOTE: Reference ranges can vary depending on the assays, equipment, and techniques used. Use the reference range supplied by the laboratory that performed the test and use caution comparing values from different labs. Due to inter and intra-patient variability, interpret laboratory findings with consideration of normal physiological fluctuations (e.g. assess trends rather than an isolated laboratory value) and the patient's clinical presentation.

If lab samples are inadequately collected, processed or transported, hemolysis and subsequent falsely increased results (e.g., potassium, magnesium, iron, lactate dehydrogenase, phosphorus, ammonia, total protein) and falsely decreased results (red blood cell count, hemoglobin, hematocrit) can occur.[19]

Hematology Tests (Revised Nov 2023)	
Normal Range*	**Interpretation Tips[1-5]**
A **Complete Blood Count with differential (CBC & diff)** measures the types and number of white blood cells, platelets, and red blood cells. These results are located under the *CBC and Peripheral Smear* section in the electronic health record used at BC Cancer. See the Hematology Lab Tests section for related information.	

White blood cells (WBC)/ Leukocytes: 4–10 x 10^9 /L
 	
Neutrophils
- Absolute Neutrophil Count (ANC): 2 – 7.5 x 10^9/L
- Calculated ANC: WBC x (segs+bands) / 100
- Band neutrophils: < 0.7 x 10^9/L
 	
Basophils: < 0.2 x 10^9/L
 	
Eosinophils: < 0.7 x 10^9/L
 	
Lymphocytes: 1 – 4 x 10^9/L
 	
Monocytes: 0.1 – 0.8 x 10^9/L
	WBCs are measured as part of a complete blood count and differential (CBC & diff). They protect the body from infection.
	
	Increased Counts
	- Leukocytosis and neutrophilia can be caused by infection, myeloproliferative disorders, inflammation, and medications.
	  ○ In cancer patients, supportive medications such as corticosteroids and colony stimulating factors can cause elevated counts. Treatment is not required unless they are associated with bone pain, which may improve with analgesic therapy.
	  ○ When leukocytosis is accompanied by increased immature neutrophils (band neutrophils) and fever, infection is a likely cause. Band neutrophils often increase in number to fight infections (also called "a shift to the left").
	- Elevated lymphocyte counts are associated with increased risk of cytokine-release syndrome (see BC Cancer Protocol LYCHOPR) or tumour lysis syndrome (see BC Cancer Protocol ULYVENETO) and prophylaxis may be indicated. Consult respective protocol and/or tumor group chair for management recommendations.
	
	Decreased Counts
	- Leukocytopenia and neutropenia can result from nutritional deficiency, autoimmune disease, bone marrow infiltration (i.e., leukemia or myelodysplastic syndrome), radiation, and myelosuppression due to medications (including many cancer drugs).
	  ○ Many treatment protocols require dose adjustments or the addition of colony stimulating factors (e.g., filgrastim) if ANC

Hematology Tests (Revised Nov 2023)	
Normal Range*	**Interpretation Tips[1-5]**
	drops below 1.5 x 10^9/L. Some protocols tolerate lower thresholds. - Febrile neutropenia is defined as the presence of neutropenia plus concurrent fever (ANC < 1 x 10^9/L and single oral temperature of ≥ 38.3°C orally or a temperature of ≥ 38°C over 1 h). It is a medical emergency which requires treatment with antibiotics +/- supportive medications.

Platelets (Thrombocytes)
150 – 400 x 10^9/L
	Platelets are measured as part of a complete blood count (CBC). They are involved in blood clotting.
	Increased Counts
	- Thrombocytosis can be caused by bone marrow disorders, various cancers, inflammatory disease, or surgical removal of the spleen.
	  ○ In patients with myeloproliferative disorders, thrombocytosis is generally caused by the malignancy.
	  ○ In patients without myeloproliferative disorders, it is prudent to notify the prescriber if thrombocytosis occurs. Treatment is generally not required unless the patient is symptomatic.
	Decreased Counts
	- Thrombocytopenia can be caused by bone marrow disorders, bone marrow infiltration (i.e., leukemia, lymphoma), viral infections, or cancer drug therapy and radiation.
	  ○ Many protocols require a dose reduction or delay if platelet count is < 100 x 10^9/L. Some protocols tolerate lower thresholds.
	  ○ If the thrombocytopenia is disease-related, no dose change may be necessary.

Red Blood Cells (RBCs, Erythrocytes) Females: 3.5 – 5 x 10^{12}/L Males: 4.2 – 5.4 x 10^{12}/L **Hemoglobin (Hgb)**	RBCs are measured as part of a complete blood count (CBC). They use hemoglobin (Hgb) to help deliver oxygen to body tissues. **Increased Counts** - Erythrocytosis and hemoglobinemia can occur to compensate for low oxygen levels (heart disease, lung disease, high altitude), or may be caused by

Hematology Tests (Revised Nov 2023)	
Normal Range*	**Interpretation Tips[1-5]**
Females: 115 – 155 g/L Males: 135 – 170 g/L	other conditions such as polycythemia vera, dehydration, and kidney tumours that produce excess erythropoietin. **Decreased Counts** - Decreased Hgb and RBCs can result from chronic anemia, blood loss (hemorrhage, hemolysis), nutritional deficiency, bone marrow disorders, cancer, or medications (including many cancer treatment drugs).

Liver Function Tests (LFTs): Synthetic Ability (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
The liver is involved in the synthesis of a variety of compounds, including blood proteins, which can be used as markers for the liver's synthetic ability. In the electronic health record used at BC Cancer, albumin results are located under *General Chemistry* and the other tests in this section are found under *Coagulation*. See the Liver Function Tests section for related information.	
Albumin 35 – 50 g/L	Albumin is a protein synthesized by the liver and can be an indicator of the liver's synthetic ability. Since it has a long half-life of 20-30 days, and levels often remain normal even in acute disease, it is not always useful in assessing acute hepatic injury. - Decreased albumin levels can occur in chronic diseases such as cirrhosis, cancer and malnutrition.
Prothrombin Time (PT) 9.5 – 14 seconds **International Normalized Ratio (INR)** 0.8 – 1.2 seconds (normal) **Partial Thromboplastin Time (PTT)** Individual Lab Range **Activated Partial Thromboplastin Time (aPTT)**	The liver is responsible for synthesizing a number of different clotting factors. Unlike albumin, PT offers a good reflection of acute changes in liver function because of the short half-life of clotting factors. Monitoring these coagulation tests also helps evaluate for coagulopathies and decreases the risk of bleeding events. PT may be reported as a standardized INR value or tested in conjunction with partial thromboplastin time (PTT) or activated partial thromboplastin time (aPTT) - aPTT may be reported as "PTT" in the electronic health records. - Liver damage can significantly prolong clotting time (e.g., PT) and increase the risk of bleeding.

Liver Function Tests (LFTs): Synthetic Ability (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
27 - 38 seconds	○ PT may rise to 50 sec or greater in acute liver failure. ○ PT is usually 2 to 5 times the upper limit of normal (ULN) in cirrhosis. - INR, PT, PTT and aPTT times may deliberately be kept longer, at 1.5 to 2.5 times the normal value, for patients on anticoagulant therapy or patients with artificial heart valves. - Other factors that can prolong PT include vitamin K deficiency (an essential co-factor in the clotting cascade), inherited clotting factor deficiencies and certain types of leukemia.
Fibrinogen[6,7] 2.0 - 4.1 g/L	Fibrinogen is a protein produced in the liver and is converted to fibrin by thrombin during coagulation. Fibrin is a major structural component that stabilizes blood clots by forming a meshwork. Monitoring fibrinogen levels and coagulation tests in patients with Cytokine Release Syndrome (CRS) is done to help avoid potentially fatal thrombotic events (such as disseminated intravascular coagulation) and bleeding events. - Patients with abnormal blood levels or abnormally functioning fibrinogen can present with bleeding or thrombosis caused by genetic or acquired conditions including liver cirrhosis, systemic inflammation, and certain cancers. - Increased fibrinogen levels can be related to tumour progression and other poor cancer outcomes.

Liver Function Tests (LFTs): Hepatocellular Injury (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Elevations in ALT and AST that are out of proportion to ALP and bilirubin are indicative of a hepatocellular pattern of injury or disease. These results are located under *General Chemistry* in the electronic health record used at BC Cancer. See the Liver Function Tests section for related information.	

Liver Function Tests (LFTs): Hepatocellular Injury (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Alanine Aminotransferase (ALT) Females: < 36 U/L Males: < 50 U/L	ALT is an enzyme found primarily in hepatocytes, but also in the skeletal muscle, heart and kidneys. It is a useful marker of hepatic injury. - ALT is released into the blood when the liver is damaged or inflamed. Liver cancer or liver metastases may elevate ALT. - ALT is higher than AST (aspartate aminotransferase) in most types of liver disease (i.e., AST/ALT ratio is < 1). NAFLD (non-alcoholic fatty liver disease) is a common cause of abnormally elevated ALT, AST and GGT levels with AST/ALT ratio < 1 in asymptomatic patients. - Very high ALT levels (> 1000 U/L) though rare, are most commonly due to acute viral hepatitis, acute liver ischemia, or liver injury due to a drug or toxin.
Aspartate Aminotransferase (AST) < 36 U/L	AST is a less specific indicator of hepatic injury than ALT because it is found in the liver, heart, red blood cells, skeletal muscle, kidneys, brain and pancreas. - Liver cancer or liver metastases may elevate AST. - AST elevation generally indicates liver damage if ALT, bilirubin and ALP (alkaline phosphatase) are also elevated. NAFLD (non-alcoholic fatty liver disease) is a common cause of abnormally elevated ALT, AST and GGT levels (with AST/ALT ratio < 1) in asymptomatic patients. - Elevated AST in relation to ALT (i.e., AST/ALT ratio > 2), along with high GGT, can occur with alcoholic hepatitis. - Isolated AST elevation (without ALT elevation) may indicate cardiac or muscle disease. This is often accompanied by an elevated serum creatine kinase (CK), which can also indicate cardiac or muscle injury. - Very high AST levels (> 1000 U/L) are most commonly due to acute viral hepatitis, acute ischemia or liver injury due to a drug or toxin.

Liver Function Tests (LFTs): Hepatocellular Injury (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Lactate Dehydrogenase (LD, LDH) 110 - 230 U/L	LDH is an enzyme involved in energy production and is present in almost all body tissues, but particularly in the heart, blood cells, kidneys, liver, lungs, and skeletal muscle. - LDH is released into the blood when cells are damaged or destroyed, however, it is a non-specific marker for hepatocellular injury. ○ Elevated LDH (i.e., > 2 x ULN) is associated with a greater risk of Tumor Lysis Syndrome (TLS) in patients with aggressive hematologic cancers, or other cancers with a large tumour burden or high sensitivity to treatment. - LDH can be used in oncology as a non-specific marker to monitor for tumour progression or as a prognostic factor for various cancers (e.g., lymphoma). - LDH activity is affected by hemolysis of red blood cells (RBCs). Procedural errors in collection, processing or transport of blood specimens can cause an artificial increase of LDH due to release from ruptured erythrocytes.

Liver Function Tests (LFTs): Cholestasis (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Infiltrating liver diseases such as lymphoma, amyloidosis or liver metastasis can cause cholestasis (marked reduction in bile secretion and flow). A cholestatic pattern of LFTs indicates biliary obstruction and is characterized by elevated ALP, GGT and bilirubin that is out of proportion to AST and ALT. These results are located under *General Chemistry* in the electronic health record used at BC Cancer. See the Liver Function Tests section for related information.	
Alkaline Phosphatase (Alk Phos, ALP) Females: 35 – 120 U/L Males: 40 – 145 U/L	ALP is an enzyme found in several tissues throughout the body, but primarily in the liver, bile duct and bone. - ALP levels > 3 times ULN are generally associated with cholestasis. Bile accumulation increases liver synthesis of ALP and GGT; levels tend to normalize within 2-4 weeks after the cholestasis is resolved. ○ Biliary obstruction secondary to cancers, metastases, or hepatic

Liver Function Tests (LFTs): Cholestasis (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**

	infiltration by hematological cancers can markedly elevate ALP.
	- ALP levels ≤ 3 times ULN in the presence of other elevated liver enzymes generally indicate a hepatocellular source.
	  ○ Liver cancer, liver metastases, and hepatic infiltration by hematological cancers can elevate ALP.
	- ALP levels ≤ 3 times ULN in the absence of other elevated liver enzymes generally indicate a non-hepatic source.
	  ○ Bone cancers (e.g., osteosarcomas) or bone metastases can elevate ALP.
	- Some tumours without liver or bone involvement (e.g., renal, Hodgkin lymphoma) can secrete ALP or cause it to leak into the bloodstream.

Total Bilirubin (T.Bili) < 17 umol/L	Bilirubin is a waste product of heme metabolism, primarily derived from red blood cell breakdown. It is conjugated by the liver to facilitate its excretion as bile into the gut. Total serum bilirubin represents the sum of unconjugated bilirubin (indirect/albumin-bound) and conjugated bilirubin (direct/unbound) present in the blood, with the majority (almost 100%) being unconjugated. The binding affinity for albumin to bilirubin is extremely high and reversible. Unconjugated (indirect) bilirubin is fat soluble, unlike conjugated (direct) bilirubin which is conjugated by the liver into a water soluble form. - Bilirubin is not a sensitive indicator of hepatic dysfunction since total serum levels may be normal in the presence of liver injury. The liver has a reserve capacity to remove at least twice the normal daily bilirubin load without developing hyperbilirubinemia. - Bilirubin may be elevated in inherited liver disorders, hepatocellular injury or cholestasis, conditions that block the bile ducts (e.g., gallstones, pancreatic cancer), or hemolysis.

Liver Function Tests (LFTs): Cholestasis (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
	○ High bilirubin levels accompanied by elevated ALT or AST, may indicate hepatitis or cirrhosis. ○ High bilirubin levels accompanied by elevations specifically in ALP and GGT, may suggest a cholestatic disorder. - If the liver is unable to secrete the conjugated bilirubin into bile (biliary tract obstruction), it can get filtered into the urine. Conjugated bilirubin in the urine generally indicates underlying liver disease.
Gamma Glutamyl Transpeptidase (GGT, GGTP or GTP) Females: < 44 U/L Males: < 65 U/L	GGT is an enzyme found primarily in the liver and bile ducts, but also in many other tissues throughout the body. - Since GGT levels quickly elevate with bile accumulation, it is considered the most sensitive test for cholestatic disorders. - As GGT is not found in the bone, it is useful in determining if an ALP elevation is secondary to a liver or a bone pathology. If both ALP and GGT are elevated, the source is likely the liver. - Elevated GGT, combined with an AST/ALT ratio > 2, is suggestive of alcoholic liver disease. - Elevated GGT, combined with AST/ALT ratio is < 1 has been associated with non-alcoholic fatty liver disease (NAFLD).

Renal: Renal Function Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
These serum test results are located under *General Chemistry* in the electronic health record used at BC Cancer. See the Renal Function Tests section for related information.	
Serum Creatinine (SCr) Females: 45 – 90 umol/L Males: 45 – 110 umol/L	Creatinine is a waste product of muscle breakdown which gets removed from blood by the kidneys. Many different variables can affect its levels (e.g., dehydration, nutritional status, muscle mass, ingestion of meat, certain medications).

Renal: Renal Function Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
	- Increased SCr levels may suggest kidney dysfunction or damage (e.g., nephrotoxic drug). - Increased SCr levels can also be caused by other conditions such as renal infection or inflammation (e.g., glomerulonephritis, pyelonephritis), post-renal obstruction (e.g., kidney stones, prostate disease), or pre-renal reduced blood flow (e.g., dehydration, atherosclerosis, congestive heart failure, shock, or diabetes).
Creatinine Clearance (CrCl), Glomerular Filtration Rate (GFR) eGFR > 60 mL/min	CrCl measures the kidneys' ability to remove creatinine from blood, which helps to estimate GFR, the amount of blood filtered per minute through the kidneys. The most accurate method of assessing GFR is to measure it using a nuclear renogram, but this method is not commonly used. It is more common to estimate GFR by calculating CrCl using the Cockcroft-Gault formula or by using laboratory estimated rates (eGFR) which use other recognized formulae (MDRD and CKD-EPI) (see Renal Function Tests [Clinical Pharmacy Guide]). - Decreased CrCl rates may suggest decreased renal function. ○ Some protocols require dose changes or delays based on CrCl. - Certain protocols with medications primarily eliminated via the kidneys (e.g., cisplatin, carboplatin) have baseline thresholds for CrCl or GFR.
Blood Urea Nitrogen (BUN, urea nitrogen, or urea) 2 – 9 mmol/L **Blood Urea Nitrogen:Creatinine Ratio (BUN:Cr ratio)** Between 10:1 and 20:1	Urea is a nitrogen waste product of protein and amino acid metabolism. The liver releases urea into blood and it is filtered by the kidneys into urine. A blood urea nitrogen (BUN) test, also called a urea test, measures this nitrogen waste product. A BUN may be ordered along with a serum creatinine test to determine the BUN to creatinine ratio (BUN:creatinine). - Increased urea levels may indicate kidney dysfunction. They can also be caused by dehydration or heart failure (low renal blood flow), increased protein intake, increased protein breakdown from muscle damage or gastrointestinal

Renal: Renal Function Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
	bleeding. These factors could also increase the BUN to creatinine ratio. - Decreased urea levels do not have a renal cause. Liver disease or damage or malnutrition can lower urea levels in blood which can also lower BUN to creatinine ratio.
Uric Acid Females: 140 - 360 umol/L Males: 150 – 430 umol/L	Uric acid is a waste product that the body makes when it breaks down purines. Purines are either acquired through diet or can be released when the cells die. Most uric acid dissolves in the blood, gets filtered by the kidneys, and is excreted in the urine. It can be measured with blood or urine tests. - Some cancers and cancer treatments can cause increased uric acid levels in the blood (hyperuricemia). The risk is higher in preexisting renal dysfunction. - When chemotherapy is used to treat highly proliferative tumours with massive tumour burden, such as some high-grade lymphomas, leukemias or myeloproliferative disease, the rapidly dying cancer cells release their intracellular contents into the blood resulting in hyperuricemia. Tumour lysis syndrome (TLS), an oncologic emergency, is diagnosed when hyperuricemia is combined with other irregular blood levels such as high levels of potassium and phosphate and low levels of calcium. Increased uric acid levels in the blood may also be caused by gout, kidney stones, kidney failure or too many purines ingested in the diet.

Renal: Urine Chemistry and Urinalysis Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Urinalysis can be performed at the lab or as a dipstick urine test in clinic. It analyzes the urine's colour, appearance, odour, acidity, and presence of bacteria, blood, glucose, ketones, bilirubin and protein. The provider can also add a microscopic analysis and a urine culture to the lab reported urine test. Urine cultures detect bacteria or fungi that grow from the urine sample and can determine drug sensitivities to these growths. Local antibiograms (a profile of antimicrobial susceptibility) are used to select the appropriate antibiotics for treatment. These urine test results are located under *Urinalysis*	

Renal: Urine Chemistry and Urinalysis Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
in the electronic health record used at BC Cancer. See the Renal Function Tests section for related information.	
Urine Protein Random < 0.3 g/L **Urine protein 24-hour** < 0.15 g/L	Urine protein tests detect the amount of protein being released into the urine. Urine protein can be measured by using a dipstick, obtaining a random laboratory urine sample, or analyzing a 24-hour urine collection done by the patient at home. - Normal urinary protein levels are low; persistently elevated levels can suggest renal damage. - Increased protein in urine (proteinuria) may be related to multiple myeloma, medications toxic to the kidneys, bladder cancer, or urinary tract infection.
Urine Uric Acid < 5.9 mmol/d	Urine uric acid tests detect the amount of uric acid being released into the urine and are usually collected over 24 hours. - High uric acid levels in the urine can be caused by the same medical conditions that cause high uric acid levels in the blood. Sometimes leukemia, multiple myeloma or metastatic cancer can also increase urine uric acid levels.

Electrolyte Tests (Revised Sep 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Electrolytes (lytes) are minerals that carry a positive or negative electric charge in body fluids. They are required to maintain fluid balance and generate the electrical signals used to regulate heart rhythm, muscle contraction and nerve function. Electrolyte levels are regulated in the body through hormonal mechanisms and renal excretion. An electrolyte panel test generally includes sodium, potassium, chloride, and bicarbonate. Additional electrolytes monitored in cancer patients include calcium, magnesium and phosphate. These serum tests results are located under *General Chemistry* in the electronic health record used at BC Cancer. - Abnormal electrolyte levels can be caused by the cancer itself, drug treatment (e.g., abiraterone, cisplatin), or treatment-related side effects (e.g., renal toxicity, excessive vomiting or diarrhea). - Generally, acute or severe changes in electrolyte levels require more aggressive management.	

Electrolyte Tests (Revised Sep 2024)	
Normal Range*	**Interpretation Tips[1-5]**
	○ QT prolongation of cardiac rhythm can be caused by electrolyte abnormalities such as hypokalemia, hypocalcemia or hypomagnesemia. ○ Tumour Lysis Syndrome (TLS) can cause both electrolyte and metabolic abnormalities such as hyperkalemia, hyperphosphatemia, hypocalcemia, and hyperuricemia. - Patients with renal dysfunction may be at higher risk for electrolyte abnormalities. - Dehydration or other medications (e.g., furosemide, hydrocortisone) may also cause electrolyte imbalances.
Sodium (Na) 135 – 145 mmol/L	Sodium, primarily an extracellular cation, helps regulate the amount of body fluids and helps cells in the nerves and muscles function normally. - Patients with either hyponatremia or hypernatremia may be asymptomatic, or may experience neurological symptoms (e.g., nausea, vomiting, malaise, headache, muscle twitching, restlessness and seizures).
Potassium (K) 3.5 – 5 mmol/L	Potassium, primarily an intracellular cation, helps cells in the nerves, skeletal and cardiac muscles function normally. - Patient with hypokalemia or hyperkalemia may be asymptomatic or may experience muscle weakness or cardiac arrhythmias (i.e., ECG changes); cardiac monitoring may be required.
Calcium (Ca) 2.1 – 2.6 mmol/L **Ionized calcium** 1.15 – 1.40 mmol/L **Corrected Calcium** (corrected for low albumin)	Calcium cations are essential for cell signaling, blood coagulation, maintenance of bones and teeth, and proper muscle, nerve and heart function. The vast majority of calcium is complexed in the bones. Of the small portion circulating in the blood, roughly one-half is “free” and metabolically active, while the rest is protein-bound (e.g., to albumin). The ionized calcium test measures the free form of serum calcium only. A total calcium test is most frequently used to measure serum calcium levels because it is simpler to perform; it measures both free and bound forms. Some protocols ask that the total serum calcium result be corrected for low albumin levels on the assumption that lower albumin levels will falsely decrease the total calcium level (e.g., ULYVENETO). - Corrected calcium (mmol/L) = total calcium *(mmol/L)* + (0.02 x [40 – albumin *in g/L*]). - Hypercalcemia of malignancy is common in patients with advanced cancers and can be symptomatic,

Electrolyte Tests (Revised Sep 2024)	
Normal Range*	**Interpretation Tips[1-5]**
	requiring treatment. It may be caused by hormonal mechanisms, or cancers affecting the bones.
Magnesium (Mg) 0.64 – 0.98 mmol/L	Magnesium cations are important enzyme cofactors and are involved in energy production, protein synthesis, gene maintenance, nerve function, muscle contraction, and bone formation. Hypomagnesemia can be induced by certain cancer medications such as cisplatin and panitumumab, and associated treatment protocols may include magnesium supplementation guidelines.
Phosphate (PO_4) 0.8 – 1.5 mmol/L	Phosphate anions are vital for cell energy production, muscle and nerve function, blood coagulation and bone growth. A serum phosphate test measures inorganic phosphate levels, which are generally inversely regulated in proportion to serum calcium levels. Hypophosphatemia may be caused by some tumours, but hyperphosphatemia from decreased renal function or TLS is more commonly seen in cancer patients.

Endocrine Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Endocrine tests measure various endocrine hormone levels and are used to assess if the endocrine glands are functioning correctly. Hormone levels can be used for screening and determining treatment response in patients receiving hormone treatment, such as estrogen levels in breast cancer or testosterone levels in prostate cancer. These test results are located under *Endocrine* in the electronic health record used at BC Cancer. - Endocrine gland tumours, such as some adrenal gland tumours, can cause increases in hormone production. - Immunotherapies can induce immune-mediated adverse reactions that damage the endocrine glands and impact associated feedback mechanisms. This could result in endocrine hormone deficits which may require supplementation (see Endocrine section in BC Cancer Supportive Care Protocol SCIMMUNE).	
Thyroid Stimulating Hormone (TSH) 0.32 – 5.04 mIU/L	TSH is produced by the pituitary gland as part of the body's feedback system to maintain stable amounts of the thyroid hormones, T3 and T4, in the body. T3 and

Endocrine Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**

Thyroxine (T4 free)
9.0 – 19.0 pmol/L
 	
Triiodothyronine (T3 free)
2.6 – 5.8 pmol/L
	T4 can be bound (inactive) or free (active); free levels are usually ordered.
	- Certain immunotherapy protocols require TSH monitoring. Since TSH level changes can be transient, they are usually repeated with T3 and/or T4 tests added to confirm the diagnosis.
	- Hypothyroidism may require thyroid supplementation. T4 is a more sensitive test than T3 for hypothyroid patients, while T3 is often useful to diagnose hyperthyroidism.
	  ○ Primary hypothyroidism reflected by an elevated TSH, along with low T4, is most common.
	  ○ Secondary (central) hypothyroidism is reflected by low-to-normal TSH, along with low T4.
	  ○ Subclinical hypothyroidism is defined as elevated TSH but normal T4.
	- Hyperthyroidism is reflected by low TSH and elevated T3 and/or T4 and may require treatment.

AM Cortisol 140 – 535 nmol/L **Adrenocortiocotropic Hormone (ACTH)** 1.6 – 13.9 pmol/L	Cortisol is a hormone secreted by the adrenal glands. It is involved in protein, lipid, and carbohydrate metabolism and helps the body manage stress. Cortisol levels are generally highest early in the morning and timing of the cortisol test is very important. - Immunotherapy-induced hypocortisolism requires screening and monitoring with AM Cortisol which is usually drawn prior to 10AM.[9] However, individual labs may have their own specific cut-off times for AM Cortisol. ACTH is a hormone that stimulates the production of cortisol. ACTH is produced by the pituitary gland. - Immunotherapy-induced adrenal insufficiency or hypophysitis (inflammation of the pituitary gland) may require steroid supplementation.
Follicle-Stimulating Hormone (FSH) Females: varies by menstrual phase Males: < 9.5 U/L	FSH and LH are produced by the pituitary gland. In women, FSH is associated with ovulation and egg development. FSH, LH and estradiol are often ordered together to assess a woman's menopausal status. In

Endocrine Tests (Revised Dec 2024)	
Normal Range*	**Interpretation Tips[1-5]**
Luteinizing Hormone (LH) Females: varies by menstrual phase Males: 1.1 – 8.8 U/L **Testosterone** Females (age 11-50): < 1.8 nmol/L Females (age >50): < 1.5 nmol/L Males: 8.4 – 28.8 nmol/L **Estradiol (E2)** Females: varies by menstrual phase Males: < 162 pmol/L	men, LH is associated with testosterone and sperm development. Testosterone is an androgen produced by Leydig cells in the testes of men, the ovaries in women and in small amounts by the adrenal glands (both men and women). Testosterone production is stimulated and controlled by LH. Estradiol is an estrogen produced mainly by the ovaries in pre-menopausal women and is present in postmenopausal women from the conversion of estrone (E1) to estradiol (E2) by the enzyme aromatase. It is a good marker of ovarian function, and it plays a role in bone metabolism and growth. Estradiol is primarily produced by the Leydig and germ cells in the testes of men and plays a critical role in male sexual function. - Women will have FSH, LH and estradiol levels ordered if postmenopausal status is in question before starting treatment with an aromatase inhibitor. (e.g., BRAJANAS, BRAJEXE, BRAJLET)
Human Chorionic Gonadotropin (hCG or bhCG) **Pregnancy Test** (Beta HCG + Intact, Choriogonadotropin Intact + Beta Subunit or Choriogonadotropin Beta Subunit) Pregnancy Test: < 3 U/L (non-pregnant) **Tumour Marker** (Beta HCG Tumour Marker) Tumour Marker: 0 - 2 IU/L	hCG is a hormone that the placenta produces. It plays an important role in pregnancy with levels varying widely during this time and between individuals. Outside pregnancy, a high hCG level may be a sign of a health condition such as cancer or liver disease. People who use cannabis may also have a high level. There are two different types of blood tests to detect hCG. A qualitative test detects if hCG is present in the blood. A quantitative test (or beta test, b-hCG) measures the amount of hCG present in the blood. - Woman of childbearing potential should be screened for pregnancy by testing hCG levels prior to starting any cancer treatment. Results generally reported under *Chemistry*. hCG levels can help diagnose gestational trophoblastic disease (GTD) and germ cell tumours of the ovary and testicle and can be used to monitor treatment effectiveness in these cancers and in select patients with other cancers who have high levels (e.g., GUBEP, GOBEP). Results generally reported under *Tumour Marker.*

Other Lab Tests (Revised Jan 2024)	
Normal Range*	**Interpretation Tips[1-5]**
These serum test results are located under *General Chemistry* in the electronic health record used at BC Cancer.	
Lipase < 75 U/L **Amylase** 0 – 100 U/L	Lipase is an enzyme produced by the pancreas to digest dietary fats. Amylase is an enzyme produced by the pancreas to digest carbohydrates. - The levels of these enzymes can increase in the blood when the pancreas is injured (pancreatitis), or when the pancreatic duct is blocked by gall stones or pancreatic tumours. - Immunotherapy-induced pancreatic injury can also elevate serum lipase or amylase levels.
Serum Glucose Fasting: 3.3 – 5.5 mmol/L Random: 3.3 – 11 mmol/L	Glucose is the body's main energy source and is regulated by insulin and glucagon hormones produced in the pancreas. - Patients with diabetes may require dose modifications of their medications and glucose levels should be closely monitored. - There is an increased risk of hyperglycemia in patients receiving corticosteroids or certain cancer medications such as immunotherapy.
C-Reactive Protein (CRP) < 5 mg/L	C-reactive protein (CRP) is produced by the liver and released into the blood during injury, infection, or inflammation. - CRP is a sensitive and non-specific indicator of acute inflammation, which can be increased in patients with cancer. - CRP may also be used as a prognostic indicator (in combination with other prognostic markers) in solid tumors, with elevated CRP suggestive of a more negative prognosis.

Cardiac Tests (Revised Aug 2024)	
Normal Range*	**Interpretation Tips**[1-5,10]
These tests are found in the **Diagnostic** (not Lab) test section of the electronic health record used in BC Cancer.	
Left Ventricular Ejection Fraction (LVEF) ≥ 50 % normal	LVEF is a measurement of the percentage of blood leaving the heart's main pumping chamber, the left ventricle, each time it contracts. It is used as an assessment of heart function. An echocardiogram (ECHO) or multigated acquisition (MUGA) scan can be used to measure LVEF. - A reduced LVEF can be caused by various heart conditions, or by certain cardiotoxic cancer medications (see protocol BRAJTR).
Electrocardiogram (ECG or EKG) **QT interval (QT)** **Corrected QT interval (QTc)** Females Normal: QTc < 460 milliseconds (ms) Prolonged: QTc > 480 milliseconds (ms) Males Normal: QTc < 450 milliseconds (ms) Prolonged: QTc > 470 milliseconds (ms)	An ECG graphically assesses heart rhythm by recording the electrical activity of the heart. The QT interval on the ECG represents the time it takes for the ventricles of the heart to depolarize (contract) and repolarize (relax). Heart rate affects the QT interval as it lengthens with bradycardia and shortens with tachycardia. Therefore, a corrected QT interval (QTc) accounting for heart rate is frequently calculated and used. Patients who experience a prolonged QTc interval are at risk for developing torsade de pointes (TdP), a ventricular tachycardia which can be life-threatening. - Certain cancer medications, such as oxaliplatin, are directly associated with an increased risk of TdP (see Pharmacy FAQ QT Prolongation in Oncology). - Other medications can increase risk via drug interactions or by contributing to bradycardia or electrolyte abnormalities.

Circulating Tumour Markers (Created Nov 2024)	
Normal Range*	**Interpretation Tips**[1-5,11]
Circulating tumour markers are substances such as proteins that are released by tumour cells and other cells of the body, including healthy tissues. They can be found in blood, urine, stool and other bodily fluids.[11] These tests are found in the *Tumour Marker* test section of the electronic health record used in BC Cancer. Refer to the **Circulating Tumour Marker** section under Biomarker Tests in Lab Test Interpretation for related information.	

Circulating Tumour Markers (Created Nov 2024)	
Normal Range*	**Interpretation Tips[1-5,11]**
- Circulating tumour markers can aid in diagnosis and estimation of prognosis in conjunction with imaging and other tests and are used to determine the effectiveness of treatment and progression of disease. Refer to the Biomarker Tests section of Module 3 Lab Test Interpretation of the Clinical Pharmacy Guide. - There are a number of circulating tumour markers that are monitored during cancer therapy. Some protocols will monitor more than one type of tumour marker, depending on the site of the cancer. Some examples are listed below.	
Alpha-Fetoprotein (AFP) < 8.4 ug/L	AFP is a protein produced by a developing fetus and is normally found in very low levels in the blood of adults. - AFP can be increased in a number of cancers including non-seminomatous testicular, ovarian germ cell, extragonadal germ cell, childhood CNS germ cell, pancreatic, stomach and liver cancers and is used for monitoring treatment effectiveness in a number of protocols (e.g., GUBEP, GOBEP). - AFP testing is used to manage liver problems such as cirrhosis and Hepatitis B and C infections.
Beta-2-Microglobulin (B2M) < 2.2 mg/L	B2M is a protein that can be measured in the blood, urine or cerebrospinal fluid and can be found in high levels in multiple myeloma, chronic lymphocytic leukemia and certain types of lymphoma. - Higher levels are associated with poorer prognosis and kidney dysfunction in multiple myeloma and B2M tests are a part of regular baseline tests in patients with this cancer (e.g., MYDARLD). ○ Non-cancerous conditions that can increase B2M include kidney disease, HIV/AIDS and multiple sclerosis.
Cancer Antigen (CA) 15-3 < 23 kU/L	CA 15-3 is a protein that can be elevated in the blood in advanced cancers of the breast, lung, pancreas, ovary and prostate. - CA 15-3 is overexpressed in metastatic breast cancer, but is rarely higher than normal in early stage breast cancer and therefore, it is not measured in this patient group (e.g., BRAVRIBAI). - Non-cancerous conditions that can increase CA 15-3 include liver disease, pelvic inflammatory disease, endometriosis and pregnancy.

Circulating Tumour Markers (Created Nov 2024)	
Normal Range*	**Interpretation Tips[1-5,11]**
Cancer Antigen (CA) 19-9 < 27 kU/L	CA 19-9 is a protein released in the blood mainly in pancreas, biliary tract, colorectal and gastric cancers, but is also detected in lung, breast, uterine and ovarian cancers. - The highest level is seen in advanced pancreatic cancer but may still be monitored in patients with very early stages of the disease (e.g., GIFIRINOX, GIPAJFIROX). - Non-cancerous conditions that can increase CA 19-9 include pancreatitis, gallstones, liver diseases such as cirrhosis or hepatitis, cystic fibrosis and bile duct obstruction.
Cancer Antigen (CA) 125 < 36 kU/L	CA-125 is a protein released into the blood by cancers such as ovarian, uterine, pancreatic, endometrial, breast, lung, colorectal and gastric and can be found in small amounts in normal tissue. - Most epithelial ovarian cancer protocols will monitor CA-125 levels due to its high prevalence in this patient group (e.g., GOOVCARB). Non-cancerous conditions that can increase CA-125 include menstruation, pregnancy, endometriosis, pelvic inflammatory disease, benign ovarian cysts and uterine fibroids.
Carcinoembryonic Antigen (CEA) < 4.7 ug/L	CEA is a protein that is produced during fetal development and normally adults have very low levels in their blood. - It is an important tumour marker for colorectal and gastric cancers and esophageal adenocarcinoma but can also be present in other cancers such as pancreatic, breast, lung, liver and ovarian cancers (e.g., GIGAJCOX). Non-cancerous conditions that can increase CEA include peptic ulcer disease, ulcerative colitis, rectal polyps, emphysema, benign breast disease, pancreatitis and cholecystitis.
Human Chorionic Gonadotropin (hCG, bhCG, Beta HCG Tumour Marker)	Please refer to the Endocrine section of the Lab Test Interpretation Table
Prostate-Specific Antigen (PSA)	PSA is released by the prostate and is found normally in low levels in the blood. It does tend to increase with

Circulating Tumour Markers (Created Nov 2024)	
Normal Range*	**Interpretation Tips[1-5,11]**
< 50 years old: < 2.5 ug/L 50 -59 years old: < 3.5 ug/L 60-69 years old: < 4.5 ug/L >69 years old: < 6 ug/L	age and can be increased in prostate cancer or when there is inflammation in the prostate. - Some men with prostate cancer have normal PSA levels while others can have extremely high levels. Prostate cancer protocols routinely monitor PSA to determine effectiveness of the treatment (GUPDOCADT, UGUPENZ). Non-cancerous conditions that can increase PSA include prostatitis, urinary tract infection, a bladder or prostate exam, sexual activity, warmer climates, bike riding and an enlarged prostate due to BPH.

Protein Electrophoresis & Immunoglobulin & Free Light Chains Panel (Created Dec 2024)	
Normal Range*	**Interpretation Tips[1-5,12-16]**
These tests are used to help diagnose and monitor disorders that result in abnormal protein production or loss of protein. The majority of multiple myeloma patients will be monitored using one or all of these tests. These tests can also be used for Waldenstrom macroglobulinemia (WM - a rare type of non-Hodgkin's lymphoma), amyloidosis, monoclonal gammopathy of unknown significance (MGUS – a possible precursor to multiple myeloma), lymphoma and chronic lymphocytic leukemia (CLL). The serum and urine test results are respectively located under *General Chemistry* and *Urine Chemistry* in the electronic health record used at BC Cancer. See the **Multiple Myeloma** section under Biomarker Tests in Lab Test Interpretation for related information.	
Protein Electrophoresis Panel: **Serum Protein Electrophoresis (SPEP)** Levels for: Albumin: 35 - 50 g/L Alpha 1 Globulin: 2 - 4 g/L Alpha 2 Globulin: 5 - 9 g/L Beta 1 Globulin: 3 – 6 g/L Beta 2 Globulin: 2 – 5 g/L Gamma Globulin: 7 – 14 g/L	Protein Electrophoresis separates proteins in the blood, urine or cerebrospinal fluid (CSF) by size and electrical charge to find abnormal or missing protein levels. The two major groups of protein in the body are albumin and globulins. - Serum Protein Electrophoresis (SPEP) measures albumin and globulins in the blood where there is a normally high level of albumin and lower level of globulins present. - Urine Protein Electrophoresis (UPEP) measures the albumin and globulins in the urine where there is a very low level of albumin and no globulins normally present. **Serum Protein Electrophoresis** test results are divided into six groups: albumin, alpha 1 & 2 globulin, beta 1 &

Protein Electrophoresis & Immunoglobulin & Free Light Chains Panel (Created Dec 2024)	
Normal Range*	**Interpretation Tips**[1-5,12-16]
Urine Protein Electrophoresis (UPEP) Levels for: Albumin < 0.05 g/L Protein: < 0.15 g/L Albumin/Creatinine < 2.0 mg/mmol	2 globulin and gamma globulin. Levels of each protein are affected by a number of factors. The predominant proteins in gamma globulin levels are **immunoglobulins** and are also known as antibodies**.** - In most multiple myeloma patients, the gamma globulin level would show as a large peak on the graph, indicating an abnormal **M protein** level. M proteins are sometimes referred to as **M spike, monoclonal proteins**, or **monoclonal immunoglobulins** and are found in unusually large amounts in the blood or urine of people with multiple myeloma and other types of plasma cell tumours. - **Albumin blood levels** are often decreased in advanced stage multiple myeloma. **Urine protein electrophoresis** can detect proteins in the urine including M-protein and albumin. - **Urine albumin to creatinine ratio** (microalbumin creatinine ratio) indicates the level of albumin in the urine and is measured in those patients with multiple myeloma who may be at higher risk of developing kidney dysfunction.
Immunoglobulin Panel **IgA** Level: 0.7 – 4 g/L **IgG** Level: 7 – 16 g/L **IgM** Level: 0.4 – 2.3 g/L	**Immunoglobulin Panel** is a test that measures the quantity of different immunoglobulins in the blood. Immunoglobulins are made up of two heavy protein chains and two light protein chains bound together and are produced by B cells as part of the immune response. Of the five types of heavy chain proteins (IgA, IgG, IgM, IgD and IgE), the panel measures three (IgA, IgG and IgM). The two types of light chain proteins, kappa and lambda, are reported in the Immunoglobulin Free Light Chains Panel (see below). Cancer treatment and the disease itself can impact levels of immunoglobulins. - Multiple myeloma plasma cells can crowd out healthy cells and secrete **nonfunctional** immunoglobulins (M protein). Since these cells are clones from one plasma cell, they are identical (**monoclonal**). The Immunoglobulin Panel may show an increase in this one type of M protein and

Protein Electrophoresis & Immunoglobulin & Free Light Chains Panel (Created Dec 2024)	
Normal Range*	**Interpretation Tips**[1-5,12-16]
	a decrease in other immunoglobulins. Multiple myeloma is grouped by what kind of heavy chain is overproduced by the myeloma cells and what type of light chain it is bound to. - The most common types of heavy chains produced in multiple myeloma are IgG (about 70%) and IgA (about 20%). Overproduction of IgM heavy chains in multiple myeloma are rare so when elevated are typically the result of Waldenstrom's Macroglobulinemia. IgG immunoglobulins typically fight bacterial and viral infections and can cross the placenta to protect a fetus. Low IgG levels can help diagnose the reason for recurring infections and high IgG levels can indicate chronic infection such as long-term hepatitis. - Immunosuppression caused by cancer or cancer treatment can decrease immunoglobulin production and leave patients more prone to infection. If levels are too low, intravenous immunoglobulin (IVIG) replacement therapy may be considered.
Immunoglobulin Free Light Chains Panel (Serum Free Light Chains Test) Kappa Level: 3.3 – 19.4 mg/L Lambda Level: 5.7 – 26.3 mg/L Kappa Lambda Free Light Chains Ratio Level: 0.26 – 1.65	Serum Free Light Chains test measures free light chains in the blood and calculates their ratio. Whole immunoglobulins are made of heavy and light chains and normally extra light chains are produced in equal amounts that are not bound to heavy chains (free) and are released into the blood. There are two types of light chains – kappa and lambda. - In multiple myeloma, the malignant plasma cells overproduce one of the two types of light chains causing an abnormal balance of one over the other. This test is used to monitor effectiveness of treatment and progression of disease.

Transfusion Tests (Revised Nov 2023)	
Normal Range*	**Interpretation Tips**[1-5,17,18]
BC Cancer protocols containing the anti-CD38 drugs daratumumab or isatuximab require pre-treatment blood screening at baseline (e.g., MYDARBD). Daratumumab and isatuximab target CD38 which is also widely expressed on RBCs and interfere with cross-matching and RBC antibody detection. The Pharmacy FAQ Daratumumab & Isatuximab Pre-Treatment Blood Screening has more information on what these tests are and why they are done before treatment starts. These test results are located under *Transfusion* in the electronic health record used at BC Cancer.	
Group and Screen ABO (ABO/Rh(D)) **Group and Screen Ab Screen** **Red Blood Cell Phenotype (RBC Antigens Phenotype)**	Tests can include blood antigen typing and antibody screening. This is to ensure the most compatible blood can be given if transfusion is ever required in a surgical or medical setting. **ABO Test** - The ABO test shows if the patient has one of four blood types – A, B, O, or AB – based on the type of antigens present on their RBCs, and whether they are Rh positive or negative. **Antibody Screen** - The antibody screen determines if the patient's plasma/serum contains antibodies that could react with antigens on transfused RBCs. **RBC Antigens Phenotype** - The RBC antigen phenotype detects antigens present on the patient's RBCs.

References

1. Life Labs reference ranges section (HCP – reference ranges page) [Internet] Burnaby: Life Labs; March 15, 2024. Available from: Reports – LifeLabs
2. HealthLinkBC. Medical Tests [Internet] Victoria: Government of BC; 1995 [cited 2024 Dec 18]. Available from: https://www.healthlinkbc.ca/health-topics/zp3409
3. Medical Council of Canada [internet]. Normal lab values. [cited 2025 Feb 1] Available from: https://mcc.ca/examinations-assessments/resources-to-help-with-exam-prep/normal-lab-values/
4. MedlinePlus [Internet]. Bethesda (MD): National Library of Medicine (US); [cited 2025 Feb 1]. Available from: https://medlineplus.gov/lab-tests
5. Canadian Cancer Society. Tests and Procedures [internet]. Accessed 2025 Feb 1
6. Pieters M, Wolberg AS. Fibrinogen and fibrin: An illustrated review. Res Pract Thromb Haemost. 2019;3(2):161-172. Published 2019 Mar 4. doi:10.1002/rth2.12191
7. Casini A, Bérubé C. Disorders of fibrinogen. In: UpToDate, Leung LK, Tirnauer JS (Ed), Wolters Kluwer. (Accessed on Dec 1, 2024.)
8. Druce I, Tawagi K, Shaw JLV, Ibrahim A, Lochnan H, Ong M. Routine Screening for Central and Primary Adrenal Insufficiency during Immune-Checkpoint Inhibitor Therapy: An Endocrinology Perspective for Oncologists. Curr Oncol. 2022;29(7):4665-4677. Published 2022 Jul 2. doi:10.3390/curroncol29070370.
9. Island Health. Patient Preparation Instructions General Information. Department of Laboratory Medicine, Pathology and Medical Genetics. Published: 2022 Jan 26 (version 1.0)
10. Davies, Ross A. et al. The 2023 Canadian Cardiovascular Society Clinical Practice Update on Management of the Patient With a Prolonged QT Interval. Canadian Journal of Cardiology, Volume 39, Issue 10, 1285 - 1301
11. Filella X, Rodríguez-Garcia M, Fernández-Galán E. Clinical usefulness of circulating tumor markers. Clin Chem Lab Med. 2022;61(5):895-905. Published 2022 Nov 17. doi:10.1515/cclm-2022-1090
12. Gutzeit C, Chen K, Cerutti A. The enigmatic function of IgD: some answers at last. Eur J Immunol. 2018;48(7):1101-1113. doi:10.1002/eji.201646547
13. Canadian Cancer Society. Diagnosis of multiple myeloma [internet]. [Cited 2024 Dec 1] Access from: Diagnosis of multiple myeloma | Canadian Cancer Society
14. Parsons B. Understanding multiple myeloma and laboratory values [presentation]. Gundersen Health System Center for Cancer and Blood Disorders. La Crosse, WI. Leukemia & Lymphoma Society. [Cited 2024 Dec 1]
15. International Myeloma Foundation. Studio City, CA. What Are Monoclonal Gammopathy of Undetermined Significance, Smoldering Multiple Myeloma, and Active Myeloma? [internet]. [Cited 2024 Dec 1]
16. International Myeloma Foundation. Studio City, CA. Types of Myeloma [internet]. [Cited 2024 Dec 1]
17. Chami B, Okuda M, Moayeri M, et al. Anti-CD38 monoclonal antibody interference with blood compatibility testing: Differentiating isatuximab and daratumumab via functional epitope mapping. Transfusion. 2022;62(11):2334-2348. doi:10.1111/trf.17137
18. Dean L. Blood Groups and Red Cell Antigens [Internet]. Bethesda (MD): National Center for Biotechnology Information (US); 2005. Chapter 2, Blood group antigens are surface markers on the red blood cell membrane. Available from: https://www.ncbi.nlm.nih.gov/books/NBK2264/
19. Casapu A. McNeil K (reviewer). LabCE course. Pre-analytical Challenges Encountered with Capillary Blood Collection and Testing [internet]. [Cited 2024 Dec 1]