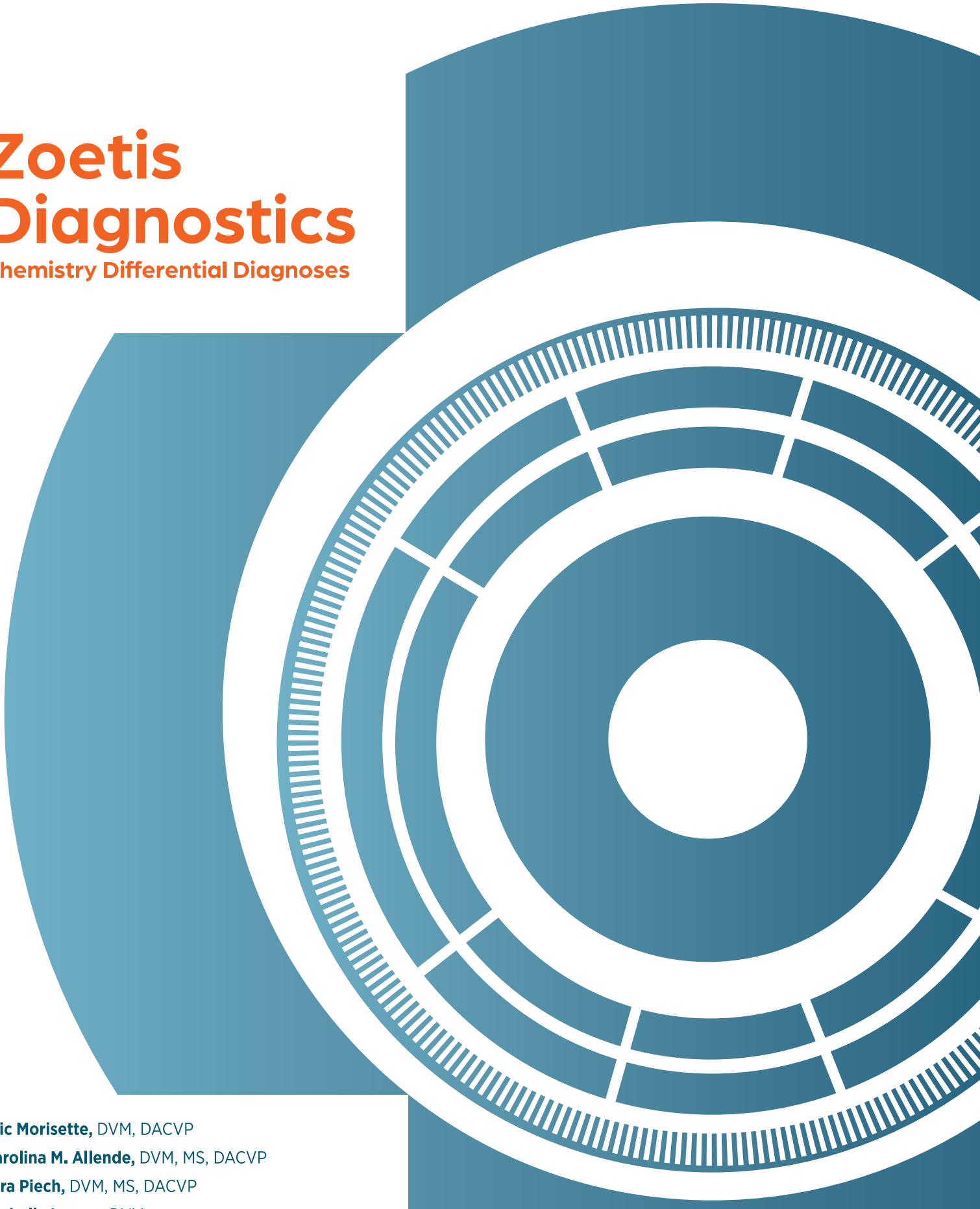
Zoetis Diagnostics

Chemistry Differential Diagnoses



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Virtual Lab

Anywhere. Anytime. Any device.

The Zoetis Virtual Laboratory is the next evolution in the connected veterinary practice. With access to Responsible Trending™, Vetscan Imagyst results, and clinical consultations, the Virtual Laboratory allows for efficient medical decisions and access to specialists.

Access results on any device with ZoetisDx

- View and share patient results
- Drive informative discussions
- Improve pet owner/veterinarian communication

Integrate results with your practice management software*

- Analyze Zoetis diagnostic information from multiple sources in a single glance
- Review easy-to-interpret graphics and Responsible Trending data
- Access patient information before appointments and surgeries

What is Responsible Trending?

Responsible Trending, available on the ZoetisDx online platform, focuses on showing test analyte results as a sequence of graphs. This visual format provides a clear story of each patient's trends in test results over time with results from different instruments and Zoetis Reference Laboratories together, but always relative to each analyte's reference interval on each instrument.

Head to ZoetisDx.com to Book a Clinical Consultation:

Request a Specialist Consult.
Choose when, where, and how:

ZOOM VIDEO ZOOM AUDIO EMAIL

Common Examples of a Clinical Consultation:

- Internal medicine advice on managing subclinical UTIs
- Current treatment protocols for IMHA
- Oncology advice on treatment and prognosis for various neoplasias
- Dermatology advice for chronic pyoderma

*Compatible with select PIMS

For Zoetis DX application

This guide is intended to aid in interpretation of results for biochemical parameters. No differential list is meant to be exhaustive and examining only one parameter at a time could result in an erroneous diagnosis. When abnormalities are detected or suspected clinically, a Complete Blood Count (CBC), urinalysis, and additional diagnostic testing may be warranted to aid in interpretation and case management.

Alanine Aminotransferase (ALT)

Definition

Increased

Hepatocellular Injury

Degenerative
- **Anoxia due to anemia/shock/ passive congestion[1, 2]**

Anomalous
- Portosystemic shunt (generally mild increase)[1]

Inflammatory
- **Infectious: leptospirosis, histoplasmosis, FIP, bacterial cholangiohepatitis [1, 2], canine adenovirus, leishmania, toxoplasma, neospora, hepatozoon, dirofilariosis**
- **Non-infectious: chronic hepatitis, cholangitis, cirrhosis**

Inherited
- Copper storage disease
- Lysosomal storage diseases[1]

Toxic (Not an exhaustive list)
- Acetaminophen (especially cats)
- Barbiturates
- Carprofen
- Glucocorticoids (dogs only)
- Phenobarbital
- Primidone
- Trimethoprim-sulfa drug
- Xylitol

Metabolic
- **Hepatic lipidosis**
- **Diabetes mellitus**
- **Feline hyperthyroidism**
- **Hyperadrenocorticism[1, 2]**

Neoplastic
- Lymphoma
- Hepatocellular carcinoma
- Metastatic neoplasia[1, 2]

Nutritional
- Copper toxicosis
- Hemochromatosis[1]

Traumatic
- Hit by car (hepatocellular or skeletal muscle damage)[1]

Skeletal Muscle Injury

Inherited
- Muscular dystrophy (rare)

Miscellaneous
- Hit by car/other sources of muscle injury
- Myositis

Artifacts

- Hemolysis can cause mild increase[3]
- Lipemia can cause artifactual increase[3]

Decreased

- Not clinically significant
- Can occur with hepatic atrophy due to portosystemic shunt, chronic liver failure, or cirrhosis.

Interpret With

- Bilirubin
- Hepatic enzymes
- Creatine kinase

Bold Indicates a common cause

Albumin (ALB)

Definition

Increased

Hemoconcentration

- **Fluid losses/dehydration**

Decreased

Decreased Albumin Synthesis

- **Inflammation**[4]
- **Hepatic insufficiency (chronic hepatic disease)**[4,5]
- **Malabsorption and maldigestion**[4]
- Cachectic/catabolic state[4]
- Hypergammaglobulinemia[4]

Increased Albumin Loss

- **Blood loss (hemorrhage)**[4,5]
- **Protein-losing nephropathy**[4,5]
  - Glomerulonephritis
  - Amyloidosis
- **Protein-losing enteropathy**[4,5]
  - Small intestinal mucosal disease
  - Lymphangiectasia
  - Intestinal blood loss
- **Cutaneous losses (burns/exudative skin disease)**

Sequestration[4]

- **Third space losses (pleural/peritoneal effusion)**

Hemodilution

- Excess administration of Intravenous fluid[4,5]
- Edematous disorders[4]
  - Congestive heart failure
  - Cirrhosis
  - Nephrotic syndrome

Artifacts

- High fibrinogen levels in heparinized plasma samples used with a BCG method may cause false increases[8]
- Hemolysis or hemoglobinemia can cause false increases
- Marked lipemia or hypertriglyceridemia can cause false decreases
- Severe hypoalbuminemia can cause a falsely elevated albumin concentration (rare)[9]

Interpret With

- Total protein
- Globulins
- Blood urea nitrogen
- Creatinine
- Liver panel +/- bile acids
- Packed cell volume
- Urinalysis

Bold Indicates a common cause

Alkaline Phosphatase (ALP)

Definition

Increased

Most Common Causes

Physiologic
- **Age (young dogs with rapid bone growth)**
- **Endogenous corticosteroid release**[1]
- **Ingestion and absorption of colostrum by neonatal foals and pups may increase serum ALP activity**[1]

Degenerative
- **Hepatocyte swelling or necrosis (leads to impaired bile flow)**[1]

Metabolic
- **Diabetes mellitus**
- **Hyperadrenocorticism**
- **Hypothyroidism (dogs) mild**
- **Hyperthyroidism (cats)**
- **Hyperparathyroidism (primary or secondary)**
- **Hepatic lipidosis**[1] **(in the initial phase of feline hepatic lipidosis, ALP activity will be markedly increased with little to no increase in GGT activity)**
- **Cholelithiasis**

Inflammatory
- **Periportal hepatitis**
- **Chronic hepatitis**
- **Cholangiohepatitis/cholangitis**
- **Feline infectious peritonitis**
- **Cirrhosis/fibrosis**
- **Pancreatitis (local inflammation)**[2]

Neoplastic
- **Lymphoma**
- **Hemangiosarcoma**
- **Mammary neoplasia (benign and malignant)**
- **Hepatocellular carcinoma**
- **Metastatic carcinoma**[1]

Induction by Drugs or Hormones (Not an Exhaustive List)
- **Barbiturates**
- **Estrogens (urinary incontinence medication)**
- **Glucocorticoids (dogs only)**
- **Phenobarbital**
- **Primidone**

Cardiogenic
- **Chronic passive congestion from right heart failure**[2]

Other Causes

Physiologic
- Breed (Siberian Huskies – benign familial hyperphosphatasemia; Scottish Terriers)[10, 11]

Biliary Tract Disease
- Bile duct neoplasia
- Cholecystitis
- Gall bladder mucocele
- Ruptured gallbladder
- Pancreatic neoplasia[1, 2]

Inflammatory
- Copper storage disease
- Toxic hepatitis
- Aflatoxin
- Certain types of mushrooms
- Sago palm
- Drug induced[1]

Induction by Drugs or Hormones (Not an Exhaustive List)
- Anabolic steroids/androgens
- Asparaginase
- Azathioprine
- Cephalosporins
- Cyclophosphamide
- Dapsone
- Erythromycin estolate
- Griseofulvin
- 6-Mercaptopurine
- Methimazole
- Methotrexate
- Nitrofurantoin
- Phenothiazines
- Progesterone
- Testosterone
- Tetracyclines
- Thiabendazole
- Trimethoprim-sulfa
- Vitamin A

Decreased

- Not clinically significant

Artifacts

- Severe hemolysis may falsely decrease ALP[2]

Interpret With

- Hepatic enzymes
- Cholestatic markers

Bold Indicates a common cause

Amylase (AMY)

Definition

Increased

Pancreatic Acinar Cell Damage

- **Inflammation (AMY and LIP)**[1, 2]
- **Neoplasia (AMY and LIP)**

Decreased Renal Clearance/Renal Disorder

- **Dehydration**[1, 2]
- **Acute or chronic renal diseases (AMY and LIP)**[1]
- Shock (AMY and LIP)[1, 2]
- **Urinary tract obstruction (AMY and LIP)**
- Macroamylasemia[1]

Miscellaneous Causes

- Gastrointestinal obstruction (AMY and LIP)
- Dexamethasone treatment
- Pancreatic or hepatic neoplasia

Decreased

- Not clinically significant

Artifacts

- Can be artifactually decreased due to Vitamin C

Interpret With

- Pancreatitis specific markers (i.e., canine pancreas-specific lipase)
- Blood urea nitrogen
- Creatinine
- Hepatic enzymes
- Bilirubin
- Urinalysis
- Lipase

Bold Indicates a common cause

Anion Gap

Definition

Increased

Metabolic Acidosis

- **Lactic acidosis: increased lactate or D-lactate**
- **Ketoacidosis: increased ketone bodies (BHB or AcAc)**
- **Renal failure: increased PO_4, sulfate, or citrate**
- Massive rhabdomyolysis: possibly associated with increased lactate or PO_4
- Drugs/toxins
  - Ethylene glycol
  - Methanol poisoning
  - Paraldehyde
  - Metaldehyde poisoning (snail bait)
  - Penicillin
- Hyperalbuminemia

Decreased (Minimal Clinical Significance)

Decreases in Unmeasured Anions-

- **Hypoalbuminemia**
- Acidemia

Increases in Unmeasured Cations+

- Hypercalcemia
- Hypermagnesemia

Iatrogenic

- Bicarbonate-rich fluids

Artifacts

- Increased Na+ and K+, decreased Cl- can lead to false increases
- Increased Cl- and HCO_3- can lead to false decreases
- Potassium bromide can lead to false increases

Interpret With

- Electrolytes
- Bicarbonate
- Blood-gas values/acid-base status

Bold Indicates a common cause

Aspartate Aminotransferase (AST)

Definition

Increased

Hepatic Damage

- See hepatocyte damage conditions listed for increased alanine aminotransferase (ALT) activity[1, 2]

Muscular

- See skeletal muscle damage condition listed for increased creatine kinase (CK) activity[1, 2]

Decreased

- Not clinically significant

Artifacts

- Hemolysis will increase AST serum activity[19]
- Icterus may affect results
- Marked lipemia may interfere with spectrophotometric assays[19]
- Metronidazole may artifactually depress AST activity[19]

Interpret With

- Alanine aminotransferase
- Alkaline phosphatase
- Total bilirubin
- Gamma-glutamyl transferase
- Bile acids
- Creatine kinase

Bold Indicates a common cause

Base Excess

Definition

Increased

Excess of base (gain of HCO_3- or loss of acid)

- Metabolic alkalosis
- Refer to bicarbonate (HCO_3-) and TCO_2 for additional differentials

Decreased

Insufficient Base

- Metabolic acidosis
- Refer to bicarbonate (HCO_3-) and TCO_2 for additional differentials

Artifacts

- Exposure to room air can cause a false increase

Interpret With

- Electrolytes
- Bicarbonate
- Anion gap
- Proteins
- Renal function values

Bold Indicates a common cause

Bicarbonate (HCO3)

Definition

Increased

Metabolic Alkalosis

Loss of H+

- **Gastric loss**
- Renal loss
  - Loop or thiazide diuretics
  - Secondary to respiratory acidosis
  - **Hypokalemia**
- Sweat loss

Iatrogenic

- Administration of bicarbonate solutions, lactate, citrate, or magnesium hydroxide

Decreased

Metabolic Acidosis

Generation of H+

- **Lactic acidosis**
- **Ketoacidosis**
- **Toxins: ethylene glycol**

Decreased renal excretion of H+

- Renal failure
- Uroperitoneum or urinary tract obstruction

Increased HCO_3^- loss

- Alimentary losses: diarrhea, sequestration, vomiting (pancreatic secretions)
- Renal losses: proximal or distal renal tubular acidosis

Other Causes

- Hypoaldosteronism

Artifacts

- Severe muscle injury can cause false elevation
- Aged samples can lead to false increases or decreases
- Over dilution of heparin and prolonged venous stasis can cause false decrease
- Lipemia, hemolysis, and icterus can cause false decrease
- Dilutional acidosis (with saline) can decrease

Interpret With

- Electrolytes
- Anion gap
- Renal values
- Blood gas/acid-base status

Bold Indicates a common cause

Bile Acids (BA)

Definition

Increased

Most Common Causes

Physiologic

- **Spontaneous gallbladder contraction (without feeding)[2]**

Decreased Functional Hepatic Mass

- **Diffuse hepatocellular disease[22]**

Decreased Portal Blood Flow to Liver

- **Congenital and acquired portosystemic shunts[22]**
- **Hepatic microvascular dysplasia[2]**

Hepatic Cholestasis (Obstructive)

- **Cirrhosis**
- **Cholangitis/Cholangiohepatitis**
- **Periportal hepatitis**

Post-Hepatic Cholestasis

- **Cholangitis**
- **Bile duct carcinoma**
- **Liver fluke**
- **Cholelithiasis**
- **Cholecystitis**
- **Pancreatitis**
- **Pancreatic carcinoma[22]**

Other Causes

Hepatic Cholestasis (Obstructive)

- Hepatic lipidosis
- Diabetes mellitus
- Steroid hepatopathy
- Lymphoma
- Histoplasmosis
- Cytauxzoonosis
- Pyrrolizidine alkaloid toxicosis[22]

Functional Cholestasis

- Sepsis-associated cholestasis[22]

Decreased

- Low clinical significance

Artifacts

Decreased BA value-

- Hemolysis[23]
- Heparin BA[23]
- Lipid-clearing agents[23]
- Incomplete gallbladder contraction after feeding may result in a lower value than expected[2]

Increased BA Value

- Lipemia (spectrophotometry)[23]
- Treatment with ursodiol (a synthetic BA)[23]

Interpret With

- Pancreatic specific markers (canine or feline pancreas-specific lipase)
- Hepatic enzymes
- Cholestatic markers
- Bilirubin
- Ammonia

Bold Indicates a common cause

Blood Urea Nitrogen (BUN)

Definition

Increased

Most Common Causes

Pre-Renal Conditions

- **Hypovolemia/dehydration**
- **Decreased cardiac output**
- **Shock**

Renal Conditions

- **Inflammatory**
  - **Glomerulonephritis**
  - **Pyelonephritis (e.g., ascending UTI, leptospirosis)**
- **Toxic nephrosis**
  - **Hypercalcemia**
  - **Ethylene glycol intoxication**
  - **NSAID intoxication[24]**
  - **Lily toxicity**
  - **Gentamicin**
- **Renal ischemia or hypoxia**
  - **Poor renal perfusion**
  - **Infarction[24]**

Post-Renal Conditions

- **Urinary tract obstruction**
  - **Urolithiasis**
  - **Urethral plugs in cats**
  - **Neoplasia**
  - **Uroabdomen[24, 25]**
  - **Prostatic disease**
- **Urine leakage**
  - **Trauma**
  - **Neoplasia**

Increased Production

- **Hemorrhage into the upper gastrointestinal system**
- **High protein diet**

Other Causes

Renal Conditions

- Inflammatory
  - Tubular-interstitial nephritis[24, 25]
- Amyloidosis
- Toxic nephrosis
  - Myoglobin
- Renal ischemia or hypoxia
- Congenital hypoplasia or aplasia[24]
- Hydronephrosis
- Neoplasia (renal or metastatic)[24, 25]

Increased Production

- Exercise

Decreased

Most Common Causes

Decreased BUN Synthesis

- **Hepatocellular disease**
- **Portosystemic shunts (congenital or acquired)**

Other Causes

Decreased BUN Synthesis

- Dietary restriction of protein
- Urea cycle enzyme deficiencies[24, 25]

Increased Renal Excretion of Urea

- Impaired proximal tubular resorption of urea: glucosuria[24]
- Central or nephrogenic diabetes insipidus (polyuria/polydipsia)[24]

Artifacts

- Severe hemolysis will increase BUN concentration[24, 26]
- Severe icterus may increase BUN concentrations[24]
- Severe lipemia may decrease BUN concentrations
- Contamination of the sample with ammonium (NH_4)[24, 26] (e.g., benzalkonium chloride disinfectants) can increase BUN results obtained by reflectance spectrophotometry

Interpret With

- Creatinine
- Total protein
- Albumin
- Electrolytes
- Anion gap
- Calcium
- Phosphate
- Hepatic function tests
- Hematology
- Urinalysis

Bold Indicates a common cause

Total Calcium (CA)

Definition

Increased

Most Common Causes

Physiologic

- **Healthy young, fast-growing dogs (young dog < 6 months, large or giant breed)[27, 28]**

Increased PTH or PTHrp Activity

- **Primary hyperparathyroidism (PTH)**
  - **Parathyroid neoplasia[27]**
- **Hypercalcemia of Malignancy / Humoral Hypercalcemia (PTHrp)**
  - **Lymphoma**
  - **Apocrine gland adenocarcinoma[27, 28]**
  - **Other carcinoma**
  - **Multiple myeloma**

Increased Vitamin D Activity (Hypervitaminosis D)

- **Exogenous Vitamin D**
  - **Rodenticides containing cholecalciferol**
- **Endogenous Vitamin D**
  - **Granulomatous inflammation**
    - **Some fungal and parasitic infections**

Decreased Urinary Excretion of Calcium

- **Renal failure[27, 28]**
- **Hypoadrenocorticism**

Other or Unknown Mechanisms

- **Idiopathic hypercalcemia in cats[32]**

Other Causes

Increased Vitamin D Activity (Hypervitaminosis D)

- Exogenous Vitamin D
  - Tacalcitol or calcipocriol
  - Plants containing ergocalciferol (Vitamin D_2)
  - Excess dietary supplementation[27, 28]

Increased Protein-Bound Calcium

- Hyperglobulinemia in multiple myeloma
- Hyperalbuminemia[27]

Iatrogenic Disorders

- Excessive calcium supplementation (Intravenous)[27]
- Excessive oral phosphate buffers[27]
- Calcipotriene[28] (psoriasis treatment)

Decreased

Most Common Causes

Hypoalbuminemia

- **Hypoproteinemia[27, 28]**

Pregnancy, Parturient, or Lactational Hypocalcemia

- **Eclampsia[27, 28]**
- **Milk fever in cattle**

Excess Urinary Excretion of Calcium

- **Ethylene glycol toxicosis (dogs and cats)**

Other or Unknown Mechanisms

- **Acute pancreatitis in dogs and cats**
- **Urinary tract obstruction**

Other Causes

Primary Hypoparathyroidism

- Naturally acquired
- Post-thyroidectomy[27]

Hypovitaminosis D

- Chronic renal disease or failure
- Protein-losing enteropathy in dogs
- Dietary vitamin D deficiency (rare)[27, 28]

Pregnancy, Parturient, or Lactational Hypocalcemia

- Postpartum/periparturient hypocalcemia/ puerperal tetany

Hypercalcitonism

- Thyroid C-cell neoplasia
- Iatrogenic (calcitonin therapy)[27]

Excess Urinary Excretion of Calcium

- Intravenous HCO_3 infusions
- Furosemide treatment[27]

Calcium Binding Anticoagulants

- EDTA, citrate, oxalate (in vivo or in vitro)[27]

Other or Unknown Mechanisms

- Exocrine pancreatic insufficiency (dogs)[27, 28]
- Vitamin D-receptor defect rickets[27]
- Oxalate toxicity[28]
- Tetracycline administration[27]
- Calcium deposition during fracture healing
- Acute and chronic renal failure
- Phosphate enema
- Sepsis
- Acute tumor lysis syndrome
- Nutritional secondary hyperparathyroidism[27, 28]

Artifacts

- Total Ca is falsely increased by lipemia and hemolysis[33]
- Total Ca can be decreased by marked bilirubinemia[33]
- Prolonged occlusion during phlebotomy may mildly increase Ca[33]
- Use of an inappropriate anticoagulant (EDTA, citrate anticoagulants) may cause falsely decreased results[33]

Bold Indicates a common cause

Calcium (CA), Continued

Interpret With

- Albumin
- Ionized calcium
- Phosphate
- Blood urea nitrogen
- Creatinine
- Urinalysis

Note: Frequency of hypercalcemia due to listed neoplastic processes may differ by species and/or breed.

Bold Indicates a common cause

Chloride (CL)

Definition

Increased

Most Common Causes

Inadequate Water Intake
- **Water deprivation**

Water Loss
- **Pure water loss**
  - **Insensible loss: panting, hyperventilation, or fever**

Alimentary Loss of Bicarbonate
- **Bicarbonate loss/small bowel diarrhea**
- **GI loss/sequestration (diarrhea)**

Hyperchloremic Metabolic Acidosis
- **GI loss of bicarbonate**
- **Renal loss of bicarbonate**
  - **Proximal or distal renal tubular acidosis**

Other Causes

Inadequate Water Intake
- Defective thirst response (hypothalamic defect)

Water Loss
- Pure water loss
  - Diabetes insipidus
- Renal
  - Osmotic diuresis
  - Hypoadrenocorticism
- Phosphate enema[34]

Excessive Gain of Chloride Relative to Sodium
- Salt poisoning
- Diabetes mellitus
- Fluid therapy (e.g., 0.9% sodium chloride, hypertonic saline, potassium chloride-supplemented fluids)
- Therapy with chloride salts: KCl or NH_4Cl[35]

Decreased Renal Excretion of Na and Cl
- Hyperaldosteronism[34]

Renal Chloride Retention
- Proximal renal tubular acidosis
- Distal renal tubular acidosis
- Hypoadrenocorticism[36]
- Drug-induced: acetazolamide, spironolactone[36]
- Compensatory response to chronic respiratory alkalosis
  - Hyperventilation or hypocapnia
  - Hypoxemia
  - Primary pulmonary disease
  - Pain[35]

Bicarbonate Consumption (Titration Acidosis)
- Decreased excretion of non-carbonic acid:
  - Sulfates
  - Phosphates
  - **Renal Failure**
  - **Toxicity (Ethylene glycol, Salicylate, Methanol)[35]**

Decreased

Most Common Causes

Gastrointestinal
- **Loss or sequestration of chloride rich fluid**
  - **Vomiting/diarrhea**
  - **Sequestration**
  - **Pyloric obstruction**
  - **Gastric rupture**
  - **Gastric dilation-volvulus**
  - **Trichuriasis**

Metabolic Acidosis
- **Ketoacidosis**
- **Lactic acidosis**
- **Ingestion of foreign substances generating strong anions (ethylene glycol)**

Other Causes

Renal Loss
- Hypoadrenocorticism
- Osmotic diuresis (diabetes mellitus)
- Proximal renal tubular dysfunction (prolonged diuresis)
- Hypoaldosteronism
- Hyperadrenocorticism[36]
- Glucocorticoid administration[36]
- Ketonuria
- Sodium-wasting nephropathies
- Compensatory response to chronic respiratory acidosis
- Furosemide therapy
- Thiazide therapy

Third Space Losses
- Pancreatitis
- Peritonitis
- Uroabdomen
- Chylothorax with repeated pleural fluid drainage[35]
- Acute internal hemorrhage
- Acute exudation
- Cutaneous (sweating)

Edematous Disorders
- Congestive heart failure
- Hepatic disease/hepatic cirrhosis
- Nephrotic syndrome
- Advanced renal failure[34]

Expanded Extracellular Fluid Volume (Without Edema)
- Excess sodium-poor fluid administration (parenteral)[34]
  - Fluid therapy with 5% dextrose, 0.45% saline solution, or hypotonic fluids[35]
- Syndrome of inappropriate antidiuretic hormone secretion (SIADH)
- Antidiuretic drugs (e.g., heparin solutions containing chlorbutanol, vincristine, cyclophosphamide, nonsteroidal anti-inflammatory drugs)[35]
- Myxedema coma of hypothyroidism (rare)[35]
- Psychogenic polydipsia[35]

Extracellular Translocation of Water
- Hyperglycemia
- Mannitol infusion (intravenously)[34]

Intracellular Translocation of Na (Cl Follows)
- Hypokalemia (to maintain the intracellular electronegativity)
- Acute muscle injury[34]

Extravascular Fluid Translocation of Na (Cl Follows)
- Uroperitoneum (ruptured bladder, or abdominal urethra)[34]

Bold Indicates a common cause

Chloride (CL), Continued

Artifacts

- Lipemia causing pseudo-hypochloremia (ion-exclusion effect when using the titrimetric methods) or causing pseudo-hyperchloremia (using the colorimetric method)[35]
- Potassium bromide therapy will falsely increase the reported chloride concentration (common and important)[35]
- Hyperviscosity may cause problems in analyzers that dilute samples before analysis[35]

Interpret With

- Electrolytes (Na+, K+)
- Urinalysis
- Total carbon dioxide/bicarbonate
- Anion gap
- Acid-base analysis

Bold Indicates a common cause

Cholesterol (CHOL)

Definition

Increased

Most Common Causes

Postprandial Hypercholesterolemia[28, 37, 40]

Secondary Hypercholesterolemia

- **Hypothyroidism**
- **Diabetes mellitus**[37, 40]
- **Nephrotic syndrome or protein-losing nephropathy**[28, 37, 40]
- **Cholestasis**[37, 40]
- **Acute pancreatitis**[38, 40]
- **Hyperadrenocorticism or excess iatrogenic glucocorticoids**

Other Causes

Primary Hypercholesterolemia

- Idiopathic hyperlipoproteinemia (Miniature Schnauzers and other breeds)[28, 37, 40]
- Hypercholesterolemia in Briards (dog)[40]
- Idiopathic hyper-chylomicronemia (cat)[28]
- Lipoprotein lipase deficiency (cat)[28, 37, 40]
- Idiopathic hypercholesterolemia[28, 37]

Secondary Hypercholesterolemia

- Hepatic insufficiency[28]
- Excess negative energy balance
  - Starvation/anorexia
  - Pregnancy or lactation

Drug Induced Hypercholesterolemia

- Megestrol acetate (cat)[28]
- Glucocorticoids[28]

Decreased

Most Common Causes

Severe Malnutrition[40]

Malabsorption/Maldigestion

- **Protein-losing enteropathy**[28]
- **Lymphangiectasia**[40]
- **Exocrine pancreatic insufficiency**[40]

Decreased Cholesterol Production

- **Portosystemic shunt**
- **Chronic liver disease**[37]
- **Liver failure**[40]

Altered Metabolism

- **Inflammatory cytokines**[37]

Increased Lipoprotein Uptake

- **Rapidly proliferating neoplastic cells (histiocytic sarcoma, multiple myeloma)**[38, 39]

Other Causes

- Hypoadrenocorticism[40]

Artifacts

- Hemolysis and hyperproteinemia artifactually increase results[40]
- Bilirubin and ascorbic acid negatively interfere with enzymatic assays[40]
- Postprandial cholesterol increase may be mistaken for metabolic disease[40]

Interpret With

- Glucose
- Blood urea nitrogen
- Creatinine
- Hepatic enzymes
- Bilirubin
- Triglycerides
- Urinalysis

Bold Indicates a common cause

Cobalamin

Definition

Increased

Hepatocellular injury or necrosis
Endocrine
Neoplastic disorders

Decreased

Preabsorptive defect in dogs and cats
- **EPI: pancreatic atrophy, chronic pancreatitis**
- **Intestinal bacterial overgrowth: EPI, impaired gastric acid secretion, enteric disorders**

Defective absorption of cobalamin in ileum of dogs and cats
- **Ileal disease: inflammation, resection, villous atrophy (viral atrophy, hypersensitivity, cytotoxic drugs)**
- Congenital deficiency of receptor in Giant Schnauzers and Border Collies

Severe cobalamin deficiency in cats (probable congenital malabsorption defect)
Cobalt deficiency in cattle

Artifacts

- Can be increased with oral or parenteral cobalamin supplementation

Interpret With

- Folate
- Pancreatic lipase
- TLI
- Hepatic enzymes
- Glucose

Bold Indicates a common cause

Creatine Kinase (CK)

Definition

Increased

Most Common Causes

Skeletal Muscle Damage

Degenerative

- **Hypoxia caused by exertion or seizures, exertional Rhabdomyolysis, saddle thrombus**[1, 43]

Traumatic

- **Intramuscular injections**
- **Hit by car**
- **Prolonged recumbency**
- **Seizures**
- **Exertion**
- **Post-surgical**[1]

Other Causes

Neoplastic

- Metastatic neoplasia with striated muscle involvement

Nutritional

- White muscle disease (vitamin E-selenium deficiency), polioencephalomalacia[1, 43]

Inflammatory

- Myositis caused by Neospora, Toxoplasma, bacteria, or other agents[1]

Toxic

- Monensin, ricin (Castor Bean), mycotoxin, gossypol, snakebite[1]

Inherited

- Muscular dystrophy (Cavalier King Charles Spaniel dystrophin-deficient muscular dystrophy)
- Hyperkalemic periodic paralysis
- Malignant hyperthermia[1]

Other Pathologies with Uncertain Pathogeneses

- Critically ill anorectic cat[44]

Decreased

- Not clinically significant

Artifacts

- May increase the measured CK activity
  - Hemolysis[1, 43]
  - Muscle penetration during venipuncture[1]
  - Underfilling of lithium heparin tube[45]

Bold Indicates a common cause

Creatinine (CRE)

Definition

Increased

Most Common Causes

Pre-Renal Conditions

- **Hypovolemia/dehydration**
  - **Hypoadrenocorticism**
  - **Blood loss**
- **Decreased cardiac output**
  - **Cardiac insufficiency**
  - **Shock**
  - **Hypoadrenocorticism**
- **Shock**
  - **Hypovolemic**
  - **Cardiogenic**
  - **Anaphylactic**
  - **Septic**
  - **Neurogenic**[1]

Renal Conditions

- **Inflammatory**
  - **Glomerulonephritis**
  - **Pyelonephritis**
- **Toxic nephrosis**
  - **Hypercalcemia**
  - **Ethylene glycol intoxication**
  - **NSAID intoxication**
- **Renal ischemia or hypoxia**
  - **Poor renal perfusion**
  - **Infarction**

Post-Renal Conditions

- **Urolithiasis**
- **Urethral plugs in cats**
- **Leakage of urine from the urinary tract within the abdominal cavity: trauma, neoplasia**[1, 25]

Physiologic Increase

- **Heavily muscled dogs (Greyhounds) or other heavily muscled animals**[1]

Other Causes

Renal Conditions

- Inflammatory
  - Tubular-interstitial nephritis
  - Amyloidosis
- Toxic nephrosis
  - Myoglobin
  - Aminoglycosides
- Renal ischemia or hypoxia
- Congenital hypoplasia or aplasia
- Hydronephrosis
- Neoplasia (renal or metastatic)[1, 25]

Post-Renal Conditions

- Neoplasia
- Prostatic disease

Physiologic Increase

- Post-protein meal[1]

Decreased

Not a clinically significant finding

Most Common Causes

Physiologic

- **Young dogs**[46]
- **Small breed dog**[47]
- **Decreased muscle mass**[1, 25]

Other Causes

Decreased Production

- Starvation
- Cachexia
- Hepatic insufficiency: hepatocellular disease
- Portosystemic shunts (congenital or acquired)[48]

Artifacts

- Presence of acetoacetate, glucose, Vitamin C, uric acid, pyruvate, cephalosporins, and amino acids in the sample[1]
- Lidocaine: increases values (dry chemistries)[49]
- Nitrofurantoin: increases values (Jaffe reaction)[49]
- Cefoxitin: increases values (Jaffe reaction)[49]
- Dobutamine: decreases values[49]
- Proline from hyperalimentation fluids increases values[49]

Interpret With

- Blood urea Nitrogen
- Hepatic enzyme activity
- Creatine kinase
- Lactate dehydrogenase
- Urinalysis

Bold Indicates a common cause

DGGR Lipase

Definition

Increased

- Acute pancreatitis
- Gastrointestinal disease
- Hepatic disease
- Azotemia
- Hyperadrenocorticism

Decreased

- Not clinically significant

Artifacts

- Hemolysis can lead to false decreases
- Lipemia causes false increases
- Glucocorticoids cause false increases

Interpret With

- cPL
- Folate
- Cobalamin
- TLI

Bold Indicates a common cause

Free T4

Definition

Increased

Increased production by thyroid neoplasia

- **Thyroid adenoma (common in cats, not dogs, rare in horses)**
- **Thyroid adenocarcinoma (dogs, cats, horses)**
- Multiple endocrine neoplasia (type II)

Administration of T4, TSH, or TRH

Administration of compounds containing iodide

Decreased

Most Common Causes

Decreased production of T4

- **Primary hypothyroidism**
  - **Lymphocytic thyroiditis**
  - **Idiopathic thyroid atrophy**
  - **Congenital thyroid gland dysgenesis**
  - **Destruction of thyroid tissue**
    - **Neoplasia**
    - **Surgery**
    - **Radioactive iodide**

Multifactorial or unknown mechanisms

- **Nonthyroidal disease: hyperadrenocorticism, inflammatory diseases**
- **Drugs: glucocorticoids, trimethoprim-sulfadiazine, trimethoprim-sulfamethoxazole, phenobarbital, phenylbutazone, clomipramine**

Other Causes

Decreased production of T4

- Secondary hypothyroidism
  - TSH deficiency caused by pituitary malformation or destruction by neoplasia, radiation, or other
- Defective thyroxine production
  - Iodine organification defect
  - Congenital thyroid peroxidase deficiency in Toy Fox Terriers
  - Iodine deficiency

Multifactorial or unknown mechanisms

- Diets high in energy, protein, copper, zinc, endophyte-infected fescue grass (horse)
- Food deprivation for 4 days (horses)
- Diet high Leucaena leuocephala (cattle)

Artifacts

- Thyroxine autoantibodies (T4AA) can interfere with some fT4 assays

Interpret With

- tT4
- TSH
- Hepatic enzymes

Bold Indicates a common cause

Fructosamine

Definition

Increased

Increased fructosamine concentration and increased glycated hemoglobin percentage or concentration

- **Diabetes mellitus/persistent hyperglycemia**
- Insulin overdose (Somogyi rebound)
- **Hypothyroidism**

Decreased

- Insulinoma
- Hyperlipidemia
- Hypoproteinemia
- **Anemia**
- **Azotemia**
- Hyperthyroidism

Artifacts

- Hemolysis will artificially increase levels (some methodologies)
- Drugs: Lexodopa and oxytetracycline increase levels

Interpret With

- Glucose
- Proteins
- CBC
- Hepatic enzymes
- Insulin levels
- Urinalysis

Bold Indicates a common cause

Gamma–Glutamyltransferase (GGT)

Definition

Increased

Biliary Tract Abnormalities (same as Alkaline Phosphatase, ALP)[1, 2]

Hepatic Parenchyma Disease/Condition

- **Degenerative, metabolic, inflammatory, neoplastic (same as ALP)[1, 2]**

Induction by Drugs or Hormones

- **Corticosteroids endogenous or exogenous (dog)[1]**
- Phenobarbital, Phenytoin, Primidone[1]

Physiologic

- Can be elevated in neonates, mainly cattle, and horses

Decreased

- Not clinically significant

Artifacts

- Hemolysis or icterus may decrease the measured GGT activity[55]
- Underfilling of lithium heparin tube may increase GGT activity[45]

Interpret With

- Hepatic enzymes
- Markers of cholestasis

Bold Indicates a common cause

Globulin (GLOB)

Definition

Increased

Most Common Causes

Hemoconcentration
- **Dehydration[4, 5]**

Iatrogenic
- **Corticosteroids (dogs)**

Inflammation/Infection

Infectious
- **Bacterial**
  - **Brucellosis**
  - **Pyoderma (suppurative dermatopathies)**
  - **Bacterial endocarditis[4, 5]**
  - **Rickettsial**
    - **Ehrlichiosis[5]**
- **Viral**
  - **Feline infectious peritonitis (FIP)**
  - **Feline immunodeficiency virus (FIV)**
  - **Feline leukemia virus (FeLV)[4, 5]**
- **Fungal**
  - **Systemic fungal infections**
    - **Blastomycosis**
    - **Histoplasmosis**
    - **Cryptococcosis**
    - **Coccidioidomycosis[4, 5]**
- **Parasitic**
  - **Dirofilariasis**
  - **Demodicosis**
  - **Scabies[4, 5]**

Immune-Mediated Disease
- **Inflammatory (immune complex)**
  - **Feline cholangitis/cholangiohepatitis**
  - **Pyometra[5]**

Neoplasia
- **Multiple myeloma**
- **Lymphoma**
- **Extramedullary plasmacytoma (rare)**
- **Chronic lymphocytic leukemia**
- **Waldenström's macroglobulinemia[5]**

Other Causes

Inflammation
- Acute phase response
- Nephrotic syndrome (α-globulins)[4]
- Inflammation (acute, chronic)
  - Active liver disease
  - Nephrotic syndrome (β -globulins)[4]

Immune-Mediated Disease
- Systemic lupus erythematosus (SLE)
  - Glomerulonephritis
  - Immune-mediated hemolytic anemia (IMHA), thrombocytopenia (IMT), and polyarthritis[5]
- Immune mediated hemolytic anemia (IMHA)[5] and Immune-mediated thrombocytopenia (IMT) - not because of SLE[5]
- Pemphigus complex, bullous pemphigoid[5]
- Rheumatoid arthritis[5]
- Neoplasia[4, 5]

Infection
- Ehrlichiosis
- Leishmaniosis
- Feline infectious peritonitis (rare)
- Idiopathic
- Benign monoclonal gammopathy[5]

Miscellaneous
- Cutaneous amyloidosis[56]
- Lymphocytic-plasmacytic gastroenterocolitis

Decreased

Most Common Causes

- **Blood Loss (hemorrhage)[5]**
- **Protein Losing Enteropathy (PLE)[5]**
- **Markedly damaged glomeruli (protein losing nephropathy- PLN)[5]**
- **Skin (plasma exudation)**

Other Causes

- Acquired
  - Chemotherapy, radiation therapy, or other compounds (e.g., toxins, drugs)
  - Failure of passive transfer
- Inherited
  - IgM deficiency (Dobermans)[4]
  - Primary severe combined immunodeficiency (Jack Russell Terriers, Basset Hounds, Cardigan Welsh Corgis, Dachshunds)[4, 56]
  - IgA deficiency (Shar Peis, Beagles, Airedale Terriers, and German Shepherd Dogs)[4]
  - Transient hypogammaglobulinemia (dogs)[4]
- Infectious
  - Viral: FeLV, FIV, canine parvovirus, canine distemper virus

Interpret With

- Albumin
- Packed cell volume
- Leukogram
- Renal Values
- Hepatocellular enzymes

Bold Indicates a common cause

Glucose (GLU)

Definition

Increased

Most Common Causes

Physiologic

- **Post-prandial**
- **Excitement, fright**
- **Stress (endogenous corticosteroids)**
- **Diestrus/pregnancy[28, 57]**

Primary Pancreatic Condition

- **Pancreatitis**
- **Pancreatic carcinoma[57]**

Endocrine

- **Diabetes mellitus**
  - **Immune-mediated[57]**
  - **Obesity**
- **Pancreatic insular amyloidosis (mostly cats)**
- **Hyperadrenocorticism (Cushing's)**

Pharmacologic or Toxicological Hyperglycemia (Iatrogenic)

- **Intravenous glucose administration**
- **Steroids (glucocorticoids)**
- **Ethylene glycol**
- **Insulin (Somogyi effect)**

Other Causes

Endocrine

- Glucagonoma
- Acromegaly
- Hyperpituitarism
- Hyperthyroidism (transient, cats)
- Hypothyroidism (dogs)
- Pheochromocytoma
- Hepatocutaneous syndrome (dogs)[57]

Other

- Sepsis (initial phase, transient)[57]
- Anti-insulin antibodies[57]
- Head trauma[28]

Pharmacologic or Toxicological Hyperglycemia (Iatrogenic)

- Megestrol acetate
- Ketamine[28, 57]
- Glucagon
- Thyroxine
- Alpha-2 agonists (xylazine, detomidine, medetomidine, dexmedetomidine)
- Propranolol
- Morphine
- Progestins[57]

Decreased

Most Common Causes

- **Pancreatic β-cell neoplasia (insulinoma)**
- **Hypoadrenocorticism (Addison's)**
- **Hepatic insufficiency/failure (acquired, congenital)**
- **Insulin therapy**
- **Xylitol toxicosis (dogs)[28]**
- **Sepsis (especially with endotoxemia)**

Other Causes

- Porto-systemic shunt
- Starvation, malabsorption, and severe malnutrition[28, 57]
- Exertional hypoglycemia ("hunting dog hypoglycemia")[28, 57]
- Growth hormone deficiency
- Hypopituitarism[57]
- Glycogen storage diseases (rare) (e.g., Pompe's disease, von Gierke's disease)[57]

Pharmacologic or Toxicologic Hypoglycemia

- Sulfonylurea compounds (glipizide, glyburide)
- Ethanol[28, 57]

Uncertain Pathogeneses

- Non- β-cell neoplasms[28]
  - Hepatocellular carcinoma
  - Hepatoma
  - Leiomyosarcoma
  - Leiomyoma
  - Hemangiosarcoma
- Pregnancy hypoglycemia
  - Bovine ketosis
  - Ovine pregnancy toxemia
- Malonic aciduria (Maltese dogs)[57]
- Idiopathic hypoglycemia
  - Neonatal hypoglycemia
  - Juvenile hypoglycemia (especially toy breeds)[28]

Artifacts

- Delayed analysis of blood sample/failure to remove serum or plasma from blood cells can cause a decrease in glucose concentration[58]
- Sample bacterial contamination/bacteremia (parasitemia) can cause a decrease in glucose concentration (increased glycolysis)[59]
- Extreme leukocytosis can cause a decrease in glucose concentration (increased glycolysis)[28, 57]
- Extreme erythrocytosis can cause a decrease in glucose concentration (increased glycolysis)[57]
- Bromide (KBr) interference with glucose in some of the oxidase activity used to measure glucose concentration[57]

Bold Indicates a common cause

Glucose (GLU), Continued

Interpret With

- Ketones (serum, urine)
- Hepatic enzymes serum activity
- Urinalysis
- Fructosamine
- Glucose curve or continuous monitoring

Bold Indicates a common cause

Ionized Calcium

Definition

Increased

Physiologic
- Healthy young, fast-growing dogs (young dog < 6 months, large or giant breed)[27, 28]

Primary Hyperparathyroidism (PTH)
- Parathyroid neoplasia[27]

Hypercalcemia of Malignancy/Humoral Hypercalcemia (PTHrp)
- Lymphoma
- Apocrine gland adenocarcinoma[27, 28]
- Other carcinoma
- Multiple myeloma

Increased Vitamin D Activity (Hypervitaminosis D)
- Exogenous Vitamin D
- Rodenticides containing cholecalciferol
- Endogenous Vitamin D
- Granulomatous inflammation
  - Some fungal and parasitic infections

Decreased Urinary Excretion of Calcium
- **Renal failure**[27, 28]
- Hypoadrenocorticism

Other or Unknown Mechanisms
- Idiopathic hypercalcemia in cats[32]

Decreased

Chronic Renal Disease in Dogs and Cats

Hypoparathyroidism (rare)

Pregnancy, Parturient, or Lactational Hypocalcemia
- Eclampsia[27, 28]
- Milk fever in cattle

Excess Urinary Excretion of Calcium
- Ethylene glycol toxicosis (dogs and cats)

Other or Unknown Mechanisms
- **Acute pancreatitis in dogs and cats**
- Urinary tract obstruction
- Hyperthyroidism in cats

Artifacts

- Decreased pH due to physiologic causes or sample handling will falsely increase calcium
- Anticoagulants (EDTA, citrate, excess heparin) will falsely decrease calcium
- Severe lipemia may increase iCa

Interpret With

- Total calcium
- Albumin
- PTH, PTHrp
- Other minerals and electrolytes

Bold Indicates a common cause

Lactate

Definition

Increased

Insufficient Oxygen Supply (Type A)

- Relative
  - **Strenuous exercise**
  - Muscle tremors
  - Shivering
  - Seizures
  - Struggling/restraint
- Absolute
  - **Hypoperfusion/shock**
  - **Severe anemia and hypoxemia**
  - Regional ischemia
  - Carbon monoxide

Adequate Oxygen Supply (Type B)

- Disease
  - **Neoplasia: lymphoma**
  - **Diabetes mellitus**
  - **Hepatic failure**
  - Thiamine deficiency
  - Hyperthyroidism
  - Impaired gluconeogenesis
  - Alkalosis
  - **SIRS/sepsis**
  - Pheochromocytoma
- Drugs/toxins
  - Glucocorticoids
  - Xylitol
  - Glucose
  - Strychnine
  - Lactulose
  - 5-Fluorouracil
  - Epinephrine
  - Acetaminophen
  - Ethylene glycol
  - Propofol
- Congenital
  - Mitochondrial myopathy
  - PDH deficiency

Decreased

- Clinically not significant

Artifacts

- Rapid infusion of Lactated Ringers solution
- Ethylene glycol

Interpret With

- CBC
- Electrolytes
- Hepatic enzymes
- Renal enzymes
- Acid-base evaluation
- Anion Gap

Bold Indicates a common cause

Magnesium (MG)

Definition

Increased

Decreased urinary excretion
- **Renal failure/Insufficiency**
- **Pre-renal/Decreased GFR**
- Post-renal azotemia

Shift of fMg_2+ from ICF to ECF
- Active in vivo hemolysis

Increased [PTH]
- **Milk fever**

Increased intestinal absorption of Mg_2+ without increased PTH or PTHrp
- Antacids or cathartics in cattle
- $MgSO_4$ (horses)

Miscellaneous
- Intravenous administration of Mg2+

Decreased

Hypoproteinemia

Inadequate ruminal or intestinal absorption
- **Prolonged anorexia or poor food intake**
- **Grass tetany (cattle)**
- Enteric diseases: chronic diarrhea, loss of saliva in cattle (choke, rabies), hyperaldosteronism
- Calves on whole milk diets
- Malabsorption

Excess loss
- **Osmotic diuresis**
- **Ketonuria**
- Blister beetle poisoning in horses
- Lactation
- Sweat

Artifacts

- Delayed removal of serum from blood clot leading to false increase

Interpret With

- Other minerals
- Electrolytes
- Renal enzymes

Bold Indicates a common cause

Osmolality

Definition

Increased

Disorders that cause increases in

- **Glucose**
- **Urea**
- **Sodium**

Administration or ingestion of

- Mannitol
- Radiographic contrast media
- Ethanol, methanol, or ethylene glycol

Decreased

Disorders that cause decreases in

- **Sodium (see hyponatremia for more info)**

Artifacts

- Radiographic contrast media

Interpret With

- Electrolytes
- Renal enzymes
- Glucose

Bold Indicates a common cause

pH

Definition

Increased (Alkalemia)

Loss of H+

- **Gastric loss: vomiting or pyloric obstruction**
- **Renal Loss**
  - Loop or thiazide diuretics
  - Secondary to respiratory acidosis
  - Hypokalemia
- **Respiratory alkalosis**
  - **Hypoxemia**
  - Pulmonary disease
  - Metabolic acidosis
  - **Septicemia**
  - Heat stroke
  - Central neurologic disease
  - Pain or anxiety

Decreased (Acidemia)

Accumulation/decreased excretion of H+

- **Renal failure**
- Uroperitoneum
- **Ketoacidosis**
- Respiratory acidosis
  - Upper airway dysfunction
  - Inhibition or dysfunction of respiratory muscles
  - Inhibition or dysfunction of medullary respiratory center
  - Impaired gas exchange at pulmonary capillaries
  - Restrictive disease
  - Vascular disorders: right-to-left shunts
  - Metabolic alkalosis

Increased HCO_3^- loss

- **GI loss**
  - Diarrhea
  - Salivary loss (ruminants)
- **Organic acidosis**
  - Lactic acidosis
  - Ketoacidosis
  - Ethylene glycol
  - Uremic acids

Artifacts

- Falsely decreased pH
  - Can occur in aged samples – increased lactate production
- Falsely increased pH
  - Can occur secondary to severe muscle injury (rare)
  - Exposure to air/air bubbles
  - Excess heparin

Interpret With

- Complete acid-base analysis
- Electrolytes

Bold Indicates a common cause

Phenobarbital (PHB)

Definition

Increased

- **High therapeutic dose**
- Severe anuric or oliguric renal failure
- Drugs: chloramphenicol, felbamate
- Low protein or fat diets

Decreased

- Malabsorption
- Increased urine flow (mannitol)
- Drugs: rifampin

Artifacts

- Serum separator tubes can produce a false decrease

Interpret With

- Liver enzymes
- CBC

Bold Indicates a common cause

Phosphorus (PHOS)

Definition

Increased

Most Common Causes

Physiologic

- **Post-Prandial**
- **Young fast-growing dog (generally large breed dog)[27, 28]**

Renal (Decreased PHOS Excretion)

- **Decreased glomerular filtration rate (GFR)**
- **Pre-renal azotemia**
- **Renal failure**
- **Post-renal obstruction**

Other Causes

Renal (Decreased PHOS Excretion)

- Urinary bladder rupture or urine leakage into tissues
- Decreased parathyroid hormone (PTH) concentration or activity (hypoparathyroidism)
- Hyperthyroidism
- Acromegaly[27, 28]

Intestinal (Increased PHOS Absorption)

- Increased vitamin D
  - Ingestion of cholecalciferol rodenticides and plants (e.g., Cestrum diurnum, Solanum sp.)
- Phosphate enema or ingestion of phosphate urinary acidifier
- Ischemic intestinal lesions (shift intracellular fluid to extracellular fluid)
- Granulomatous disease
  - Fungal, parasitic
- Humoral hypercalcemia of malignancy
- Diet with a low calcium/phosphorus ratio (rare)[27]

Bone

- Osteolytic bone lesions (neoplasia)[28]

Other or Unknown Mechanisms

- Malignant hyperthermia[27, 28]
- Acute tumor lysis syndrome[27, 28]
- Hyperthyroidism in cats
- Metabolic acidosis
- Hyperadrenocorticism in dogs[27, 28]

Decreased

Most Common Causes

Intestinal (Decreased PHOS Absorption)

- **Prolonged anorexia or phosphorus-deficient diet**

Iatrogenic

- **Treatment of diabetes ketoacidosis[65]**

Other Causes

Renal (Increased Renal PHOS Excretion)

- Prolonged diuresis[27]
- Increased PTH or PTHrp activity
- Primary hyperparathyroidism (parathyroid neoplasia)[27, 28]
- Humoral hypercalcemia of malignancy[27, 28]
- Eclampsia
- Fanconi syndrome (dogs)[27]
- Hyperadrenocorticism/iatrogenic steroid administration[28, 65]

Intestinal (Decreased PHOS Absorption)

- Vomiting/diarrhea
- Phosphorus-binding agents
- Hypovitaminosis D
- Intestinal malabsorption/steatorrhea[27, 28]

Increased Loss

- Vomiting/diarrhea
- Diabetes
- Diabetic ketoacidosis[65]

Defective Mobilization of Phosphorus from Bone

- Puerperal tetany
- Eclampsia

Iatrogenic

- Glucose infusion[27]
- Sodium bicarbonate administration
- Parenteral glucose administration
- Aggressive parenteral fluid therapy[28]

Other Causes

- Respiratory alkalosis[27]
- Monoclonal gammopathy[66]
- Hyperinsulinism (endogenous or exogenous)
- Hepatic lipidosis (cats)
- Re-feeding syndrome[65]

Bold Indicates a common cause

Phosphorus (PHOS), Continued

Artifacts

- Drugs or Substances That May Cause Increased Serum PHOS[67]
  - Bilirubin (icterus)
  - Hemoglobin (hemolysis)
  - Lipemia
  - Amino salicylic acid
  - Detergents contaminating glassware
  - Fat emulsions
  - Methotrexate
  - Naproxen
  - Rifampin
- Drugs or Substances That May Cause Decreased Serum PHOS[67]
  - Phenothiazine
  - Cefotaxime
  - Citrates
  - Mannitol
  - Oxalate
  - Promethazine

Interpret With

- Calcium
- Blood Urea Nitrogen
- Creatinine
- Urinalysis

Bold Indicates a common cause

Potassium (K)

Definition

Increased

Most Common Causes

Decreased Renal Excretion
- **Urinary tract obstruction**
- **Ruptured bladder/ureter (uroabdomen)**
- **Renal insufficiency or failure (primarily oliguric or anuric patients)**
- **Hypoaldosteronism**
  - **Hypoadrenocorticism (pathologic)**

Metabolic
- **Metabolic acidosis by accumulation of inorganic acid (NH_4Cl, HCl, etc.)[68]**

Hypertonicity
- **Diabetes mellitus**

Other Causes

Decreased Renal Excretion
- Hypoaldosteronism
  - Angiotensin-converting enzyme inhibitors (iatrogenic)
  - Hyporeninemic hypoaldosteronism with diabetes or renal failure (rare)[34]

Increased Intake
- Administration of potassium-rich fluid

Drugs
- Angiotensin-converting enzyme inhibitors (e.g., enalapril)
- Potassium-sparing diuretics (e.g., spironolactone, amiloride, triamterene)
- Prostaglandin inhibitors
- Heparin
- Non-specific beta blockers (e.g., propranolol)[35]

Hypertonicity
- Mannitol infusion
- Massive intravascular hemolysis with potassium-rich erythrocytes
- Massive tissue damage
  - Acute tumor lysis syndrome
  - Reperfusion of extremities after aortic thromboembolism in cats with cardiomyopathy
  - Crush injuries[35]
  - Hyperkalemic myopathy (Rhabdomyolysis or other muscle damage)[34]

Other/Unknown Mechanism
- Repeated drainage of chylous thoracic effusions[35]
- Peritoneal effusions in cats[35]

Iatrogenic
- IV fluids or IV fluid line contamination with potassium supplementation
- Use of the wrong anticoagulant (K+ EDTA)

Decreased

Most Common Causes

Decreased Intake
- **Anorexia**

Gastrointestinal Loss
- **Vomiting or sequestration of H+ and Cl- causing metabolic alkalosis**
- **Diarrhea[34]**
- **Excess salivation**

Renal Loss
- **Chronic renal failure in cats**
- **Post-obstructive diuresis**
- **Increased fluid flow in distal nephron (collecting tubule)**
  - **Osmotic (diabetes)**
  - **Sodium-losing nephropathies[34]**

Increased Renal Excretion of Anions
- **Ketonuria**
- **Lactaturia**
- **Bicarbonaturia**

Drugs
- **Loop diuretics (e.g., furosemide)**
- **Glucose-containing fluids ± insulin[35]**

Other and Unknown Mechanisms
- **Metabolic/respiratory alkalosis with alkalemia[35]**
- **Hypokalemic renal failure in cats**

Other Causes

Increased Renal Excretion of Anions
- Distal (type I) renal tubular acidosis (rare)[35]
- Proximal (type II) renal tubular acidosis after $NaHCO_3$- treatment (rare)[35]
- Hyperaldosteronism (primary)[34]

Drugs
- Thiazide diuretics (e.g., chlorothiazide, hydrochlorothiazide)
- Amphotericin B
- Penicillin (rare)
- Albuterol overdose (rare)[35]
- Inadequate fluid therapy
  - Inadequate potassium supplementation
  - Potassium-free fluids (e.g., 0.9% NaCl, 5% dextrose in water)[35]

Other and Unknown Mechanisms
- Catecholamine release[35]
- Endotoxemia[34]
- Third space loss (body cavity effusion)[34]
- Hypokalemic myopathy of Burmese kittens

Bold Indicates a common cause

Potassium (K), Continued

Artifacts

- Lipemia may cause a decreased measured K+ concentration (ionic exclusion phenomenon)[68]
- Serum K+ is slightly higher than plasma K+ of healthy animals
  - Release of K+ from platelets during clotting[35]
- Elevations in K+ levels
  - Potassium oxalate or K_2 or K_3 EDTA anticoagulants[68]
  - Severe bilirubinemia: slight increase (ion-selective electrodes)[35]
  - Marked thrombocytosis[34, 35]
  - Marked leukocytosis (physiologic or neoplastic)[68]
  - In vitro hemolysis of K-rich erythrocytes in the Akita and Shiba Inu breeds[2]
  - In vivo hemolysis in phosphofructokinase deficiency in predisposed canine breeds[2, 3]
    - English Springer Spaniels, American Cocker Spaniels

Interpret With

- Electrolytes
- Blood urea nitrogen
- Creatinine
- Total carbon dioxide
- Anion gap
- Acid-base analysis
- Urinalysis

Bold Indicates a common cause

Progesterone

Definition

Increased

- **Before ovulation**
- **Mid-pregnancy**
- Ovarian tumors
- False pregnancy

Decreased

- **Before parturition**
- **Anestrus**
- **Proestrus**

Interpret With

- Vaginal cytology
- Anti-Mullerian hormone (AMH)
- Luteinizing hormone (LH)

Bold Indicates a common cause

Sodium (NA)

Definition

Increased

Most Common Causes

Inadequate Water Intake
- **Water deprivation (inadequate access to water)**

Excess Pure Water Loss
- **Panting**
- **Fever**
- **Hyperventilation[34]**

Renal Water Loss
- **Diabetes mellitus**
- **Chronic renal failure**

Extra-Renal Water Loss
- **Vomiting**
- **Osmotic diarrhea**
- **Osmotic sequestration (small intestinal obstruction)**
- **Peritonitis, pancreatitis, cavitary effusions[35]**

Other Causes

Inadequate Water Intake
- Primary adipsia/hypodipsia (defective thirst response secondary to hypothalamic disease or lesion)[34]

Excess Pure Water Loss
- Diabetes insipidus
- Central
- Nephrogenic

Renal Water Loss
- Osmotic
- Mannitol infusion
- Chemical diuresis (pharmacologic)
- Post-obstructive diuresis
- Non-oliguric renal failure[35]

Extra-Renal Water Loss
- Third space water losses
- Cutaneous water losses
- Burn lesions

Excess Intake of Sodium
- Salt poisoning (with concurrent water deprivation)
- Administration of hypertonic fluid
  - Hypertonic saline
  - Sodium bicarbonate
  - Parenteral nutrition
  - Sodium phosphate enema

Increased Renal Sodium Retention
- Hyperaldosteronism[35]

Other/Unknown Mechanism
- Hyperadrenocorticism[35]

Therapeutics
- Administration of hypertonic saline or sodium bicarbonate

Decreased

Most Common Causes

Gastrointestinal Sodium Loss
- **Vomiting/diarrhea**
- **Sequestration**
- **Canine whipworm infection**
- **Excess salivation**
- **Bovine hemorrhagic bowel syndrome**

Renal Sodium Loss
- **Hypoadrenocorticism**
- **Osmotic diuresis (diabetes mellitus)**
- **Hypoaldosteronism**
- **Ketonuria**
- **Sodium-wasting nephropathies[34]**

Third Space Sodium Loss
- **Pancreatitis**
- **Peritonitis**
- **Uroabdomen**

Edematous Disorders
- **Congestive heart failure causing ascites**

Extracellular Translocation of Water
- **Hyperglycemia**

Extravascular Fluid Translocation of Sodium
- **Uroperitoneum (ruptured bladder or abdominal urethra)[34]**

Other Causes

Renal Sodium Loss
- Proximal renal tubule dysfunction (prolonged diuresis)

Third Space Sodium Loss
- Chylothorax with repeated pleural fluid drainage[35]
- Acute internal hemorrhage or acute exudation[34, 35]

Cutaneous Loss
- Sweating
- Exudative skin lesions

Edematous Disorders
- Hepatic disease/hepatic cirrhosis causing ascites
- Nephrotic syndrome causing effusion
- Advanced renal failure (primarily oliguric or anuric)[35]

Expanded Extracellular Fluid Volume (Without Edema)
- Excess sodium-poor fluid administration (parenteral)
- Inappropriate fluid therapy with 5% dextrose, 0.45% saline solution, or hypotonic fluids[35]
- Syndrome of inappropriate antidiuretic hormone secretion (SIADH)[34, 35]
- Antidiuretic drugs (e.g., heparin solutions containing chlorbutanol, vincristine, cyclophosphamide, nonsteroidal anti-inflammatory drugs)[35]
- Myxedema coma of hypothyroidism (rare)[35]
- Psychogenic polydipsia[35]

Extracellular Translocation of Water
- Mannitol infusion (intravenously)[34]

Intracellular Translocation of Sodium
- Hypokalemia
- Acute muscle injury[34]

Bold Indicates a common cause

Sodium (NA), Continued

Artifacts

- Lipemia may cause pseudo-hyponatremia (ion-exclusion effect)[35]
- Marked hyperproteinemia may cause a false decrease in measured sodium[35]
- Hemolysis may cause a decreased sodium concentration
- Sample dehydration may cause artefactually increased sodium[34]
- Anticoagulant: Na2EDTA will increase the Na plasma concentration
  - Use of Na-Heparin will not cause clinically relevant changes in heparinized plasma Na[34]

Interpret With

- Electrolytes (K+, Cl–)
- Total protein
- Blood urea nitrogen
- Creatinine
- Osmolality
- Urinalysis
- Hematocrit

Bold Indicates a common cause

Symmetric Dimethylarginine (SDMA)

Definition

Increased

Physiologic

- Neonatal foals[71]
- Greyhounds/sighthounds[72]
- Birman cats[72]
- A small percentage of puppies and kittens may have values slightly above the adult reference interval

Non-azotemic

- **Lymphoma[73]**
- Pancreatitis[74]
- Dermatopathies[75]
- Psychogenic polydipsia[75]

Pre-renal

- **Dehydration**

Renal disease

- **Acute kidney injury**
- **Chronic kidney disease**

Decreased

- Not clinically significant

Artifacts

- No known artifacts/interferents

Interpret With

- Urinalysis including urine specific gravity
- Renal values (BUN and creatinine)
- Electrolytes
- CBC

Bold Indicates a common cause

Thyroxine (Total T4)

Definition

Increased

Most Common Causes

Hyperthyroidism

- **Thyroid adenoma/adenomatous hyperplasia (common in cats, rare in dogs)**[28, 76, 77]

Other Causes

Hyperthyroidism

- Thyroid carcinoma/adenocarcinoma (cats, rare in dogs)[28, 76, 77]
- Hyperplasia[76]
- Multiple endocrine neoplasia (Type II)[76]

Drugs (Dogs)[28]

- Amiodarone
- Ipodate
- Overdose of levothyroxine supplementation[76]

Decreased

Most Common Causes

Primary Hypothyroidism (Dogs)

- **Lymphocytic thyroiditis**
- **Idiopathic thyroid atrophy**
- **Congenital thyroid gland dysgenesis**
- **Destruction of thyroid gland (neoplasia, surgery, radioactive iodide treatments, etc.)**[28, 76, 77]

Non-Thyroidal Illnesses: "Euthyroid Sick Syndrome"[28]

- **Acute diseases**
  - **Bacterial bronchopneumonia**
  - **Sepsis**
  - **Distemper**
  - **Autoimmune hemolytic anemia**
  - **Systemic lupus erythematosus**
  - **Intervertebral disk disease**
  - **Polyradiculoneuritis**
  - **Acute renal failure**
  - **Acute hepatitis**
  - **Acute pancreatitis**
- **Chronic diseases**
  - **Generalized demodicosis**
  - **Generalized bacterial furunculosis**
  - **Systemic mycoses**
  - **Lymphoma**
  - **Chronic renal failure**
  - **Diabetes mellitus**
  - **Congestive heart failure**
  - **Cardiomyopathy**
  - **Chronic hepatitis, cirrhosis**
  - **Gastrointestinal disturbances**
  - **Megaesophagus**

Other Causes

Secondary Hypothyroidism

- Hyperadrenocorticism[76]
- Pituitary failure
- May be normal for some breeds

Defective Thyroxine Production

- Iodine organification defect[76]
- Congenital thyroid peroxidase deficiency in Toy Fox Terriers[76]
- Iodine deficiency[76]

Drugs

- Dogs[28]
  - Aspirin
  - Carprofen
  - Glucocorticoids
  - Clomipramine
  - Furosemide
  - Methimazole
  - Phenobarbital
  - Phenylbutazone
  - Progestagens
  - Propylthiouracil
  - Sulfonamides
- Cats
  - Following radioactive iodine or methimazole therapy for hyperthyroidism[76]

Bold Indicates a common cause

Thyroxine (Total T4), Continued

Variables That May Affect Baseline T4 in Dogs

Age ..... Inversely proportional effect[28]
- Neonate (< 3 mo) ..... Increased T4
- Aged (> 6 yr) ..... Decreased T4

Body size ..... Inversely proportional effect[28]
- Small (< 10 kg) ..... Increased T4
- Large (> 30 kg) ..... Decreased T4

Breed
- Sight Hounds (e.g., Greyhound) ..... T4 may be lower than normal range established for dogs[28]
- Nordic breeds (e.g., Huskies)

Strenuous exercise[28] ..... Increased T4

Pregnancy (progesterone)[28] ..... Increased T4

Surgery/anesthesia[28] ..... Decreased T4

Concurrent illness (Euthyroid Syndrome)[28] ..... Decreased T4

Artifacts

- Presence of anti-T4 autoantibodies can cause an artefactual increase in T4 (radioimmunoassay) (dogs)[28]
- Administration of compound containing iodine

Interpret With

- Cholesterol
- Free T4
- Thyroid Stimulating Hormone (canine)
- Alanine Aminotransferase (feline)
- Kidney values (feline)

Bold Indicates a common cause

Trypsin–Like Immunoreactivity (TLI)

Definition

Increased

Increased release from acinar cells

- **Pancreatitis**
- Gastrointestinal obstruction
- Endotoxic shock

Decreased renal clearance

- **Pre-renal, renal, or post-renal disorders**

Decreased

Decreased cellular release

- **Chronic pancreatitis**
- **Pancreatic acinar atrophy/exocrine pancreatic insufficiency (EPI)**

Artifacts

- No known interferences
- Recommended patient fasted for testing

Interpret With

- PLI
- Cobalamin
- Folate
- DGGR lipase

Bold Indicates a common cause

Total Bilirubin (TBIL)

Definition

Increased

Most Common Causes

Fasting/Anorexia (Especially Horses)

Hemolysis

Immunological Alterations

- **Immune Mediated Hemolytic Anemia (IMHA)** [79, 80]
- **Blood transfusion reaction**

Infectious

- **Mycoplasma haemofelis**
- **Mycoplasma haemocanis**
- **Babesia canis**
- **Cytauxzoon felis**
- **Anaplasma spp.**
- **Feline leukemia virus (FeLV)**
- **Bacteremia**[79]

Oxidative Damage

- **Heinz body anemia**

Erythrocyte Fragmentation in Blood

- **Disseminated intravascular coagulation**
- **Hemangiosarcoma**

Hepatobiliary Disease

Cirrhosis

- **Chronic active hepatitis**

Metabolic or Endocrine

- **Hepatic lipidosis**
- **Diabetes mellitus**
- **Hyperadrenocorticism**
- **Hyperthyroidism**

Immunological

- **Chronic active hepatitis**
- **Feline lymphocytic or suppurative cholangiohepatitis**
- **Cirrhosis**

Neoplasia

- **Lymphoma**
- **Hepatocellular carcinoma**
- **Hepatoma**

Biliary Disorders

- **Cholangitis (bile sludge)**
- **Gall bladder stones**
- **Pancreatic disease (extrahepatic biliary obstruction)**
- **Neoplasia (gallbladder, bile duct adenocarcinoma)**
- **Biliary mucocele**

Other Causes

Hemolysis

Immunological Alterations

- Drug induced hemolytic anemia
- Vaccine associated[79, 80]

Toxins

- Lead poisoning
- Zinc/copper toxicity[79, 80]

Oxidative Damage

- Methemoglobulinemia
- Eccentrocytic hemolysis (acquired or inherited)[79]

Defect in Adenosine Triphosphate (ATP) Generation

- Pyruvate kinase (PK) deficiency[79, 80]
- Phosphofructokinase deficiency[79, 80]
- Hypophosphatemic hemolysis[80]

Erythrocyte Fragmentation in Blood

- Vasculitis
- Microangiopathic disease
- Rheological processes
  - Caval syndrome of dirofilariasis
  - Cardiac valvular disease[79]

Other Unknown Pathogeneses

- Envenomation[79]
- Hemophagocytic histiocytic sarcoma[79]
- Increased osmotic fragility[79]
- Hereditary non-spherocytic hemolytic anemia of Beagles[79]
- Idiopathic hemolytic anemia of Abyssinian and Somali cats[79]

Hepatobiliary Disease

Infectious

- Viral
- Bacterial
- Systemic fungal infection

Toxins

- Mushrooms
- Chemicals – insecticides, carbon tetrachloride
- Numerous pharmaceuticals
- Plants – aflatoxins, pyrrolizidine alkaloids, glycosides (sago palm)

Sepsis Associated Cholestasis

- Escherichia coli, Staphylococcus intermedius infection
  - Pneumonia
  - Peritonitis
  - Endocarditis
  - Urinary tract infection

Decreased

- Not clinically significant

Artifacts

- Hemolysis or lipemia may artifactually increase values[81]
- Exposure to ultraviolet light (including sunlight) will decrease bilirubin levels[81]

Bold Indicates a common cause

Total Bilirubin (TBIL), Continued

Interpret With

- Hepatic enzyme activity
- Creatine kinase
- Lactate dehydrogenase, if available
- Complete blood count
- Hematocrit

Bold Indicates a common cause

Total Carbon Dioxide (TCO2)

Definition

Increased

Most Common Causes

Metabolic Alkalosis

- **Gastrointestinal loss/sequestration H+ and Cl–**
- **Vomiting, gastric atony/torsion/pyloric obstruction (functional or mechanical)**

Renal Loss of H+

- **Hypokalemia**[34]

Iatrogenic

- **Administration of bicarbonate containing solutions**

Other Causes

Metabolic Alkalosis

- Contraction alkalosis secondary to vomiting[34]

Renal Loss of H+

- Loop or thiazide diuretics (e.g., furosemide)[34]
- Renal compensation for respiratory acidosis (chronic)[34]

Decreased

Most Common Causes

Bicarbonate Consumption (Titration Acidosis)

- **Lactic acidosis**
- **Ketoacidosis (diabetes mellitus)**
- **Decreased excretion of non-carbonic acid**
  - **Sulfates**
  - **Phosphates**
  - **Renal failure**
- **Toxicity (ethylene glycol, paraldehyde, salicylate, methanol)**[34]

Decreased Renal Excretion of H+

- **Hypoadrenocorticism**[34]

Bicarbonate Loss (Hyperchloremic Metabolic Acidosis)

- **Vomiting (biliary and/or pancreatic fluids)**
- **Diarrhea**
- **Sequestration or GI fluids**[34]

Other Causes

Decreased Renal Excretion of H+

- Proximal renal tubular acidosis
- Distal renal tubular acidosis (Type I)[34]
- Uroperitoneum and/or urinary tract obstruction[34]

Compensation for Primary Respiratory Alkalosis

- Hyperventilation – hypoxemia
- Primary pulmonary disease
- Pain

Dilutional Acidosis

- Rapid infusion of saline

Iatrogenic

- Ammonium chloride administration

Artifacts

- Increased contact with room air may decrease tCO_2[82]
  - Underfilling the sample tube (heparin or plain tube)
  - Failure to properly cap the sample or repeatedly opening the tube
- Prolonged venous stasis will decrease tCO_2[82]
- Use of EDTA, oxalate, or fluoride anticoagulants will decrease tCO_2[82]
- Prolonged contact with the clot can cause decrease in tCO_2[82]

Interpret With

- Acid-Base analysis
- Anion gap
- Electrolytes
- Glucose
- Blood Urea Nitrogen
- Creatinine
- Urinalysis

Bold Indicates a common cause

Total Protein (TP)

Definition

Increased

Most Common Causes

Decreased Blood Volume

- **Hemoconcentration – dehydration (most common cause)[4, 5]**

Increased Protein Production

- **Inflammatory Disease**
  - **Infectious**
    - **Bacterial**
    - **Viral**
    - **Fungal**
    - **Protozoal[4]**
  - **Noninfectious**
    - **Necrosis**
    - **Neoplasia**
    - **Immune-mediated disease[4]**

Other Causes

B-Lymphocyte Neoplasia

- Plasma cell (monoclonal gammopathy): multiple myeloma, plasmacytoma[4]
- Lymphocyte: lymphoma, lymphocytic leukemia[4]

Decreased

Most Common Causes

Protein Loss

- **Blood loss**
- **Protein-losing nephropathy**
  - **Glomerulonephritis**
  - **Amyloidosis**
- **Protein-losing enteropathy**
  - **Small intestinal mucosal disease**
  - **Lymphangiectasia**
  - **Intestinal blood loss**
- **Plasma loss (sequestration/third space losses)**
  - **Peritonitis/pleuritis**

Decreased Protein Synthesis/Increased Protein Catabolism

- **Hepatic insufficiency**
- **Malabsorption or maldigestion**
  - **Intestinal mucosal disease**
  - **Exocrine pancreatic insufficiency (EPI)[4, 5]**
- **Cachectic state**
  - **Chronic disease**
  - **Neoplasia**
  - **Malnutrition**
  - **Starvation**

Hemodilution

- **Edematous disorders**
  - **Congestive heart failure**

Other Causes

Protein Loss

- Plasma loss (sequestration/third space losses)
  - Vasculitis
  - Exudative dermatopathies[4, 5]

Decreased Protein Synthesis/Increased Protein Catabolism

- Cachectic state
  - Lymphoid hypoplasia[4, 5]

Hemodilution

- Excess administration of intravenous fluid
- Edematous disorders
  - Cirrhosis
  - Nephrotic syndrome
  - Excess ADH secretion (SIADH)[4, 5]

Artifacts

- Hemolysis or gross lipemia may cause an increase in measured TP[4, 85]
- Icterus may falsely decrease the measured total protein value[4, 5, 83, 84, 85]
- Plasma > serum (very slight difference)
  - Fibrinogen may slightly increase the plasma TP concentration[85]

Bold Indicates a common cause

Total Protein (TP), Continued

Interpret With

- Albumin
- Globulin
- Blood urea nitrogen
- Liver enzymes
- Creatinine
- Hematology
- Urinalysis
- Urine protein:creatinine ratio

Bold Indicates a common cause

Triglycerides (TGA)

Definition

Increased

Increased triglyceride production

- **By enterocytes: Postprandial hyperlipemia/hyperlipidemia**
- **By hepatocytes: Equine hyperlipemia/hyperlipidemia**

Decreased lipolysis or intravascular processing of lipoproteins

- Hypothyroidism
- Nephrotic syndrome

Other, unknown, or multiple mechanisms

- **Acute pancreatitis**
- **Diabetes mellitus**
- High lipid diet
- Endogenous or exogenous glucocorticoids
- Idiopathic hyperlipidemia of Miniature Schnauzers

Increased lipolysis

- **Metabolic syndrome (obesity + insulin resistance)**
- Pregnancy
- Stress
- Lactation in horses
- Pregnancy toxemia
- Ketosis in camelids

Decreased

May not be clinically significant

- **Exocrine pancreatic insufficiency**
- **Protein-losing enteropathy**
- Portosystemic shunt
- Inflammatory bowel disease
- Hepatic insufficiency
- Hypoadrenocorticism
- Hematopoietic neoplasia
- Hyperthyroidism

Interpret With

- Glucose
- ALT
- ALP
- GGT
- Total bilirubin
- Cholesterol

Bold Indicates a common cause

Uric Acid (UA)

Definition

Increased

Increased production

- **Post-prandial in carnivorous species**
- **Gout**
- Starvation
- Tissue necrosis

Decreased excretion

- **Renal disease**
- **Severe dehydration**

Decreased

- Not clinically significant

Artifacts

- Can be artifactually increased in samples from toenail clippings due to fecal urate contamination

Interpret With

- Calcium
- Phosphorus
- BUN
- +/- Creatinine
- Electrolytes

Bold Indicates a common cause

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