

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*

- Analyse 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, 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.

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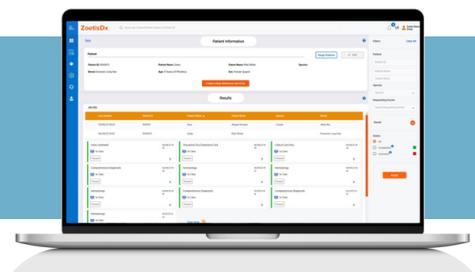
ZOOM VIDEO



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. In addition, discretion is required when assessing this list as differentials may not all be appropriate depending on the geographical location of the patient and their species.

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Alanine Aminotransferase (ALT)

Definition

Increased

Hepatocellular Injury

Degenerative

- **Anoxia due to anaemia/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 diseases¹

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
- Haemochromatosis¹

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

- Haemolysis can cause mild increase³
- Lipaemia can cause artifactual increase³

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

Haemoconcentration

- Fluid losses/dehydration

Decreased

Decreased Albumin Synthesis

- Inflammation⁴
- Hepatic insufficiency (chronic hepatic disease)^{4,5}
- Malabsorption and maldigestion⁴
- Cachectic/catabolic state⁴
- Hypergammaglobulinaemia⁴

Increased Albumin Loss

- Blood loss (haemorrhage)^{4,5}

- **Protein-losing enteropathy**^{4,5}

- Glomerulonephritis
- Amyloidosis^{4,5}

- **Protein-losing nephropathy**

- Small intestinal mucosal disease
- Lymphangiectasia
- Intestinal blood loss

- **Cutaneous losses (burns/exudative skin disease)**

Sequestration⁴

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

Haemodilution

- Excess administration of Intravenous fluid^{4,5}
- Oedematous disorders
 - Congestive heart failure
 - Cirrhosis
 - Nephrotic syndrome

Artifacts

- High fibrinogen levels in heparinised plasma samples used with a BCG method may cause false increases⁸
- Haemolysis or haemoglobinemia can cause false increases
- Marked lipaemia or hypertriglyceridaemia can cause false decreases
- Severe hypoalbuminaemia 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 release¹
- Ingestion and absorption of colostrum by neonatal foals and pups may increase serum ALP activity¹

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 (in the initial phase of feline hepatic lipidosis,¹ 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
- Haemangiosarcoma
- Mammary neoplasia (benign and malignant)
- Hepatocellular carcinoma
- Metastatic carcinoma¹

Induction by Drugs or Hormones (Not an Exhaustive List)

- Barbiturates
- Oestrogens (urinary incontinence medication)
- Glucocorticoids (dogs only)
- Phenobarbital
- Primidone

Cardiogenic

- Chronic passive congestion from right heart failure²

Other Causes

Physiologic

- Breed (Siberian Huskies – benign familial hyperphosphatasaemia; Scottish Terriers)^{10, 11}

Biliary Tract Disease

- Bile duct neoplasia
- Cholecystitis
- Gall bladder mucocoele
- Ruptured gallbladder
- Pancreatic neoplasia^{1, 2}

Inflammatory

- Copper storage disease
- Toxic hepatitis
- Aflatoxin
- Certain types of mushrooms
- Sago palm
- Drug induced¹

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 haemolysis may falsely decrease ALP²

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)**
- Macroamylasaemia¹

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



Increased

Metabolic Acidosis

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

Decreased (Minimal Clinical Significance)

Decreases in Unmeasured Anions-

- **Hypoalbuminaemia**
- Acidaemia

Increases in Unmeasured Cations+

- Hypercalcaemia
- Hypermagnesaemia

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

- Haemolysis will increase AST serum activity¹⁹
- Icterus may affect results
- Marked lipaemia may interfere with spectrophotometric assays¹⁹
- Metronidazole may artifactually depress AST activity¹⁹

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⁻ or loss of acid)

- Metabolic alkalosis
- Refer to bicarbonate (HCO₃⁻) and TCO₂ for additional differentials

Decreased

Insufficient Base

- Metabolic acidosis
- Refer to bicarbonate (HCO₃⁻) and TCO₂ 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
- **Hypokalaemia**
- 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 HCO₃ - loss

- Alimentary losses: diarrhoea, 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
- Lipaemia, haemolysis, 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 disease²²

Decreased Portal Blood Flow to Liver

- Congenital and acquired portosystemic shunts²²
- Hepatic microvascular dysplasia²

Hepatic Cholestasis (Obstructive)

- Cirrhosis
- Cholangitis/Cholangiohepatitis
- Periportal hepatitis

Post-Hepatic Cholestasis

- Cholangitis
- Bile duct carcinoma
- Liver fluke
- Cholelithiasis
- Cholecystitis
- Pancreatitis
- Pancreatic carcinoma²²

Other Causes

Hepatic Cholestasis (Obstructive)

- Hepatic lipidosis
- Diabetes mellitus
- Steroid hepatopathy
- Lymphoma
- Histoplasmosis
- Cytauxzoonosis
- Pyrrolizidine alkaloid toxicosis²²

Functional Cholestasis

- Sepsis-associated cholestasis²²

Decreased

- Low clinical significance

Artifacts

Decreased BA value-

- Haemolysis²³
- Heparin BA²³
- Lipid-clearing agents²³
- Incomplete gallbladder contraction after feeding may result in a lower value than expected²

Increased BA Value

- Lipaemia (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

- Hypovolaemia/dehydration
- Decreased cardiac output
- Shock

Renal Conditions

- Inflammatory
 - Glomerulonephritis
 - Pyelonephritis (e.g., ascending UTI, leptospirosis)
- Toxic nephrosis
 - Hypercalcaemia
 - Ethylene glycol intoxication
 - NSAID intoxication²⁴
 - Lily toxicity
 - Gentamicin

- Renal ischaemia or hypoxia
 - Poor renal perfusion
 - Infarction²⁴

Post-Renal Conditions

- Urinary tract obstruction
 - Urolithiasis
 - Urethral plugs in cats
 - Neoplasia
 - Uroabdomen^{24, 25}
 - Prostatic disease
- Urine leakage
 - Trauma
 - Neoplasia

Increased Production

- Haemorrhage into the upper gastrointestinal system
- High protein diet

Other Causes

Renal Conditions

- Inflammatory
 - Tubular-interstitial nephritis^{24, 25}
- Amyloidosis
- Toxic nephrosis
 - Myoglobin
- Renal ischaemia or hypoxia
- Congenital hypoplasia or aplasia²⁴
- 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: glucosuria²⁴
- Central or nephrogenic diabetes insipidus (polyuria/polydipsia)²⁴

Artifacts

- Severe haemolysis will increase BUN concentration^{24, 26}
- Severe icterus may increase BUN concentrations²⁴
- Severe lipaemia may decrease BUN concentrations
- Contamination of the sample with ammonium (NH₄)^{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
- Haematology
- 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 neoplasia²⁷
- Hypercalcaemia of Malignancy / Humoral
- Hypercalcaemia (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 hypercalcaemia in cats³²

Other Causes

Increased Vitamin D Activity (Hypervitaminosis D)

- Exogenous Vitamin D
 - Tacalcitol or calcipocriol
 - Plants containing ergocalciferol (Vitamin D₂)
 - Excess dietary supplementation^{27, 28}

Increased Protein-Bound Calcium

- Hyperglobulinaemia in multiple myeloma
- Hyperalbuminaemia²⁷

Iatrogenic Disorders

- Excessive calcium supplementation (Intravenous)²⁷
- Excessive oral phosphate buffers²⁷
- Calcipotriene²⁸ (psoriasis treatment)

Decreased

Most Common Causes

Hypoalbuminaemia

- Hypoproteinaemia^{27, 28}

Pregnancy, Parturient, or Lactational

Hypocalcaemia

- 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-thyroidectomy²⁷

Hypovitaminosis D

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

Pregnancy, Parturient, or Lactational Hypocalcaemia

- Postpartum/parturient hypocalcemia/puerperal tetany

Hypercalcaionism

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

Excess Urinary Excretion of Calcium

- Intravenous HCO₃ infusions
- Furosemide treatment²⁷

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, rickets²⁷
- Oxalate toxicity²⁸
- Tetracycline administration²⁷
- Calcium deposition during fracture healing
- Acute and chronic kidney disease
- Phosphate enema
- Sepsis
- Acute tumor lysis syndrome
- Nutritional secondary hyperparathyroidism^{27, 28}

Artifacts

- Total Ca is falsely increased by lipaemia and haemolysis³³
- Total Ca can be decreased by marked bilirubinaemia³³
- Prolonged occlusion during phlebotomy may mildly increase Ca³³
- Use of an inappropriate anticoagulant (EDTA, citrate anticoagulants) may cause falsely decreased results³³

Bold Indicates a common cause



Calcium (CA), Continued

Definition

Interpret With

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

Note: Frequency of hypercalcaemia 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 diarrhoea
- GI loss/sequestration (diarrhoea)

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 enema³⁴

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 NH₄Cl³⁵

Decreased Renal Excretion of Na and Cl

- Hyperaldosteronism³⁴

Renal Chloride Retention

- Proximal renal tubular acidosis
- Distal renal tubular acidosis

- Hypoadrenocorticism³⁶
- Drug-induced: acetazolamide, spironolactone³⁶
- Compensatory response to chronic respiratory alkalosis
 - Hyperventilation or hypocapnia
 - Hypoxaemia
 - Primary pulmonary disease
 - Pain³⁵

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/diarrhoea
 - 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
- Hyperadrenocorticism³⁶
- Glucocorticoid administration³⁶

- 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 drainage³⁵
- Acute internal haemorrhage
- Acute exudation
- Cutaneous (sweating)

Edematous Disorders

- Congestive heart failure
- Hepatic disease/hepatic cirrhosis
- Nephrotic syndrome
- Advanced renal failure³⁴

Expanded Extracellular Fluid Volume (Without Oedema)

- Excess sodium-poor fluid administration (parenteral)³⁴

- Fluid therapy with 5% dextrose, 0.45% saline solution, or hypotonic fluids³⁵
- 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 polydipsia³⁵

Extracellular Translocation of Water

- Hyperglycemia
- Mannitol infusion (intravenously)³⁴

Intracellular Translocation of Na (Cl Follows)

- Hypokalaemia (to maintain the intracellular electronegativity)
- Acute muscle injury³⁴

Extravascular Fluid Translocation of Na (Cl Follows)

- Uroperitoneum (ruptured bladder, or abdominal urethra)³⁴

Bold Indicates a common cause



Chloride (CL), Continued

Artifacts

- Lipaemia causing pseudo-hypochloraemia (ion-exclusion effect when using the titrimetric methods) or causing pseudo-hyperchloraemia (using the colorimetric method)³⁵
- Potassium bromide therapy will falsely increase the reported chloride concentration (common and important)³⁵
- Hyperviscosity may cause problems in analysers that dilute samples before analysis³⁵

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 Hypercholesterolaemia^{28, 37, 40}

Secondary Hypercholesterolaemia

- **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 Hypercholesterolaemia

- Idiopathic hyperlipoproteinaemia (Miniature Schnauzers and other breeds)^{28, 37, 40}
- Hypercholesterolaemia in Briards (dog)⁴⁰
- Idiopathic hyper-chylomicronaemia (cat)²⁸
- Lipoprotein lipase deficiency (cat)^{28, 37, 40}
- Idiopathic hypercholesterolaemia^{28, 37}

Secondary Hypercholesterolaemia

- Hepatic insufficiency²⁸

- Excess negative energy balance
 - Starvation/anorexia
 - Pregnancy or lactation

Drug Induced Hypercholesterolaemia

- Megestrol acetate (cat)²⁸
- Glucocorticoids²⁸

Decreased

Most Common Causes

Severe Malnutrition⁴⁰

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

- Hypoadrenocorticism⁴⁰

Artifacts

- Haemolysis and hyperproteinaemia artifactually increase results⁴⁰
- Bilirubin and ascorbic acid negatively interfere with enzymatic assays⁴⁰
- Postprandial cholesterol increase may be mistaken for metabolic disease⁴⁰

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 agents¹

Toxic

- Monensin, ricin (Castor Bean), mycotoxin, gossypol, snakebite¹

Inherited

- Muscular dystrophy (Cavalier King Charles Spaniel dystrophin-deficient muscular dystrophy)
- Hyperkalaemic periodic paralysis
- Malignant hyperthermia¹

Other Pathologies with Uncertain Pathogeneses

- Critically ill anorectic cat⁴⁴

Decreased

- Not clinically significant

Artifacts

- May increase the measured CK activity
 - Haemolysis^{1,43}
 - Muscle penetration during venipuncture¹
 - Underfilling of lithium heparin tube⁴⁵

Bold Indicates a common cause



Creatinine (CRE)

Definition

Increased

Most Common Causes

Pre-Renal Conditions

- Hypovolaemia/dehydration
 - Hypoadrenocorticism
 - Blood loss
- Decreased cardiac output
 - Cardiac insufficiency
 - Shock
 - Hypoadrenocorticism
- Shock
 - Hypovolaemic
 - Cardiogenic
 - Anaphylactic
 - Septic
 - Neurogenic¹

Renal Conditions

- Inflammatory
 - Glomerulonephritis
 - Pyelonephritis

- Toxic nephrosis
 - Hypercalcaemia
 - Ethylene glycol intoxication
 - NSAID intoxication
- Renal ischaemia 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 animals¹

Other Causes

Renal Conditions

- Inflammatory
 - Tubular-interstitial nephritis
 - Amyloidosis
- Toxic nephrosis
 - Myoglobin
 - Aminoglycosides
- Renal ischaemia or hypoxia
- Congenital hypoplasia or aplasia
- Hydronephrosis
- Neoplasia (renal or metastatic)^{1, 25}

Post-Renal Conditions

- Neoplasia
- Prostatic disease

Physiologic Increase

- Post-protein meal¹

Decreased

Not a clinically significant finding

Most Common Causes

Physiologic

- Young dogs⁴⁶
- Small breed dog⁴⁷
- 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 sample¹
- Lidocaine: increases values (dry chemistries)⁴⁹
- Nitrofurantoin: increases values (Jaffe reaction)⁴⁹
- Cefoxitin: increases values (Jaffe reaction)
- Dobutamine: decreases values⁴⁹
- Proline from hyperalimentation fluids increases values⁴⁹

Interpret With

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

Bold Indicates a common cause



Increased

- Acute pancreatitis
- Gastrointestinal disease
- Hepatic disease
- Azotaemia
- Hyperadrenocorticism

Decreased

- Not clinically significant

Artifacts

- Haemolysis can lead to false decreases
- Lipaemia causes false increases
- Glucocorticoids cause false increases

Interpret With

- cPL
- Folate
- Cobalamin
- TLI

Bold Indicates a common cause



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 leucocephala* (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 haemoglobin percentage or concentration

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

Decreased

- Insulinoma
- Hyperlipidaemia
- Hypoproteinaemia
- **Anaemia**
- **Azotaemia**
- Hyperthyroidism

Artifacts

- Haemolysis 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, Primidone¹

Physiologic

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

Decreased

- Not clinically significant

Artifacts

- Haemolysis or icterus may decrease the measured GGT activity⁵⁵
- Underfilling of lithium heparin tube may increase GGT activity⁴⁵

Interpret With

- Hepatic enzymes
- Markers of cholestasis

Bold Indicates a common cause



Increased

Most Common Causes

Haemoconcentration

- Dehydration^{4, 5}

Iatrogenic

- Corticosteroids (dogs)

Inflammation/Infection Infectious

- Bacterial
 - Brucellosis
 - Pyoderma (suppurative dermatopathies)
 - Bacterial endocarditis^{4, 5}
 - Rickettsial
 - Ehrlichiosis⁵
- Viral
 - Feline infectious peritonitis (FIP)
 - Feline immunodeficiency virus (FIV)
 - Feline leukaemia virus (FeLV)^{4, 5}
- Fungal
 - Systemic fungal infections
 - Systemic fungal infections
 - Blastomycosis
 - Histoplasmosis
 - Cryptococcosis
 - Coccidioidomycosis^{4, 5}

- Parasitic
 - Dirofilariasis
 - Demodicosis
 - Scabies^{4, 5}

Immune-Mediated Disease

- Inflammatory (immune complex)
 - Feline cholangitis/cholangiohepatitis
 - Pyometra⁵

Neoplasia

- Multiple myeloma
- Lymphoma
- Extramedullary plasmacytoma (rare)
- Chronic lymphocytic leukaemia
- Waldenström's macroglobulinaemia⁵

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 haemolytic anaemia (IMHA), thrombocytopaenia (IMT), and polyarthritis⁵
- Immune mediated haemolytic anaemia (IMHA)⁵ and Immune-mediated thrombocytopaenia (IMT) - not because of SLE⁵
- Pemphigus complex, bullous pemphigoid⁵
- Rheumatoid arthritis⁵
- Neoplasia^{4, 5}

Infection

- Ehrlichiosis
- Leishmaniasis
- Feline infectious peritonitis (rare)
- Idiopathic
- Benign monoclonal gammopathy⁵

Miscellaneous

- Cutaneous amyloidosis⁵⁶
- Lymphocytic-plasmacytic gastroenterocolitis

Decreased

Most Common Causes

- Blood Loss (haemorrhage)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 hypogammaglobulinaemia (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)
- Dioestrus/pregnancy^{28, 57}

Primary Pancreatic Condition

- Pancreatitis
- Pancreatic carcinoma⁵⁷

Endocrine

- Diabetes mellitus
 - Immune-mediated⁵⁷
 - Obesity
- Pancreatic insular amyloidosis (mostly cats)
- Hyperadrenocorticism (Cushing's)

Pharmacologic or Toxicological

Hyperglycaemia (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 antibodies⁵⁷
- Head trauma²⁸

Pharmacologic or Toxicological

Hyperglycaemia (Iatrogenic)

- Megestrol acetate
- Ketamine^{28, 57}
- Glucagon
- Thyroxine
- Alpha-2 agonists (xylazine, detomidine, medetomidine, dexmedetomidine)
- Propranolol
- Morphine
- Progestins⁵⁷

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 endotoxaemia)

Other Causes

- Porto-systemic shunt
- Starvation, malabsorption, and severe malnutrition^{28, 57}
- Exertional hypoglycaemia ("hunting dog hypoglycaemia")^{28, 57}

- Growth hormone deficiency
- Hypopituitarism⁵⁷
- Glycogen storage diseases (rare)(e.g., Pompe's disease, von Gierke's disease)⁵⁷

Pharmacologic or Toxicologic Hypoglycaemia

- Sulfonylurea compounds (glipizide, glyburide)
- Ethanol^{28, 57}

Uncertain Pathogenesis

- Non- β -cell neoplasms²⁸
 - Hepatocellular carcinoma
 - Hepatoma
 - Leiomyosarcoma
 - Leiomyoma
 - Haemangiosarcoma

- Pregnancy hypoglycaemia
 - Bovine ketosis
 - Ovine pregnancy toxaemia
- Malonic aciduria (Maltese dogs)⁵⁷
- Idiopathic hypoglycaemia
 - Neonatal hypoglycaemia
 - Juvenile hypoglycaemia (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 concentration⁵⁸
- Sample bacterial contamination/bacteraemia (parasitaemia) 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 concentration⁵⁷

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



Ionised Calcium

Definition

Increased

Physiologic

- Healthy young, fast-growing dogs (young dog < 6 months, large or giant breed)^{27, 28}

Primary Hyperparathyroidism (PTH)

- Parathyroid neoplasia²⁷

Hypercalcaemia of Malignancy/Humoral Hypercalcaemia (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 hypercalcaemia in ca³²

Decreased

Chronic Renal Disease in Dogs and Cats

Hypoparathyroidism (rare)

Pregnancy, Parturient, or Lactational Hypocalcaemia

- 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 lipaemia may increase iCa

Interpret With

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

Bold Indicates a common cause



Increased

Insufficient Oxygen Supply (Type A)

- Relative
 - **Strenuous exercise**
 - Muscle tremors
 - Shivering
 - Seizures
 - Struggling/restraint
- Absolute
 - **Hypoperfusion/shock**
 - **Severe anaemia and hypoxaemia**
 - Regional ischaemia
 - 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 azotaemia

Shift of fMg_2+ from ICF to ECF

- Active in vivo haemolysis

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 Mg_2+

Decreased

Hypoproteinaemia

Inadequate ruminal or intestinal absorption

- **Prolonged anorexia or poor food intake**
- **Grass tetany (cattle)**
- Enteric diseases: chronic diarrhoea, 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



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 hyponatraemia for more info)

Artifacts

- Radiographic contrast media

Interpret With

- Electrolytes
- Renal enzymes
- Glucose

Bold Indicates a common cause



Increased (Alkalaemia)

Loss of H⁺

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

Decreased (Acidaemia)

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
- Pesticide disease
- Vascular disorders: right-to-left shunts
- Metabolic alkalosis
- Ethylene glycol
- Uraemic acids

Increased HCO₃⁻ loss

- **GI loss**
 - Diarrhoea
 - Salivary loss (ruminants)
 - Lactic acidosis
 - Ketoacidosis
- **Organic acidosis**

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



Phosphorous (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 azotaemia**
- **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
- Ischaemic intestinal lesions (shift intracellular fluid to extracellular fluid)
- Granulomatous disease
- Fungal, parasitic
- Humoral hypercalcaemia 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 diuresis²⁷
- Increased PTH or PTHrP activity
- Primary hyperparathyroidism (parathyroid neoplasia)^{27, 28}
- Humoral hypercalcaemia of malignancy^{27, 28}
- Eclampsia
- Fanconi syndrome (dogs)²⁷

- Hyperadrenocorticism iatrogenic steroid administration^{28, 65}

Intestinal (Decreased PHOS Absorption)

- Vomiting/diarrhoea
- Phosphorus-binding agents
- Hypovitaminosis D
- Intestinal malabsorption/steatorrhoea^{27, 28}

Increased Loss

- Vomiting/diarrhoea
- Diabetes
- Diabetic ketoacidosis⁶⁵

Defective Mobilisation of Phosphorus

from Bone

- Puerperal tetany
- Eclampsia

Iatrogenic

- Glucose infusion²⁷
- Sodium bicarbonate administration
- Parenteral glucose administration
- Aggressive parenteral fluid therapy²⁸

Other Causes

- Respiratory alkalosis²⁷
- Monoclonal gammopathy⁶⁶
- Hyperinsulinism (endogenous or exogenous)
- Hepatic lipidosis (cats)
- Re-feeding syndrome⁶⁵

Bold Indicates a common cause



Phosphorous (PHOS), Continued

Artifacts

- Drugs or Substances That May Cause Increased Serum PHOS ⁶⁷
 - Bilirubin (icterus)
 - Haemoglobin (haemolysis)
 - Lipaemia
 - 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 (NH₄Cl, HCl, etc.)⁶⁸

Hypertonicity

- Diabetes mellitus

Other Causes

Decreased Renal Excretion

- Hypoaldosteronism
 - Angiotensin-converting enzyme inhibitors (iatrogenic)

- Hyporeninaemic 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 haemolysis with potassium-rich erythrocytes
- Massive tissue damage
- Acute tumor lysis syndrome

- Reperfusion of extremities after aortic thromboembolism in cats with cardiomyopathy
- Crush injuries³⁵
- Hyperkalaemic myopathy (Rhabdomyolysis or other muscle damage)³⁴

Other/Unknown Mechanism

- Repeated drainage of chylous thoracic effusions³⁵
- Peritoneal effusions in cats³⁵

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
- Diarrhoea³⁴
- Excess salivation

Renal Loss

- Chronic kidney disease
- Post-obstructive diuresis
- Increased fluid flow in distal nephron (collecting tubule)
 - Osmotic (diabetes)
 - Sodium-losing nephropathies³⁴

Increased Renal Excretion of Anions

- Ketonuria
- Lactaturia
- Bicarbonaturia

Drugs

- Loop diuretics (e.g., furosemide)
- Glucose-containing fluids ± insulin³⁵

Other and Unknown Mechanisms

- Metabolic/respiratory alkalosis with alkalaemia³⁵
- Hypokalaemic 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⁻ 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 release³⁵
- Endotoxaemia³⁴
- Third space loss (body cavity effusion)³⁴
- Hypokalaemic myopathy of Burmese kittens

Bold Indicates a common cause



Potassium (K), Continued

Artifacts

- Lipaemia 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 clotting³⁵
- Elevations in K⁺ levels
 - Potassium oxalate or K₂ or K EDTA anticoagulants⁶⁸
 - Severe bilirubinaemia: slight increase (ion-selective electrodes)³⁵
 - Marked thrombocytosis^{34, 35}
 - Marked leukocytosis (physiologic or neoplastic)⁶⁸
 - In vitro haemolysis of K-rich erythrocytes in the Akita and Shiba Inu breeds²
 - In vivo haemolysis 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 tumours
- False pregnancy

Decreased

- **Before parturition**
- **Anoestrus**
- **Proestrus**

Interpret With

- Vaginal cytology
- Anti-Mullerian hormone (AMH)
- Luteinising 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
- Hyperventilation³⁴

Renal Water Loss

- Diabetes mellitus
- Chronic kidney disease

Extra-Renal Water Loss

- Vomiting
- Osmotic diarrhoea
- Osmotic sequestration (small intestinal obstruction)
- Peritonitis, pancreatitis, cavitory effusions³⁵

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
- Nephrogaenic

Renal Water Loss

- Osmotic
- Mannitol infusion
- Chemical diuresis (pharmacologic)
- Post-obstructive diuresis
- Non-oliguric renal failure³⁵

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

- Hyperaldosteronism³⁵

Other/Unknown Mechanism

- Hyperadrenocorticism³⁵

Therapeutics

- Administration of hypertonic saline or sodium bicarbonate

Decreased

Most Common Causes

Gastrointestinal Sodium Loss

- Vomiting/diarrhoea
- Sequestration
- Canine whipworm infection
- Excess salivation
- Bovine haemorrhagic bowel syndrome

Renal Sodium Loss

- Hypoadrenocorticism
- Osmotic diuresis (diabetes mellitus)
- Hypoaldosteronism
- Ketonuria
- Sodium-wasting nephropathies³⁴

Third Space Sodium Loss

- Pancreatitis
- Peritonitis
- Uroabdomen

Edematous Disorders

- Congestive heart failure causing ascites

Extracellular Translocation of Water

- Hyperglycaemia

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 drainage³⁵
- Acute internal haemorrhage 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 fluids³⁵

- Syndrome of inappropriate antidiuretic hormone secretion (SIADH)^{34, 35}
- Antidiuretic drugs (e.g., heparin solutions containing chlorbutanol, vincristine, cyclophosphamide, nonsteroidal anti-inflammatory drugs)³⁵
- Myxœdema coma of hypothyroidism (rare)³⁵
- Psychogenic polydipsia³⁵

Extracellular Translocation of Water

- Mannitol infusion (intravenously)³⁴

Intracellular Translocation of Sodium

- Hypokalaemia
- Acute muscle injury³⁴

Bold Indicates a common cause



Sodium (NA), Continued

Definition

Artifacts

- Lipaemia may cause pseudo-hyponatraemia (ion-exclusion effect)³⁵
- Marked hyperproteinaemia may cause a false decrease in measured sodium³⁵
- Haemolysis may cause a decreased sodium concentration
- Sample dehydration may cause artefactually increased sodium³⁴
- Anticoagulant: Na₂EDTA will increase the Na plasma concentration
 - Use of Na-Heparin will not cause clinically relevant changes in heparinised plasma Na³⁴

Interpret With

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

Bold Indicates a common cause



Symmetric Dimethylarginine (SDMA)

Definition

Increased

Physiologic

- Neonatal foals⁷¹
- Greyhounds/sighthounds⁷²
- Birman cats⁷²
- A small percentage of puppies and kittens may have values slightly above the adult reference interval

Non-azotaemic

- **Lymphoma**⁷³
- Pancreatitis⁷⁴
- Dermatopathies⁷⁵
- Psychogaenic polydipsia⁷⁵

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
- Iodate
- 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 haemolytic anaemia**
 - **Systemic lupus erythematosus**
 - **Intervertebral disc disease**
 - **Polyradiculoneuritis**
 - **Acute renal failure**
 - **Acute hepatitis**
 - **Acute pancreatitis**
- **Chronic diseases**
 - **Generalised demodicosis**
 - **Generalised bacterial furunculosis**

- **Systemic mycoses**
- **Lymphoma**
- **Chronic kidney disease**
- **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 effect²⁸

- Neonate (< 3 mo) Increased T4
- Aged (> 6 yr) Decreased T4

Body size Inversely proportional effect²⁸

- 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 dogs²⁸
- Nordic breeds (e.g., Huskies)

Strenuous exercise²⁸ Increased T4

Pregnancy (progesterone)²⁸ Increased T4

Surgery/anaesthesia²⁸ 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
- Recommend 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)

Haemolysis

Immunological Alterations

- Immune Mediated Haemolytic Anaemia (IMHA)^{79, 80}
- Blood transfusion reaction

Infectious

- Mycoplasma haemofelis
- Mycoplasma haemocanis
- Babesia canis
- Cytauxzoon felis
- Anaplasma spp.
- Feline leukaemia virus (FeLV)
- Bacteraemia⁷⁹

Oxidative Damage

- Heinz body anaemia

Erythrocyte Fragmentation in Blood

- Disseminated intravascular coagulation
- Haemangiosarcoma

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 mucoceles

Other Causes

Haemolysis

Immunological Alterations

- Drug induced haemolytic anaemia
- Vaccine associated^{79, 80}

Toxins

- Lead poisoning
- Zinc/copper toxicity^{79, 80}

Oxidative Damage

- Methaemoglobinemia
- Eccentric haemolysis (acquired or inherited)⁷⁹

Defect in Adenosine

Triphosphate (ATP) Generation

- Pyruvate kinase (PK) deficiency^{79, 80}
- Phosphofructokinase deficiency^{79, 80}
- Hypophosphataemic haemolysis⁸⁰

Erythrocyte Fragmentation in Blood

- Vasculitis
- Microangiopathic disease

- Rheological processes
 - Caval syndrome of dirofilariasis
 - Cardiac valvular disease⁷⁹

Other Unknown Pathogenesis

- Envenomation⁷⁹
- Haemophagocytic histiocytic sarcoma⁷⁹
- Increased osmotic fragility⁷⁹
- Hereditary non-spherocytic haemolytic anaemia of Beagles⁷⁹
- Idiopathic haemolytic anaemia of Abyssinian and Somali cats⁷⁹

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

- Haemolysis or lipaemia may artifactually increase values⁸¹
- Exposure to ultraviolet light (including sunlight) will decrease bilirubin levels⁸¹

Bold Indicates a common cause



Total Bilirubin (TBIL), Continued

Interpret With

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

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⁺

- Hypokalaemia³⁴

Iatrogenic

- Administration of bicarbonate containing solutions

Other Causes

Metabolic Alkalosis

- Contraction alkalosis secondary to vomiting³⁴

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⁺

- Hypoadrenocorticism³⁴

Bicarbonate Loss (Hyperchloremic

Metabolic Acidosis)

- Vomiting (biliary and/or pancreatic fluids)
- Diarrhoea
- Sequestration or GI fluids³⁴

Other Causes

Decreased Renal Excretion of H⁺

- Proximal renal tubular acidosis

- Distal renal tubular acidosis (Type I)³⁴

- Uroperitoneum and/or urinary tract obstruction³⁴

Compensation for Primary

Respiratory Alkalosis

- Hyperventilation – hypoxaemia
- Primary pulmonary disease
- Pain

Dilutional Acidosis

- Rapid infusion of saline

Iatrogenic

- Ammonium chloride administration

Artifacts

- Increased contact with room air may decrease tCO₂⁸²
 - Underfilling the sample tube (heparin or plain tube)
 - Failure to properly cap the sample or repeatedly opening the tube
- Prolonged venous stasis will decrease tCO₂⁸²
- Use of EDTA, oxalate, or fluoride anticoagulants will decrease tCO₂⁸²
- Prolonged contact with the clot can cause decrease in tCO₂⁸²

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

- Haemoconcentration – dehydration (most common cause)^{4,5}

Increased Protein Production

- Inflammatory Disease
 - Infectious
 - Bacterial

- Viral
- Fungal
- Protozoal⁴
- Noninfectious
 - Necrosis
 - Neoplasia
 - Immune-mediated disease⁴

Other Causes

B-Lymphocyte Neoplasia

- Plasma cell (monoclonal gammopathy): multiple myeloma, plasmacytoma⁴
- Lymphocyte: lymphoma, lymphocytic leukaemia⁴

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

Haemodilution

- Oedematous 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}

Haemodilution

- Excess administration of intravenous fluid
- Oedematous disorders
 - Cirrhosis
 - Nephrotic syndrome
 - Excess ADH secretion (SIADH)^{4,5}

Artifacts

- Haemolysis or gross lipaemia 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 concentration⁸⁵

Bold Indicates a common cause



Total Protein (TP), Continued

Interpret With

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

Bold Indicates a common cause



Triglycerides (TGA)

Definition

Increased

Increased triglyceride production

- **By enterocytes:** Postprandial hyperlipaemia/hyperlipidaemia
- **By hepatocytes:** Equine hyperlipaemia/hyperlipidaemia

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 hyperlipidaemia of
- Miniature Schnauzers

Increased lipolysis

- **Metabolic syndrome (obesity + insulin resistance)**

- Pregnancy
- Stress
- Lactation in horses
- Pregnancy toxaemia
- Ketosis in camelids

Decreased

May not be clinically significant

- **Exocrine pancreatic insufficiency**
- **Protein-losing enteropathy**

- Portosystemic shunt
- Inflammatory bowel disease
- Hepatic insufficiency

- Hypoadrenocorticism
- Haematopoietic 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 faecal urate contamination

Interpret With

- Calcium
- Phosphorous
- BUN
- +/- Creatinine
- Electrolytes

Bold Indicates a common cause



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