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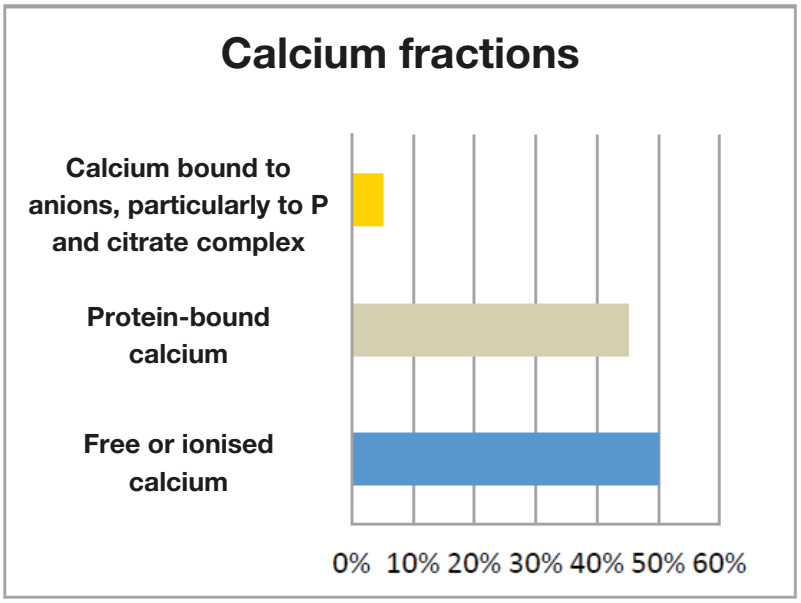
LABOKLIN aktuell

Function and significance of certain electrolytes and their informative value: calcium (Ca), phosphorus (P) and magnesium (Mg)

Calcium

98% of the calcium (Ca) is contained in the bones and ensures their stability. In addition, it is also important for blood coagulation and muscle contraction. It is ingested with the food: bones, bone meal and egg shells contain calcium. Calcium is excreted in urine, faeces and, to a small extent, in sweat. The calcium and phosphorus balance is regulated by absorption from the small intestine, incorporation in or demineralisation of the bones and renal excretion. Parathyroid hormone (PTH), which is produced in the parathyroid gland, plays a central role here.

Despite the influence of many exogenous factors, such as varying mineral supply, this regulatory system can maintain homeostasis for a long time. **Especially calcium is regulated very tightly. This means that a calcium level which is not within the normal range should always be verified, even if it deviates only slightly.**
Determination of calcium in the blood: Calcium consists of 3 fractions: 50% as free or ionised calcium, 45% protein-bound calcium, 5% calcium bound to anions, particularly to P and citrate complex.



Protein-bound calcium (routine diagnostics)

In serum, protein-bound calcium is often measured as it can be determined more easily than ionised calcium because it is less influenced by pre-analytics.

However, its concentration in serum is influenced by the total protein, especially albumin. A drop in albumin levels causes a decrease in serum calcium.

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Ionised calcium

This is a better indicator of the biologically active calcium because serum or plasma concentrations are directly controlled by PTH and calcitriol. It is therefore the more sensitive method for measuring disturbances of calcium balance.

However, pre-analysis is much more complex. Ionised calcium can only be determined if collected under exclusion of air (sampling instructions are available from Laboklin).

Examples of hypocalcaemia

secondary hyperparathyroidism	hypocalcaemia
vitamin D deficiency	vit D↓ = absorption of Ca ingested with food↓, Ca in serum↓ = PTH↑ (Ca absorption disorder, vit D deficiency, malabsorption)
chronic kidney disease (CKD)	glomerular filtration rate (GFR)↓, P retention, thus P in serum↑, formation of complexes with free Ca = hypocalcaemia, PTH↑ = loss of bone mass = osteomalacia/rickets
nephrotic syndrome	proteinuria leads to the loss of the vitamin D-binding protein, thus low 1.25(OH) concentration in serum/plasma, Note: Ca and PTH may be in the normal range!
liver cirrhosis	albumin synthesis↓ = total calcium↓, ionised Ca stays normal, at the same time vit D deficiency = Ca retention
idiopathic hypocalcaemia	blood Ca↓, PTH↑ = Ca absorption in intestine↑, Ca reabsorption in kidney↑, if problems last longer = Ca degradation from bones, constant decrease of Ca in the blood leads to neurological hyperexcitability
tumours with osteoblastic metastases	Mammary, prostate, bronchial and thyroid carcinoma cause remineralisation of the skeleton. Ca, P in serum↓, AP↑ = “hungry bones syndrome”
acute pancreatitis	In the inflamed, necrotic tissue of the organ, fatty acids (FA) are saponified together with Ca and Mg. serum Ca↓, Ca excretion↓
adrenocortical hyperplasia (administration of glucocorticoids)	cortisol inhibits intestinal Ca absorption, increases renal elimination, excess cortisol promotes osteoporosis

Examples of hypercalcaemia

primary hyperparathyroidism	parathyroid adenoma or hyperplasia, more rarely carcinoma, Ca absorption↑, because of 1.25(OH) vit D synthesis↑ induced by PTH
vitamin A overdose	Cats are much more susceptible than dogs!!! bone resorption = Ca↑, PTH and 1.25(OH) vit D in the normal range
vitamin D-induced hypercalcaemia	unregulated increased conversion of 25(OH) vit D into 1.25(OH) vit D in macrophages of the granulomas. In serum/plasma 1.25(OH) vit D increased, PTH↓
hyperthyroidism	rare form of hypercalcaemia, PTH and 1.25(OH) vit D within reference range
Addison’s disease	lack of glucocorticoids increases intestinal Ca absorption and decreases renal excretion
neoplasia with release of PTH-related protein (PTHrp)	PTH +/-, PTHrp↑ (anal sac carcinoma, lymphoma)

Inorganic phosphorus (P)

The terms phosphorus and phosphate are used interchangeably in laboratory medicine. For clinical purposes, this is irrelevant because the phosphate content is measured as inorganic phosphorus. 85% of the phosphate is located in the bones in combination with calcium and 14% exists intracellularly. There, it is present as an anion or as a component of lipids, proteins and nucleic acids. 1% of the P content is located in plasma or in other body fluids, yet in most pathological conditions, the concentration in serum correlates with the phosphate content of the body. Renal reabsorption is an important indicator of the phosphate level in the serum. If phosphate absorption is increased or GFR is decreased, renal reabsorption is decreased. Renal reabsorption is regulated by fibroblast growth factor (FGF) and parathyroid hormone.

Examples of hypophosphataemia

primary/tertiary hyperparathyroidism	hypercalcaemia, hypophosphataemia
intestinal malabsorption	absorption of vit D and Ca↓ = secondary HPTH
vit D deficiency rickets/osteomalacia	1.25(OH) vit D↓, AP↑
diabetic ketoacidosis	first P↑, then shift of P from extracellular space (ECS) to intracellular space (ICS) = hypophosphataemia
renal damage	tubule damage due to, for example, cytostatic agents up to Fanconi syndrome
refeeding syndrome	if insufficient supply of glucose, organism covers energy needs by burning fat (lipolysis), free FA↑, glucose, insulin↓, when deficiency ends, insulin secretion↑, increase K, Mg and P in ICS, decrease in blood

Hyperphosphataemia

Hyperphosphataemia lowers the concentration of 1.25(OH) vit D and increases the secretion of PTH and FGF. These hormones have a phosphaturic effect.

Examples of hyperphosphataemia (physiological in young animals)

decreased renal excretion (feline lower urinary tract disease (FLUTD), CKD, bladder rupture)	P↑ because of retention due to GFR↓: change through active reabsorption, hormone independent, but P concentration of the ECS is also controlled by hormones: PTH and FGF↑ = phosphaturia
acute metabolic acidosis	shift of P from ICS to ECS, e.g. respiratory acidosis, diabetic ketoacidosis, tissue hypoxia

Magnesium

1% of the magnesium (Mg) is found in the extracellular fluid.
The Mg fractions in serum and plasma are present as ionised magnesium, protein-bound magnesium, mostly to albumin, and complex-bound magnesium in form of salt. The skeletal system, the gastrointestinal tract and the kidneys regulate the magnesium concentration in the plasma. Magnesium depends on the albumin concentration and the pH value. If there is alkalosis, the Mg level is reduced by

increased protein binding. However, a reduction may also be seen with normal serum levels.
Magnesium has many different tasks:
It is essential for electrolyte balance, energy metabolism (activation of ATP), neural conduction, protein synthesis, bone matrix formation and mineralisation of the skeleton as well as for cell division.

Examples of hypomagnesaemia

gastrointestinal diseases, insufficient intake	example: diarrhoea, malabsorption and diet low in Mg
inflammation	increase of C-reactive protein (CRP) in plasma is inverse to Mg
cardiac insufficiency	disorders of electrolyte and water balance and of acid and base balance caused by diuresis and reduced intake of food
pre-eclampsia/eclampsia	cardinal symptoms: hypertension and proteinuria, possibly Ca antagonism on Ca channels or intracellular
diuresis	example: diuretics or osmotic diuresis in diabetes mellitus

Hypermagnesaemia

Except for severe CKD, hypermagnesaemia is unlikely to occur with adequate substitution.

Serum electrolytes and nutrition

When evaluating serum electrolytes, special attention should be paid to nutrition. Calcium is only ingested with the food through bones, bone meal and egg shells. Muscles and innards, vegetables and fruit are significantly lower in calcium.
Ca deficiency in the diet results in increased PTH secretion. This leads to mobilisation of Ca from the bones and increased absorption from the intestine. In the long term, bone demineralisation develops and even bone deformation, particularly of the long bones, as well as other changes in the skeletal system. A typical sign is the so-called “rubber jaw”.
Ca oversupply, on the other hand, which occurs much less frequently for nutritional reasons, leads to tissue calcification, stomach ulcers and impaired muscle contraction up to tetany. Severely disturbed bone metabolism, especially in the long bones, and increased urinary excretion of calcium are signs of Ca oversupply.
Phosphate is present in many food products (meat, vegetables and fat). This means that phosphorus intake from food is usually sufficient. Phosphate is stored in the skeletal system and regulated by the kidneys.
Food should have a Ca/P ratio of 2:1 or maybe 1.5:1. Inadequate supply, even inverse Ca/P ratios, are often seen in individual rations.
Magnesium is mainly found in green vegetables, nuts, cereals, seafood and meat. But also drinking water, especially hard water, contains magnesium.

Concerning serum levels and nutrition, it is particularly important to note that serum levels in the normal range do not necessarily reflect a balanced diet. Serum electrolyte levels in the reference range do not imply that the ration sufficiently meets the needs for these parameters. A balanced ration calculation is required instead.

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