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This is a very large subject - rather than a brief overview I will concentrate on a few smaller areas to illustrate different aspects of the subject.

Firstly, electrolytes are a growing area of interest - with the development of easy-to-use patientside monitors they can be measured more accurately and so form very useful critical care parameters. The following case illustrates the importance of assessing these parameters.

HYPONATRAEMIA IN A FLOCK OF HUMBOLDT PENGUINS (*SPHENISCUS HUMBOLDTI)*

A flock of approximately 30 Humboldt penguins (*Spheniscus humboldti*) had been maintained in a zoological collection for around six years.

An adult male was presented showing weakness and incoordination. The episode was acute in onset - the bird having been feeding and acting normally the previous day. His bodyweight was 4.88kg and he was in good condition. He was anaesthetised using isoflurane (IsoFlo (Abbott Animal Health, Queenborough, UK) and body radiographs taken revealing no abnormality.

A blood sample was taken. Electrolytes were assessed using a patientside device (iStat, Heska Corp). This revealed normal levels (ionised calcium, haematocrit, haemoglobin, potassium, pH, glucose, blood gases) other than a sodium of 113mmol/l (normal value 149-163mmol/l) The remainder of the sample (submitted to an external laboratory) revealed elevated tissue enzymes (creatinine kinase 3022 iu/l (normal 67-400iu/l) and aspartate transaminadase 1411 iu/l (17-436 iu/l)) but no other changes. Serum lead levels were negligible.

Initial therapy consisted of subcutaneous fluids (100ml normal saline (Aquapharm, Animalcare Ltd, York, UK), antibiosis (marbofloxacin (Marbocyl SA, Vetoquinol, Great Slade, UK) at 10mg/kg sid intramuscularly(im)), and sodium calcium edetate ((Animalcare Ltd., York, UK) 50mg/kg im sid).

The bird recovered from anaesthesia and signs had resolved within five hours. He was eating normally the next day.

A few days later he suffered a slight relapse in signs - plasma sodium level was 112mmol/l and potassium 6mmol/l. Again the bird responded rapidly to subcutaneous injections of saline.

He was then started on oral salt supplements and there were no further signs. A month later his plasma sodium was 132mmol/l, potassium 4.3mmol/l and chloride 103mmol/l. While the sodium levels were still subnormal it was clear that there was a marked improvement.

In the absence of other causes of hyponatraemia it was decided to investigate the rest of the flock

as it was presumed to be possibly linked to management.

Four birds were selected at random, a blood sample taken and electrolytes measured (Table 1).

Table 1. Electrolyte Measurements from "Normal" Flock Birds

Bird Number	Sodium (normal= 149-163mmol/l)	Potassium (normal= 3.0-4.8mmol/l)	Chloride (normal= 107-117mmol/l)
1	117	5.7	80
2	122	4.9	89
3	132	5.3	Not done
4	139	6.6	105

Bird 1 started showing weakness and inco-ordination within an hour of blood-taking. Again, the bird responded to subcutaneous saline

All birds were then placed onto oral salt supplements. The birds were re-tested three weeks later (Table 2)

Table 2. Electrolyte Measurements from "Normal Birds after start of salt supplementation

Bird Number	Sodium	Potassium	Chloride
1	145	5.3	111
2	144	4.1	106
3	129	3.6	90
4	145	5.4	111

Overall there had been a positive result to supplementation. Bird 3 had been off food for a few days before sampling. There were no other abnormalities detected and the bird responded well to subcutaneous saline.

With no further occurrences of clinical signs the birds were not re-sampled until routine haematology sampling in the late spring/ summer. Electrolytes were normal in all birds at this stage.

DISCUSSION

As described by Mazzaro et al 2003 it is unusual to see hyponatraemia in captive penguins due to reduced dietary intake of salt. In this collection the birds are kept in fresh water and fed thawed frozen seafish (sprats). Salt supplements had been stopped over eighteen months previously and there had been no obvious reduction of plasma sodium levels during routine blood sampling. It had been noted, though, that it was unusual to see salt excretion from the nasal glands after stopping supplementation.

However, in the weeks leading up to this episode, the fish had begun to be supplied in a different form. Normally it was supplied in small frozen blocks and these were defrosted overnight in a water bath (thus allowing equilibration of salt between fish and thawed water. Recently the supplier had begun to provide much larger blocks that would not completely thaw overnight if using the normal method.

Therefore the keepers switched to using running water. This, apparently, had the effect of washing out salt from the fish.

As it was difficult to change fish supplier and thus block size, it was decide to use daily salt supplements for the birds. As was shown this allowed plasma sodium levels to recover.

It therefore appears that the problems seen originated from a simple management change. It also appears that while penguins can maintain plasma sodium levels with just the sodium in their fish diet, they are vulnerable to any reduction in dietary sodium.

With reference to therapy it is important that sodium is not replaced too quickly or cerebral oedema may result. Tilley & Smith (1997). Hence the use of the subcutaneous route for therapy. This also illustrates the importance of assessing plasma electrolytes before starting intra-venous or intra-osseous fluids.

This author would therefore recommend that birds are either given salt supplements (they are much better adapted to deal with large amounts of dietary sodium) or, if relying on "natural" dietary sodium, plasma sodium levels should be monitored on a regular basis especially after any change in management.

It is also obvious that plasma electrolytes should be checked in any bird showing typical signs of hyponatraemia – ie weakness, lethargy or neurological signs.

REFERENCES

Mazzaro L, Dunn JL, Tuttle A, Goodman J, Wyatt J, Kadyszewski E. (2003). Plasma electrolyte concentrations for African penguins (*Spheniscus demersus*) and their relationship to habitat type and salt supplementation. Proc 5th Conference on Zoo and Wildlife Nutrition, Nutrition Advisory Group, Minneapolis p 111.

Tilley LP and Smith FWK.(1997). Sodium, hyponatremia. In: Tilley LP and Smith FWK (eds): The 5 Minute Veterinary Consult: Canine and Feline. Baltimore, USA: Williams and Wilkins pp 276-7.

Most texts concentrate on clinical pathology - the following is a brief overview of clinical pathology of raptors. The talk will concentrate on the specific differences between these two groups of birds

RAPTOR CLINICAL PATHOLOGY

Raptors are frequently presented in one of two states:

1. Extreme debility/ collapse

2. Apparently well, although the falconer may report a loss of performance or the bird being underweight. It is essential that these birds are taken extremely seriously as disease in falconry birds is often detected at a very early stage owing to the strong bond between bird and handler and the accuracy with which falconers assess weight, body condition, appetite and performance. Failure to act on seemingly inapparent or nebulous signs will often result in the bird returning in the first-mentioned category!

In both states there will generally be a wide range of differential diagnoses necessitating a heavy reliance on sample taking and clinical pathology. It should be remembered, however, that this subject is very much in its infancy and "normal" values often unknown for a particular species. The clinician should therefore accept the limitations of each test and interpretation should always be with regard to the patient and its condition. It should also be borne in mind that "normal" values vary from lab-to-lab and the use of a laboratory experienced in testing raptor samples cannot be stressed too highly. It is important to bear in mind too the differences between each species and between individual birds at different life-stages, reproductive state and stage of training. It is also frequently necessary to "extrapolate" between species where normals may not be available or may be based on a small number of individuals. Clinical pathology should therefore always be regarded as a "piece in the jigsaw" and should always be interpreted in the light of findings on examination, history, radiography, etc.

Haematology/ Biochemistry. Blood collection sites are essentially the same as for other birds. The right jugular vein is the author's preferred site although restraint for the basilic vein may sometimes be easier in eagles and large falcons. The caudal tibial vein is rarely used as working this close to the feet may be dangerous! Blood should be collected into lithium heparin tubes for both haematology and biochemistry. A smear using fresh blood (no anticoagulant) should also be made as both heparin and EDTA have been associated with changes in cell morphology and count.

Haematology. Red blood cell parameters (Packed Cell Volume (PCV), Haemoglobin(Hb), Total count (TRBC), Mean Cell Haemoglobin (MCH), Mean Cell Volume (MCV), and Mean Cell Haemoglobin Concentration (MCHC)) should be checked. As a general rule, a PCV< 35% is indicative of anaemia while >45% shows haemoconcentration. However, allowances should be made for age (young raptors will have lower PCV, Hb, MCHC, TRBC).

A total white blood cell count and differential count should also be performed. In most species the heterophil is the most common cell although in owls it is often the lymphocyte. Table 1 describes common abnormalities in white cell counts:

Table 1.

Differential	**Total White Cell Count (TWBC)**	**Heterophils**	**Lymphocytes**	Monocytes
Acute Infection	+/-/N	+/N	N/-	N/+
Chronic Infection, eg. aspergillosis, TB	++	+	N/-	+
Viral Infection	N/-	-	+	N
Stress	+	N/+	N/-	N

It should be remembered that the morphology of the cells is usually more important than the absolute count. In many cases of infection the TWBC may be normal or even lowered where there is sequestration of heterophils. The presence of toxic heterophils or monocytes or band heterophils is indicative of an inflammatory, usually infectious, process.

Blood parasites may also be detected on blood smear. These infections are not uncommon in young

birds and are an important differential diagnosis in cases of anaemia.

For these reasons it is advised that blood samples are submitted to a laboratory with an experienced avian haematologist/ cytologist to read the smear.

Biochemistry. The following parameters should be checked:

Table 2. Blood Biochemistry Parameters in Raptors

Parameter	High	Low	Comments
Creatinine Kinase (CK)	Muscle/ tissue damage	N/A	May be higher in trained birds
Aspartate Aminotransferase(AST)	Liver damage, muscle damage, renal disease	N/A	If raised with normal CK value then should be suspicious of liver damage
Lactate Dehydrogenase (LDH)	Muscle or liver damage, haemolysis	N/A	Non-specific so of little diagnostic value although it has been used in the assessment of fitness in raptor rehabilitation. Very high levels may be seen in organophosphate poisoning
Bile Acids	Liver dysfunction	?	Of potential value in assessment of liver function. However, not always easy to interpret and dynamic testing needs further evaluation
Cholesterol	Fatty liver, starvation, high fat diet	Fatty liver/ kidney	Again hard to interpret. Raptors have higher normal levels than psittacids and post-prandial effects should not be ignored
Calcium	Oversupplementation of Vitamin D	Deficiency of calcium/ vitamin-D	Hypocalcaemia is an important cause of neurological signs in growing or laying birds. IONISED calcium should always be measured so effects of protein levels on total calcium measurements can be negated
Phosphorus	Renal disease, haemolysis		Only raised in advanced disease. Beware effects of haemolysis on these levels
Sodium/ potassium			These are potentially of great value in assessing electrolyte balance in fluid therapy. However, problems occur if tests are not immediate or plasma is not separated immediately as sodium levels tend to fall while potassium rises with haemolysis. For this reason these levels may be useful when submitting samples to outside labs in assessing degree of sample damage and therefore effects on other parameters, eg. phosphorus
Glucose	Diabetes mellitus	Malnutrition, underweight	Of limited use except in when assessing the “fitting” bird. Hypoglycaemia is common in underweight birds, and should always

Parameter	High	Low	Comments
			be suspected when a bird starts fitting (or becomes very weak) during or immediately after exercise
Uric Acid	Renal disease, dehydration, catabolic state, post-prandial	Liver dysfunction	This is the major parameter in assessment of renal disease. Sadly it is not very sensitive and difficult to interpret in raptors being fed on their typical high protein diet. Similarly the catabolic state induced in training/ manning raptors may also induce a raised uric acid level. Levels of uric acid >1000 mmol/l in samples taken 24 hours post-feeding are indicative of renal disease
Total Protein	Dehydration, inflammation (raised globulins), lipaemia	Malnutrition, parasitism, acute haemorrhage	Always check albumin/ globulin
Albumin	Dehydration	Malnutrition, liver disease, loss via kidney/ gut	
Globulin	Inflammatory disorders, egg-laying		Accurate assessment of albumin/ globulin should be done using serum protein electrophoresis. Not only does this give more accurate results but the identification of individual globulin peaks provides important information regarding the likelihood of acute vs chronic inflammation, egg-laying activity, etc

Mutes. This is the correct term for “droppings” in these species. As in other avian species the mute will consist of both urine and faeces. Unlike in parrots the mute is not well formed, is generally very liquid and is usually ejected a considerable distance (“slicing”).

Gross examination of the mute provides important information:

- Excess urine. Renal disease, etc
- Green-stained urine. Liver disease (jaundice), lead poisoning.
- Blood. May originate from cloaca (generally present as clots) or from higher up the gut or urinary tract (more diffuse spread or may be melaena present). May be seen in coumarol toxicity
- Faeces. Generally dark and partially formed. Very liquid or rank-smelling faeces may indicate enteritis. Dark green scanty faeces indicate starvation.
- Urinalysis. Of little value as mixing with faeces will affect parameters. However, microscopy for casts may be useful in renal disease.
- Parasitology. Endoparasitism is common and faecal floatation should be performed in all cases of underweight birds and those with evidence of gut or respiratory disease. There are various species of nematode and coccidiosis is common in young falcons, especially merlins. Care should always be taken to distinguish „passengers“ -

parasites of the prey, not the predator!

1. Gram Stains. Gram staining of faeces is popular in psittacine species. However, it is much more difficult and of much lesser value in raptors where the gut flora is predominantly Gram-negative rods. Culture and sensitivity is much more appropriate in gut disease.
2. Cytology. This is an extremely valuable tool in raptor medicine owing to its relative ease of obtaining sample, sensitivity and lack of expense. It can be performed on any aspirated fluid, fine-needle aspirates of masses, impression smears of skin lesions or of biopsied/ necropsied organs and smears may be made of swabs inserted into orifices or cavities. The author will generally use Gram and Diff Quik (Dade) with a modified Ziehl-Nielsen stain where mycobacteriosis is suspected.