Nutritional Secondary Hyperparathyroidism in Reptiles

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Learning Objective: Upon completion of this article readers will be able to describe the pathophysiology of nutritional secondary hyperparathyroidism in reptiles. Readers will also be able to identify clinical signs of nutritional secondary hyperparathyroidism, describe and perform diagnostic modalities, and explain prevention and management of nutritional secondary hyperparathyroidism in reptiles.

Nutritional secondary hyperparathyroidism (NSHP) is the most common nutritional disorder of captive reptiles, particularly herbivorous and insectivorous lizards and chelonians. NSHP is commonly referred to as metabolic bone disease. However, metabolic bone disease is an encompassing term referring to a variety of conditions that affect bone form and function, of which NSHP is the most common. A variety of husbandry and nutritional factors can contribute to a reptile developing NSHP, but the most common causes are insufficient dietary calcium, insufficient dietary vitamin D3, inappropriate calcium/phosphorus (Ca:P) ratio, insufficient ultraviolet-B (UV-B) lighting, and suboptimal temperatures. Reptiles that feed on whole prey, such as snakes, are less susceptible to NSHP, because whole prey contains...
adequate amounts of calcium and vitamin D3. NSHP causes a wide variety of clinical signs and will vary in severity. Veterinary technicians play a vital role in performing diagnostic tests and providing nursing care to hospitalized reptiles, as well as educating reptile owners about proper husbandry and dietary requirements to prevent and manage NSHP.

**Calcium/Phosphorus Homeostasis**

Reptiles rely on various nutritional and environmental factors to maintain calcium homeostasis, including vitamin D, ultraviolet light, heat, and dietary calcium and phosphorus.

**Vitamin D, Ultraviolet light, & Heat**

Vitamin D is a hormone necessary for intestinal absorption of dietary calcium and phosphorus. Unlike mammals, lizards and chelonia are unable to obtain vitamin D solely from dietary sources. Many lizards and chelonia are heliothermic, meaning they display basking behavior to attain heat and ultraviolet (UV) radiation from natural sunlight. Heliothermic reptiles rely on basking in natural sunlight to synthesize their own vitamin D3 through elaborate processes involving UV-B light and heat. Reptiles kept in captivity rely on artificial UV-B lighting and supplementary heat and dietary vitamin D to be provided for them. It is important to note that artificial UV-B lighting is only a replacement for the sunlight the reptile would otherwise be exposed to in their natural habitat.

The process of vitamin D synthesis and calcium absorption is as follows (Figure 1):

- **UV-B light in the spectrum of 290-315nm changes the structure of provitamin precursors (7-dihydrocholesterol) in the skin of reptiles to form previtamin D3.**
- **Heat is required for previtamin D3 to be converted to an inactive form of Vitamin D3 called cholecalciferol.**
- **Cholecalciferol binds to plasma proteins to be transported to the liver for conversion into calcidiol.**
- **Calcidiol is then transported to the kidneys to be converted to calcitriol (1,25 dihydroxycholecalciferol), the active form of vitamin D3.**
- **Calcitriol promotes absorption of dietary calcium from the intestines.**

Dietary vitamin D3 supplements contain the inactive form of vitamin D3, cholecalciferol. Dietary vitamin D3 supplements need to be synthesized in the liver and kidneys to become the active form of vitamin D3, calcitriol. However, more research on how various species synthesize supplemental oral vitamin D3 is necessary.

**Calcium**

Calcium is the most abundant mineral in the body. Like calcium, phosphorus is involved with the formation of bones and teeth, as well as muscle contractions, nerve transmissions, and metabolic processes. Phosphorus combines with calcium to form calcium phosphate, which is the substance that forms teeth and bones. The use of phosphorus throughout the body is connected to calcium, vitamin D, and parathyroid hormone. There is a delicate balance that needs to occur between calcium and phosphorus for proper function. A calcium/phosphorus (Ca:P) ratio of 1:1 to 2:1 is ideal. Too much phosphorus in the diet causes a decline in calcium in relation to phosphorus in the bloodstream, or an inverse Ca:P ratio. Phosphorus affects the bioavailability of calcium, because it binds with calcium in the bloodstream to create an insoluble calcium phosphate that is excreted from the body in urine and feces.

**Pathophysiology & Clinical Signs**

The term nutritional secondary hyperparathyroidism refers to excessive activity of the parathyroid gland as a result of hypocalcemia secondary to inadequate nutrition or inappropriate husbandry. A calcium deficiency can be caused by insufficient dietary calcium, a decrease in the bioavailability of calcium, vitamin D3 insufficiency, inadequate exposure to UV-B light, inadequate environmental temperature, an imbalance of the Ca:P ratio, or an increase in calcium demand during rapid growth or egg production. As previously discussed, numerous organs and mechanisms must function properly to maintain calcium homeostasis. Pathology of the kidneys, liver, gastrointestinal tract, parathyroid gland, or ultimobranchial body may also result in an imbalance of calcium homeostasis resulting in NSHP.
Recall that low levels of ionized calcium in the blood stimulate the parathyroid gland to release parathyroid hormone. The parathyroid hormone causes calcium to be released from bones into the blood stream to normalize calcium levels. Simultaneously, renal tubular reabsorption of calcium is increased, phosphorus excretion is increased, and active vitamin D3 is released from the kidneys to stimulate calcium absorption in the intestines.  

If the parathyroid hormone is unable to raise calcium levels in the blood to acceptable levels, the parathyroid gland will continue to produce parathyroid hormone, causing further calcium to be released from bone, eventually depleting the skeleton of calcium and phosphorus. Without calcium and phosphorus, osteomalacia will develop. Osteomalacia is a softening of bones due to decreased mineralization. Clinical signs of osteomalacia commonly noticed by owners include a swollen, pliable, or misshapen jaw (Figure 3), anorexia, lethargy, stunted growth, and difficulty or inability to ambulate. Pathological fractures of long bones and the spine can occur. Fibrous osteodystrophy is the body’s response to osteomalacia. Fibrous osteodystrophy is a process of laying down fibrous connective tissue across the weakened areas to attempt to reinforce the skeleton. Areas affected by fibrous osteodystrophy may appear swollen and palpate as hard lumps.

Juvenile lizards and chelonians that are rapidly growing and reproductively active female reptiles are more prone to developing NSHP because of a higher demand for calcium. Juvenile lizards and chelonians that are rapidly growing and reproductively active female reptiles are more prone to developing NSHP because of a higher demand for calcium.

**Patient History**

Obtaining a thorough patient history is essential to identify incorrect husbandry and dietary practices that may lead to NSHP.

**Physical Examination**

Performing a thorough physical examination may reveal clinical signs that influence the veterinarian to strongly suspect NSHP. Early clinical signs of NSHP can be subtle and may only recognized by an experienced owner or practitioner. Clinical signs will depend on the severity of disease, as well as the species and age of the reptile.
Blood Analysis

A complete blood count and chemistry panel should be performed to screen for underlying disease and pathology of body systems that may affect calcium homeoostasis. Plasma calcium and phosphorus levels are useful for evaluating the Ca:P ratio. A low plasma calcium level in conjunction with an elevated phosphorus level is an inverse Ca:P ratio and indicative of NSHP. Normal limits will vary by species and physiologic condition, but most reptiles have a plasma calcium concentration between 8 and 11 mg/dL and plasma phosphorus concentration between 1 and 5 mg/dL. However, a total blood calcium level within the normal range for that species does not rule out NSHP. The parathyroid hormone has stimulated mechanisms to keep calcium levels within normal range. Hypocalcemia will not be appreciated on a chemistry panel until end-stage NSHP. Instead, an ionized calcium level may be beneficial. Recall that ionized calcium is not bound by proteins and is calcium in its most active form. An ionized calcium value will provide a more accurate assessment of the reptile’s calcium status.

Radiographs

Radiographic imaging is the most valuable diagnostic tool for NSHP. Whole body radiographs will enable the veterinarian to assess bone density, skeletal deformities, and will reveal pathologic fractures. Most reptile species can be radiographed without sedation with the use of tape and foam positioners. Many lizards, iguanas in particular, are easily positioned by placing an eye lubricant in the eyes, covering the closed eyelids with cotton balls, and wrapping the head with bandage material. The pressure over the eyeballs causes a vagal reflex, decreasing their heart rate and blood pressure and inducing a catatonic state. Chelonians are comfortably positioned by placing a radiolucent apparatus that is slightly smaller than the plastron under the chelonian, preventing the feet from touching the table.

Standard radiograph projections for a lizard include a dorsoventral view and a lateral view. Standard radiograph projections for a chelonian include a dorsoventral view, lateral view, and a rostrocaudal (craniocaudal) view. Reptiles can be positioned in sternal recumbency in a natural position for all radiograph views. The x-ray beam and cassette can be repositioned to achieve the lateral and rostrocaudal views. Tape, foam blocks, boxes, bags, and other radiolucent items can be used to assist with positioning.

Treatment

Treatment of NSHP will vary depending of the severity of disease. The focus of treatment includes stabilizing the patient, treating secondary conditions, reversing bone loss, promoting new bone production, and correcting underlying nutritional and husbandry causes. Pathologic fractures and life-threatening hypocalcemia conditions should be addressed immediately upon presentation. Reptiles experiencing acute hypocalcemic crisis characterized by muscle fasciculations or tetany can be treated with injectable calcium gluconate intramuscularly or intracelomically until cessation of tetany. The patient should then be switched to an oral calcium gluconate for long-term therapy. Calcium injections are painful and can permanently damage the kidneys, so they should not be utilized long-term. Vitamin D and calcitonin can also be used to restore calcium balance. Underlying diseases and secondary conditions, such as dehydration or infection, should be treated accordingly. Most importantly, correction of the patient’s nutrition and husbandry must occur. Proper nutrition and husbandry will be discussed further in the next section. Prognosis of NSHP will vary from excellent to grave depending on the severity of disease. If corrections to husbandry and nutrition are made early, minor symptoms will subside or reverse completely. Skeletal deformities cannot be reversed, but with prompt treatment, the reptile
may return to a normal lifestyle. Severe, chronic NSHP characterized by fibrous osteodystrophy, fractures, or paralysis has a grave prognosis.\textsuperscript{3,8}

**Prevention**

Proper nutrition and husbandry are essential for the prevention of NSHP. Veterinary technicians play a vital role in educating reptile owners about proper husbandry and nutrition, as well as early detection.

**Ultraviolet light**

A source of UV-B lighting in the spectrum 290-315 nm should be provided to all diurnal lizards and chelonians. Ultraviolet light can be provided to captive reptiles in two ways: unfiltered, direct sunlight or store-bought UV-B light bulb. Owners should be encouraged to provide natural sunlight for their pet reptile whenever possible. For many owners, it is not possible to have their reptile outside for several hours a day. When natural sunlight is not possible, light bulbs that emit artificial UV-B lighting are available for purchase online and in most pet stores.\textsuperscript{2} Common bulbs purchased are incandescent bulbs and florescent bulbs. Incandescent bulbs provide heat and UV light. Florescent bulbs are generally tubular and provide a wider spectrum of UV light than the incandescent bulbs, but emit very little heat.\textsuperscript{3}

Failing to provide UV-B lighting and not using artificial lighting correctly are common mistakes made by owners that will cause NSHP. It is important to know that not all light bulbs available for purchase for reptiles omit UV-B radiation and care should be taken to read product packaging. It is often assumed that placing a reptile’s enclosure near a sunny window will allow the reptile natural UV-B light from the sun. However, glass and plastic filter out UV radiation. Artificial lighting needs to be placed in a location where the reptile can benefit from it. Enclosures constructed from plastic or glass will also filter UV radiation, making it necessary to place the artificial lighting inside the enclosure for the reptile to receive full benefits of the UV-B radiation. Manufacturers of UV lighting will provide information on the range of UV-B radiation emitted from the bulb and the distance the radiation is emitted. Most manufacturers recommend placing artificial lighting 12-18 inches from the reptile. The reptile will not receive the full benefits of the UV-B radiation if the artificial lighting is placed a further distance from the reptile than recommended. UV radiation from all artificial light bulbs decreases over time and should be replaced according to the manufacturer’s recommendations, usually every six months. Lastly, the artificial light needs to be provided for the length of time that corresponds to the daylength and time of year in the natural habitat for that species. 14 hours of light per day in the summer and 12 hours of light per day in the winter corresponds to the average day length at the equator and is the photoperiod recommended for most reptiles.\textsuperscript{3}

**Temperature**

As previously discussed, heat is required for the conversion of previtamin D\textsubscript{3} to cholecalciferol.\textsuperscript{1} Reptiles are ectothermic, meaning they rely on outside sources of heat to control their body temperature. A thermal gradient that corresponds to natural habitat temperatures should be provided to every captive reptile. Fluctuations in temperature according to the time of day and season should also be considered. A thermal gradient allows the reptile to seek warmer temperatures for basking or choose cooler temperatures if desired, replicating normal behavior of reptiles in their natural habitat.\textsuperscript{5} Every reptilian species will have an individual preferred temperature range. However, a general guideline for most diurnal species is a temperature range between 80\textdegree{}F to 95\textdegree{}F during the daytime with a basking area slightly higher than the upper end of the prevailing temperature range. Nighttime temperatures should never fall below 70\textdegree{}F for most reptile species.\textsuperscript{3} Ideally, the basking site and the UV-B lighting should be in the same location. Placing the UV lighting and the primary heat source at different sites forces the reptile to choose between basking in warmth or under UV radiation, and most reptiles will choose heat over UV radiation.\textsuperscript{1}

A variety of heat sources are available for purchase. Hot rocks are popular, but should be used with extreme caution. Hot rocks provide a focal heat that generally becomes hotter over time, increasing the risk of burns. Recommended heat sources include adjustable heating pads placed under the enclosure, incandescent bulbs, ceramic heaters, and heat tape.\textsuperscript{5} Enclosure temperature should be monitored regularly using a temperature gun, rather than a hanging thermometer. Temperature guns allow the temperature to be measured throughout the entire enclosure. Hanging thermometers measure the temperature in the exact spot it is located only, providing no insight about the temperature variance throughout the entire enclosure.

**Dietary Calcium**

Supplementary dietary calcium should be provided to all captive reptiles. A wide range of supplements containing additional varied vitamins and minerals are available for purchase.\textsuperscript{1} Dietary requirements for each reptile patient can be challenging to meet and necessitate research according to species. Most diurnal species will benefit from a supplement that does not contain phosphorus, but provides calcium only or calcium with vitamin D\textsubscript{3}.\textsuperscript{5} There are a number of supplements on the market that claim to contain vitamin D. Attention to the ingredient list is necessary to ensure the supplement contains vitamin D\textsubscript{3} (cholecalciferol), not vitamin D\textsubscript{2}. Vitamin D\textsubscript{2} is not usable by reptiles.\textsuperscript{3}

Herbivorous reptiles, such as green iguanas, uromastyx lizards, chuckwallas, and prehensile-tailed skinks tend to be the most challenging reptiles to feed. Herbivorous reptiles obtain calcium from leafy green vegetables, such as kale, okra, dandelion greens, bok choy, collard greens, mustard greens, turnip greens...
Figure 4: Bearded dragon displaying neurological signs, characteristic of hypocalcemia.

Figure 5: Chelonians are comfortably positioned for radiographs by placing a radiolucent apparatus that is slightly smaller than the plastron under the chelonian, preventing the feet from touching the table.

Figure 6: Lateral and dorsoventral projections of a blue-tongued skink with severely decreased opacity of the skeleton. Note the concavity of the ventral spine and the appearance the teeth are floating due to loss of mineralization of the perialveolar bone in the lateral projection. Also note the spinal deformities, kinked tail, and decreased aeration of the lung lobes secondary to a weakened musculature in the dorsoventral projection.
and watercress. Oxalate-rich vegetables, such as spinach and carrots, should be fed sparingly to avoid oxalates binding to calcium, preventing calcium absorption in the intestines. The rest of the diet should be composed of other nutrient-rich vegetables and less than 10% fruit.

Crickets and worms are the most common food item provided to insectivorous reptiles, such as chameleons and bearded dragons. Crickets and worms are high in fat and protein and deficient in calcium. Gut-loading crickets, or feeding a nutritious diet to the crickets for 48 hours, is recommended prior to feeding them to a captive reptile. The diet fed to the crickets will remain in the gastrointestinal tract of the cricket and be ingested by the reptile. Dusting the external surface of insects with a calcium supplement powder is also recommended. Owners should be encouraged to also provide calcium-rich leafy green vegetables and a wide variety of other insects.

Carnivores, such as snakes, that are fed a whole prey diet will consume an adequate amount of calcium and vitamin D3. However, carnivores fed only neonate prey, such as pinky mice, are susceptible to developing NSHP. Neonate prey have skeletons that are not sufficiently calcified, decreasing their calcium content and causing an inverse Ca:P ratio. Muscle and organ meat also contain an inverse Ca:P ratio. Frozen fish, mice, and rats are recommended food items for carnivorous reptiles.

**Conclusion**

Nutritional secondary hyperparathyroidism is a complex metabolic disorder common in captive reptiles. A considerable number of body systems and physiologic functions are involved in maintaining calcium homeostasis in reptiles. Veterinary technicians can advocate for captive reptiles by striving to understand the complicated nature of NSHP, recognizing early clinical signs of disease, and providing owners with information about proper husbandry and nutrition.

Figure 7: The x-ray beam and cassette can be repositioned for ease of obtaining lateral radiographic views of lizards. Note the use of foam blocks to assist with positioning of the patient.

Figure 8: Dorsoventral projection of gravid female veiled chameleon. Note the multiple oval shaped soft tissue structures in the coelomic cavity, the overall decreased bone density, and the thin, indistinct bone cortices, characteristic of nutritional secondary hyperparathyroidism.
**BASKING**
To lie in or be exposed to warmth

**HELIOTHERMIC**
To gain heat from the sun

**CHOLECALCIFEROL**
Inactive form of vitamin D3

**CALCITRIOL**
Active form of vitamin D3

**CALCIUM**
Most abundant mineral in the body; important for formation and integrity of bones and teeth, nerve transmission, blood clotting, and muscle contractions

**VITAMIN D**
Hormone necessary for intestinal absorption of dietary calcium and phosphorus

**PARATHYROID HORMONE**
Hormone responsible for maintaining blood calcium levels

**IONIZED CALCIUM**
Most active form of calcium; calcium not bound to proteins in the bloodstream

**ULTIMOBRANCHIAL GLAND**
A small organ located in the neck region of reptiles that is responsible for producing calcitonin

**OSTEOMALACIA**
Softening of the bones

**FIBROUS OSTEODYSTROPHY**
The body’s response to osteomalacia; the laying down of fibrous connective tissue across weakened areas to reinforce the skeleton

**PHOSPHORUS**
2nd most abundant mineral in the body; important for formation and integrity of bones and teeth, muscle contractions, nerve transmissions, and metabolic processes

**HYPOCALCEMIA**
Calcium deficiency in the bloodstream

**TETANY**
Muscular spasms caused by hypocalcemia or malfunction of the parathyroid gland

**ATAXIA**
Complete loss of control of bodily movements

**DIURNAL**
Most active during the daytime

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**References**
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**Article Questions**

1. The active form of Vitamin D3 is called
   a. Cholecalciferol  
   b. Calcediol  
   c. Calcitriol  
   d. 7-dihydrocholesterol

2. The primary hormone responsible for maintaining blood calcium concentration is
   a. Parathyroid hormone  
   b. Thyroid stimulating hormone  
   c. Thyroxine  
   d. Cortisol

3. The ideal Ca:P ratio for reptiles is
   a. 1:3  
   b. 3:1  
   c. 2:1  
   d. 1:2

4. What spectrum of UV-B lighting should be provided to diurnal lizards?
   a. 215-250 nm  
   b. 280-315 nm  
   c. 315-350 nm  
   d. 380-415 nm

5. What is the coolest temperature recommended for a diurnal reptile’s enclosure during the night time?
   a. 70°F  
   b. 80°F  
   c. 90°F  
   d. 100°F

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