Metabolic Bone Disease In Lizards: Prevalence And Potential For Monitoring Bone Health

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A consensus that metabolic bone disease (MBD) is the nutritional pathology (NP) most likely to occur in captive lizards was apparent in a study at the Ontario Veterinary College Teaching Hospital (OVCTH) and in two surveys on NP in accredited zoos in Canada and the United States. The prevalence, pathogensis and diagnosis of MBD relative to the OVCTH and zoological research is discussed. A proposed study to investigate the multifactorial nature of MBD in lizards in zoo populations and veterinary clinics is presented. This study includes researching a qualitative ultrasound (QUS) method to diagnose MBD in lizards and correlate that methodology to dietary and environmental factors in MBD.

Key words: nutritional pathology; osteopathy; reptiles

INTRODUCTION

A retrospective study at the Ontario Veterinary College Teaching Hospital (OVCTH) from 1992 to 1996 (inclusive) indicates 84.4% of lizard clients are diagnosed with metabolic bone disease (MBD) [McWilliams, 1998]. Metabolic bone disease is an osteopathy that results in an impairment of the remodelling, growth and health of bone. The pervasiveness of MBD in captive lizards also appeared in the results of two surveys on nutritional pathology (NP) in accredited zoos (68.8% response rate) in Canada and the United States (US) [McWilliams, 2000].

Metabolic bone disease in reptiles has been studied for at least four decades [Truit, 1962; Reichenbach-Klinke and Elkan, 1965]. Ultraviolet (UV) light, for example, is thought to be essential to reptilian health, yet many captive reptiles develop MBD despite exposure to UV light [Dickinson and Fa, 1997]. The apparent consensus that MBD still is a problem in these species may indicate that some crucial aspects of developing and maintaining skeletal health in captive reptilian species, especially lizards, are unknown [McWilliams, 1998; McWilliams, 2000; Oftedal et al., 1997].

The maintenance of calcium (Ca) homeostasis in vertebrates is a complex process involving the integument, skeletal, gastrointestinal (GI) tract, circulatory, endocrine and renal systems. This complexity may increase for ectotherms such as lizard species who use behavioral thermoregulation to manipulate environmental factors [Tosini et al., 1995; Auffenberg, 1995]. Relative to an animal's natural environment, captive lizards may have limited behavioral choices of temperature ranges, humidity levels, light spectrum and diets.

A serious difficulty in promoting bone health and treating MBD in captive lizards is monitoring the bone health of these animals. Clinical symptoms often do not appear until the prognosis for recovery is poor [McWilliams, 1998]. When clinical symptoms appear, x-rays often reveal a 30% to 80% loss of bone, multiple fractures and there is concurrent emaciation with other organ failures (Table 1) [McWilliams, 1998; Frye, 1991; Kowalchuk and Dalinka, 1998; LePage et al., 2001]. Preventive measures such as diet and environmental changes could be made early in the pathogenesis of MBD if a reliable, inexpensive method for monitoring the bone health of these animals existed. This paper will briefly present some of the OVCTH and zoo survey research and proposed research on a quantitative ultrasound (QUS) method to monitor bone health in captive reptiles.

MBD and Lizard Clients at OVCTH

Nutritional MBD in lizards develops from a dietary deficiency of Ca or vitamin D_3, an imbalanced dietary Ca to phosphorus ratio (Ca:P) and, a lack of exposure to UV light for the synthesis of vitamin D_3 (Table 1) [Bernard and Ullrey, 1995]. Metabolic bone disease includes nutritional secondary hyperparathyroidism (NSH or fibrous osteodystrophy), osteoporosis, osteomalacia and rickets [Frye, 1991]. Pathogenesis in NSH starts when a long-term dietary Ca deficit causes a hypocalcemic condition that requires bone resorption to maintain serum levels of Ca. Symptoms include osteopenia, bone marrow fibrosis and, soft tissue calcification [Frye, 1991; Darmady and MacIver, 1980]. Osteoporotic pathogenesis in lizards develops secondary to an inadequate diet, lack of UV light, or from insufficient physical activity. Morbidity includes a normal bone to matrix ratio, but both are decreased and the result is reduced compressive strength and fracture [Frye, 1991]. Morbidity in osteomalacia is similar to rickets, but it is a lack of bone calcification in adult lizards. In reptiles, osteomalacia and rickets can develop from insufficient vitamin D_3 or insufficient exposure to UVB light [Bernard and Ullrey, 1995]. Pathogenesis includes "rubbery" bones (reduced ratio of mineral to matrix); compensatory spongy, thickened bone cortices; spontaneous fractures; rachitic rosary of the rib heads; and, a waddling gait from proximal muscle weakening [Frye, 1991]. Rickets develop in juvenile reptiles and, in addition to adult symptoms of osteomalacia, it includes stunted growth, skull flattening and, a soft, blunted mandible (Table 2) [Frye, 1991].

Metabolic bone disease is also called classic MBD and hypocalcemic MBD [Korber, 1997]. Classic MBD primarily affects the skeletal system and is more prevalent in juveniles. Hypocalcemic MBD primarily affects adults. Symptoms of classic MBD include multiple fractures, partial or complete lack of truncal lifting, a pliable mandible or maxillae and, the rounded infantile skull shape of hatchlings. Symptoms of hypocalcemic MBD include muscle tremors, convulsions, a partial or full body paralysis and it may progress to heart failure [Frye, 1997].

Metabolic bone disease can be induced (iatrogenic MBD) and can include hypercalcemia, hypervitaminosis A, hypervitaminosis D and hypovitaminosis D [Frye, 1991; Frye, 1997]. Hypercalcemia is caused by excessive supplementation of vitamins A and D. Symptoms are fatigue, weakness, anorexia and soft-tissue calcification. The pathogenesis of hypervitaminosis A, from excessive supplementation of vitamin A, includes hypercalcemia, bone swelling (hyperostosis), anorexia and skin sloughing. Hypervitaminosis D is caused by excessive supplementation of vitamin D. Pathogenesis includes bone resorption, hypercalciuria, osteoporosis and soft tissue mineralization. Hypovitaminosis D in reptiles can be caused by a lack of UVB radiation, insufficient dietary vitamin D, low environmental temperatures or, an inappropriate dietary form of vitamin D [Bernard and Ullrey, 1995]. For reptiles, UVB (290 to 320 nm) is essential for cutaneous synthesis of vitamin D_3 [Holick, 1995; Oftedal and Allen, 1996; Gehrmann, 1997]. Calcium absorption can be impaired by phytates, oxalates and hypoproteinemia. Phytates (e.g., in soy) can block absorption of Ca in the GI tract. Oxalates are a salt of oxalic acid in spinach, rhubarb, cabbage, peas, potatoes and beet [Brice, 1995; Donoghue, 1995]. A diet high in oxalates can inhibit Ca absorption by binding to Ca and preventing intestinal absorption. Hypoproteinemia, insufficient protein in the blood, interferes with Ca absorption because Ca is protein bound.

MBD Survey Results: Accredited Zoos in Canada and the United States

Accredited zoological institutions in Canada and the US participated in two surveys to determine “need-based” research based on the prevalence of an NP in zoo animals. The first survey (S1) was sent to zoos and aquariums; the second survey (S2) was sent only to zoological institutes [McWilliams, 2000].

For S1, the director of each institution distributed the survey to those who functioned as the behaviorist, the general curator, the senior (head) keeper, the senior (head) nutritionist and the senior (head) veterinarian. There were two questions in S1. Question one asked for three or more captive species, in the respondent’s experience, that develop nutritional pathology. Question two asked for three or more nutritional problems likely to develop in the species listed in the response to question one. Some results from S1 are shown in Table 3.

Survey 2 was also sent to accredited zoological institutions in Canada and the US (excluding aquariums). All institutions received a copy of the complete analysis of the data from S1. As in S1, the director of each institution provided a copy of the survey form to zoo professionals. Survey 2 had two questions based on the results of S1. Question one asked if the respondent agreed that MBD, hemosiderosis and obesity, in the order listed, were the most likely NP to occur in zoo animals (as reported in S1). Question two asked respondents if they agreed if species, as listed, were most likely to develop those NP. For MBD, the species listed in the order most likely to be affected, according to S1, were iguanidae and other lizards, chelonia and nonhuman primates. Some results of S2 are in Table 4.

Diagnosing Metabolic Bone Disease in Lizards

Primarily, tests of plasma Ca and P levels and radiographs are used to diagnose MBD in lizards. Calcium and P plasma indices are not reliable Ca metabolism indicators in lizards because they can be artifactual due to compensatory physiological processes like bone resorption [Rosskopf and Woerpel, 1989]. Calcium levels for female lizards, for example, are elevated during the breeding season but they are in Ca homeostasis relative to their reproductive status [Clark et al., 1969].

Radiographs (Table 5) may not indicate MBD even when compensatory mechanisms have begun to deplete bone stores of Ca. For example, 20% to 30% of bone mineral density (BMD) must be lost before osteopenia is radiographically visible [Frye, 1991; Kowalchuk and Dalinka, 1998; LePage et al., 2001]. Other problems include radiation exposure, expense and scan time.

Research Potential: Quantitative Ultrasound (QUS)

Human and horse research using QUS methods for monitoring bone health indicate it could be used for lizards [LePage et al., 2001; Wuster et al., 1998; SUTL, 1999]. Quantitative ultrasound uses the transmission of high-frequency sound waves through bone to measure the speed of sound (SOS). For example, SOS in adult humans travels through healthy, dense cortical bone at 4000 m/s, but travels 1800 m/s through trabecular bone that is less dense and more elastic. Advantages of QUS appear to be ease of use, lack of radiation, relatively inexpensive and, the measures reflect BMD and bone architecture [LePage et al., 2001; Wuster et al., 1998; SUTL, 1999].

An SOS measure is taken with a calibrated, hand-held probe applied to the skin over the appendicular skeleton [SUTL, 1999]. The probe scans the area for a minimum of three cycles (out of five). Each cycle takes 4 to 5 s and total scan time can be 12 to 25 s. Quantitative ultrasound has a 2% to 3% precision error compared to 1% to 2% for other BMD methods like dual x-ray absorptiometry (DEXA) [NOF, 1998]. Reliability of BMD measures for QUS and other methods are similar in the lumbar spine, but the reliability varies between 0.24 and 0.9 at other probe sites [Wuster et al, 1998]. Research in humans on QUS indicate a sensitivity and specificity of 94% [SUTL, 1999].

Quantitative ultrasound has also been used to monitor changes in bone health in humans. A 2% change in SOS over one year indicates a change in bone health and the method has detected a 0.7% increase in bone SOS (22 m/s) over a period of 8 mo among prepubertal boys [Wuster et al., 1998; SUTL, 1999].

This potential could be used with captive lizards to obtain a baseline SOS reading, then yearly readings can be used to monitor bone health and may allow relative adjustments to dietary and environmental factors.

Potential problems with the application of QUS with lizards include large probes and lack of a normative database. Currently, most QUS probes are too large, but this problem may be solved by the newest unit developed by Sunlight Ultrasound Technologies [SUTL, 1999]. This unit, the 7000P, is designed for use in premature human infants (e.g., 758 g) and, the unit has successfully monitored changes in bone health through human developmental years [Nemet, 2000; Zadik, 2000]. A normative database does not exist for lizards for use with QUS methods. Quantitative ultrasound methods are based on reference values classified by age and sex, and the SOS value has meaning about bone strength and density relative to the reference values. Research software does exist to establish a normative database in any species [SUTL, 1999].

Several areas of research are needed to determine if this methodology can be used to promote and maintain bone health in captive lizards. Establishing a normative database, determing appropriate probe sites and, the investigation of the degree of invasiveness for use with lizards are only a few. Extensive field testing in zoological institutions and veterinary clinics will also be necessary to verify a QUS system application in lizard species.

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REFERENCES

Auffenberg W. 1995. The bengal monitor (*Varanus bengalensis*): a model for insectivorous feeding strategies. Proc Assoc Rept Amphib Vet p 1-2.

Bernard JB, Ullrey DE. (1995). An illuminating discussion of vitamin D, ultraviolet radiation and reptiles. Proc Assoc Rept Amphib Vet p 40-2.

Brice S. 1995. A review of feeding and lighting requirements for captive herbivorous lizards: Cyclura and Iguana. Dodo, J Wild Pres Trusts 31:120-39.

Clark NB, Pang PKT, Dix MW. 1969. Parathyroid glands and calcium and phosphate regulation in the lizard, Anolis carolinensis. Gen Comp Endo 12:614-8.

Darmady EM, MacIver AG. 1980. Renal Pathology. London (UK): Butterworth & Co.

Dickinson HC, Fa JE. 1997. Ultraviolet light and heat source selection in captive spiny-tailed iguanas (*Oplurus cuvieri*). Zoo Biol 16:391-401.

Donoghue S. 1995. Clinical nutrition of reptiles and amphibians. Proc Assoc Rept Amphib Vet p 16-37.

Falk B, Sadres E, Constantini N, Eliakim A, Zigel L, Foldes AJ. 2000. Quantitative ultrasound (QUS) of the tibia: a sensitive tool fro the detection of bone changes in growing boys. J Ped Endo Metab 13:1129-35.

Frye FL. 1991. Biomedical and surgical aspects of captive reptile husbandry:volume I. New Jersey (NY):TFH Publications

Frye FL. 1997. The importance of calcium in relation to phosphorus, especially in folivorous reptiles. Proc Nutr Soc 56:1105-17.

Gehrmann WH. 1997. Reptile lighting: a current perspective. The Vivarium 8: 44-5.

Korber K. 1997. The common green iguana. Proceedings of the CVMA/ACMV Saskatoon, 239-251.

Kowalchuk RM, Dalinka MK. 1998. The radiologic assessment of osteoporosis. Ortho J 11:67-75

Holick MF, Tian XQ, Allen ME. 1995. Evolutionary importance for the membrane enhancement of the production of vitamin D3 in the skin of poikilothermic animals. Proc Natl Acad Sci 92:3124-26.

LePage OM, Carstanhen B and Uebelhart D. 2001. Non-invasive assessment of equine bone: an update. Vet J 161:10-22.

McWilliams DA. 1998. Nutritional pathology in lizards and turtles [unpublished]. Guelph, ON: University of Guelph; 1998. 165 p.

McWilliams DA. 2000. Analysis overview: nutritional pathology survey [unpublished]. Guelph, ON: University of Guelph; 2000. 11 p.

Nemet D, Eiakim A, Wolash B, Dolphin T. 2000. Bone strength measurement in premature infants by quantitative ultrasound. Advancing Children's Health May 2000, Boston, USA

[NOF] National Osteoporosis Foundation. 1998. Osteoporosis: review of the evidence for prevention, diagnosis, and treatment and cost-effective analysis. Osteoporosis Int 8:S1-S88.

Oftedal OT, Allen ME. 1996. Nutrition as a major facet of reptile conservation. Zoo Biol 15:491-7

Oftedal OT, Chen TC, Schulkin J. 1997. Preliminary observations on the relationship of calcium ingestion to vitamin D status in the green iguana (Iguana iguana). Zoo Biol 16:201-7.

Reichenbach-Klinke H, Elkan E. 1965. Disease of Reptiles. Hong Kong: T.F.H. Publications.

Rosskopf WJ, Woerpel RW. 1989. Hematology and the use of serum chemistry profiles in reptile diagnostics. The Third International Colloquium on the Pathology of Reptiles and Amphibians, Orlando, Florida. p 58-61.

[SUTL] Sunlight Ultrasound Technologies Ltd. 1999. User Guide: Sunlight Omnisense. Rehovot (Israel).

Tosini G, Jones S, Avery R. 1995. Infra-red irradiance and set point temperatures in behaviourally thermoregulating lacertid lizards. J Therm Bio 20:497-503.

Truit JO. 1962. The Common Diseases of Captive Reptiles:Symptoms, Treatment, Prevention. Florida: Coral Gables.

Wuster C, Heilmann P, Pereira-Lima J, Schlegel J, Anstatt K, Soballa T. 1998. Quantitative ultrasonometry (QUS) for the evaluation of osteoporosis risk: reference data for various measurement sites, limitations and application possibilities. Exp Clin Endocrinol Diabetes, 106:277-88.

Zadik Z, Shamaev A, Geva D, Yaniv I. 2000. Late catch-up of bone strength in prematurely-born children: preliminary results. European Society for Pediatric Endocrinology, September 2000, Belgium.

TABLE 1. Percent incidence of dietary factors and metabolic bone disease (MBD) diagnoses with use of ultraviolet light (UV) by owners of iguana clients at Ontario Veterinary College Teaching Hospital (OVCTH) [McWilliams, 1998].

Diet (n=53)[a]	Incidence of Diet (%)	Clinician Diagnoses Relevant to MBD	Occurance (%)	Owners using UV Light (%)
Fruit/vegetables; VMS[b]	24.5	osteopenia or MBD impacted colon, anorexia (each) paralysis, limb/mandible edema osteomyelitis (each)	76.9 15.4 7.7	23.1%
Cat or dog food; fruits/vegetables; VMS[b]	22.6	osteopenia or MBD paralysis anorexia, osteomyelitis, limb/mandible edema, hypervitaminosis D	91.7 16.7 8.3	25.0%
Fruit/vegetables only	15.1	osteopenia or MBD paralysis colon prolapse, anorexia (each)	100.0 25.0 12.5	25.0%
Cat or dog food; dairy and meat products; fruits/vegetables	13.2	osteopenia or MBD paralysis, constipation (each)	100.0 14.3	28.6%
Comm. Iguana food; VMS[b], fruits/vegetables;	9.4	osteopenia or MBD limb/mandible edema fibrous osteodystrophy	60.0 40.0 20.0	20.0%
Dairy products with meat; VMS[b] fruits/vegetables;	7.6	osteopenia or MBD anorexia, dystocia (each)	75.0 25.0	25.0%
Fruits/vegetables ; insects	3.8	osteopenia or MBD dystocia; gout (each)	100.0 50.0	0.0%
Insects only	1.9	metabolic bone disease	100.0	100.0%
Cat or dog food only	1.9	osteopenia or MBD, limb and mandible edema convulsion	100.0	0.0%

[a]listed by primary dietary item; [b]vitamin and mineral supplement.

TABLE 2. Post mortem reportings of factors relevant to metabolic bone disease (MBD) in iguana and chameleon sp. at the Ontario Veterinary College Teaching Hospital (OVCTH) [McWilliams, 1998].

Post Mortem Reporting	Iguana sp. (n = 13) Average age at Death: 2.1 years	Chameleon sp. (n = 10) Average age at Death: 1.4 years	Iguana and Chameleon sp. (n = 23)
Nephrosis	84.6%	50.0%	69.6%
Skeletal deformities	76.9%	60.0%	69.6%
Soft-tissue mineralization	61.5%	40.0%	52.2%
Impacted colon/cecum	30.8%	30.0%	30.4%
Myopathy	23.1%	40.0%	30.4%
Gout (articular and fascial)	7.7%	10.0%	8.7%

TABLE 3. Percent reporting by all zoo professionals on metabolic bone disease (MBD) by species in survey 1 [McWilliams, 2000].

Species	Nutritional Pathology	% Respondents
Iguanidae	MBD	78.6
Chelonia (turtles and tortoises)	MBD	60.7
Lizards other than Iguanidae	MBD	58.3
Nonhuman primates	MBD	37.5

TABLE 4. Percent reporting by all zoo professionals on metabolic bone disease (MBD) by species in survey 2 [McWilliams, 2000]

Species	Nutritional Pathology	% Respondents
Iguanidae and other Lizards	MBD	85.4
Chelonia (turtles and tortoises)	MBD	64.1
Nonhuman primates	MBD	47.6

TABLE 5. Radiograph findings and percent occurrence correlated with clinician diagnoses in iguana clients at the Ontario Veterinary College Teaching Hospital (OVCTH) [McWilliams, 1998]

Radiograph Findings (n = 45)	Percent found on radiograph	Clinician Diagnoses[a]
Fracture(s)	48.9%	1,3,4,5,6,8,9
Osteopenia	42.2%	3,4,5,6,8,9
Bone luxation (dislocation)	6.7%	4,8
Impacted colon	6.7%	4
Good bone cortex density	4.4%	3,4,6,7
Bone disintegration	4.4%	4,6
Egg bound	4.4%	1,2,4
Spinal disorder	2.2%	4,8

[a]1 = dystocia; 2 = hyperphosphatemia; 3 = NSH; 4 = MBD; 5 = hypoproteinemia; 6 = osteomyelitis; 7 = septic arthritis; 8 = hyperplastic parathyroid hyperfunction; 9 = rickets.