REVIEW

VITAMIN D AND ULTRAVIOLET B RADIATION CONSIDERATIONS FOR EXOTIC PETS

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Abstract

Vitamin D is an essential hormone that regulates many different functions in vertebrates and can have a protective effect against various disease conditions. Providing exotic pets appropriate access to vitamin D, through the diet, ultraviolet B (UVB) exposure, or a combination of both, is important for veterinarians and exotic pet owners to consider. Although it is commonly thought that most animals derive the vitamin D they need through their diet, there are a number of species that appear to benefit more from UVB exposure. In addition, there has been minimal study to investigate appropriate dietary levels of vitamin D for many of our exotic pets. Although the recommendation of providing UVB lighting has been primarily limited to captive reptiles, research with other species (e.g., birds and small mammals) suggests that these animals may also benefit from this type of lighting. However, the provision of UVB is not without its potential side effects. The purpose of this article is to review the important roles of vitamin D in animals, the different methods animals use to acquire this hormone, the potential clinical signs associated with hypovitaminosis or hypervitaminosis D, the role of artificial UVB lighting in the synthesis of vitamin D, and the potential side effects associated with UVB radiation. Copyright 2014 Elsevier Inc. All rights reserved.

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Vitamin D is a fat-soluble vitamin that is also considered an essential nutrient for many vertebrate species. The origin of this unique vitamin dates back more than 750 million years, when it was produced by some of the earliest life forms. This substance was produced by phytoplanktons in the ocean when exposed to natural sunlight.[1] The name vitamin D is somewhat of a misnomer; research has shown that it also acts as a steroid hormone.[2] In circulation, it is bound by vitamin D–binding protein. Binding prolongs the half-life of vitamin D as a hormone. Vertebrates can acquire vitamin D through their diet, photobiochemical conversion of ultraviolet B (UVB) radiation, or a combination of both. Dietary sources of vitamin D include cholecalciferol (vitamin D_3 of animal or plant origin) and ergocalciferol (vitamin D_2, typically of plant origin).[3,4]

Although vitamin D is an integral component to the metabolism and absorption of calcium and phosphorus, it also contributes to other physiologic processes in the body. Vitamin D directly affects the growth and development of bones; neuromuscular function; and is important to reproductive, immune, and cardiovascular health.[2] Vitamin D is also responsible for mobilizing stem cells to form osteoclasts. These bone cells are responsible for remodeling and mobilizing calcium stores from the bone. In some avian and reptilian species, viability of eggs and rates of reproductive success have been correlated to optimal amounts of vitamin D_3.[4,5] In humans, vitamin D has been determined to be a selective regulator of the

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immune system and enhance the corneal epithelial barrier function.[6] The active form of vitamin D has been shown to inhibit the development of autoimmune diseases, such as inflammatory bowel disease and Crohn's disease.[7] In broiler chicks, a deficiency in vitamin D_3 was shown to depress the cellular immune response.[8]

ACQUISITION OF VITAMIN D

Vitamin D can be acquired through 2 different methods: endogenous synthesis after exposure to UVB light or via direct ingestion and absorption through the gastrointestinal (GI) tract.[2] As vitamin D is a fat-soluble compound, fat must be present for vitamin D to be absorbed. In the small intestine, vitamin D is absorbed by a nonsaturable passive diffusion, which then acts to assist in active transport of calcium.[9] Dietary sources may include animal products that have already ingested or synthesized vitamin D or via the direct ingestion of plant sources (e.g., ergocalciferol). Once absorbed, vitamin D can be stored in a variety of tissues throughout the body, including fat, liver, kidneys, and small amounts in the lungs and heart.[9] Although many animals can obtain adequate amounts of vitamin D from their diet alone, there are other vertebrate species, such as humans, New World primates, and many reptiles, that require exogenous UVB light sources to produce an adequate amount of vitamin D in the body. New World primates do not appear to have the ability to use vitamin D_2, which is found in most plant food sources.[10] Animals requiring exogenous sources of vitamin D are commonly omnivorous or insectivorous vertebrates, whose natural dietary sources may not contain sufficient levels of vitamin D, or they simply may not be able to process the vitamin D that they ingest. Many animals such as sheep, cattle, rats, horses, pigs, and humans have been shown to have the ability to synthesize vitamin D in the skin via a photobiochemical reaction, and more animals capable of this photobiochemical reaction are being discovered.[11] This method of synthesizing vitamin D_3 follows exposure to UVB radiation in the spectrum of 290 to 320 nm. This spectrum is important to consider when developing lighting protocols for animals in captivity.

Synthesis in Skin

The synthesis of vitamin D is the result of the photosynthetic conversion of 7-dehydrocholesterol (7-DHC, provitamin D_3) to previtamin D_3 in the skin of vertebrates after exposure to UVB.[2,3,11] This occurs primarily in the epidermis, but has also been shown to occur in the cornea. The previtamin D_3 is unstable and not known to be biologically active. Previtamin D_3 undergoes a temperature-dependent isomerization into vitamin D_3, which has been shown to be enhanced at higher temperatures in poikilothermic animals such as iguanas and amphibians, as well as in humans.[11] Prolonged irradiation also results in a variety of photoproducts derived from previtamin D_3, including tachysterol, lumisterol, and reversal to the parent compound, provitamin D. All of these reactions are reversible.[2] It has been shown that only radiation in the UVB wavelengths of 280 to 320 nm will convert 7-DHC to previtamin D_3.

Vitamin D_3 produced by the skin, as well as that absorbed by the intestine, is transported to the liver. There has been debate as to whether vitamin D_3 produced in the skin is equivalent to that found in dietary sources. Both seem to have the same biologic activity; however, the half-life of vitamin D_3 produced in the skin is much longer because it is 100% bound to vitamin D–binding protein. Conversely, only about 60% of dietary vitamin D_3 is bound in circulation.[12] In the liver, the first step of bioactivation occurs, which is the hydroxylation to 25-hydroxyvitamin D_3 (25-OHD_3), or calcidiol. The microsomal and mitochondrial factions of the liver catalyze this reaction.[13] This is the form of vitamin D that is bound and enters into circulation. The kidneys are responsible for the final conversion to the active form, 1,25-$(OH)_2D_3$ (calcitriol). This mechanism is regulated in part by the parathyroid glands. When the active form, calcitriol, is synthesized in the kidneys, a feedback loop inhibits parathyroid hormone (PTH) transcription and secretion at the level of the parathyroid. Conversely, when calcitriol levels are low, PTH is produced to induce hydroxylation of the main circulating form of vitamin D, 25-OHD_3, into the active form.

The active form, which is hydroxylated in the kidneys, is primarily responsible for calcium absorption through the GI tract. Calcitriol receptors (vitamin D receptors [VDRs]) are present not only in the intestine and bone, but also in a variety of other tissues, including the brain, heart, stomach, pancreas, activated T and B lymphocytes, skin, and gonads, among others.[14] Some of these receptors actually possess the enzyme responsible for conversion of 25-OHD_3 to 1,25$(OH)_2D_3$. High plasma vitamin D_3 levels may be protective against early age-related macular degeneration and possibly protective for glaucoma.[15] In humans, 1,25-$(OH)_2D_3$ enhances the production of insulin