COMPANION OR PET ANIMALS

Severe nutritional deficiencies and osteopenia in a dog fed a homemade raw diet

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SUMMARY
A seven-month-old male entire Bulldog presented for a three-week history of progressive lethargy, exercise intolerance, hindlimb paresis, muscle atrophy and hyperaesthesia. The dog had initially been raised on the bitch’s milk before maternal illness resulted in him transitioning onto milk replacer. He was weaned onto commercial puppy food until four months of age before being transitioned onto a homecooked diet. This diet comprised of raw meat, collected weekly from a local abattoir, homecooked cereals and vegetables. The patient was oxygen-dependent on presentation, requiring 40 per cent inspired oxygen concentration to maintain normoxaemia. Investigations revealed marked osteopenia with concurrent severe hypovitaminosis D, hypocalcaemia and hyperparathyroidism; hypovitaminosis A; hypothyroidism and concurrent severe pneumonia. Despite intensive medical care, nutritional interventions and escalating oxygen therapy, the dog was euthanased due to a deterioration in respiratory function. This case report highlights the severe clinical complications associated with the consumption of a nutritionally incomplete diet.

BACKGROUND
There is a growing interest among pet owners about the potential health benefits of feeding a home-cooked diet rather than traditional proprietary dog food.1 2 The reasons for this trend are ill-defined and likely multifactorial including explanations such as the desire to treat a pet, to feed a diet which some owners consider to be more wholesome and natural as well as concerns over quality control of ingredients and nutritional balance in commercial foods.2 This latter issue has become a particularly high profile concern following the recall of several brands of dog food following manufacturing errors.2–4 However, there is a growing evidence base that homecooked and raw meat based diets are not without risk with increasing evidence demonstrating that a raw food diet can lead to the transmission of foodborne pathogens.5–7 antimicrobial resistance8 and nutritional deficiencies.9

A particular challenge for owners feeding a homecooked diet is ensuring that the diet is consistently nutritionally balanced.10 11 A particular concern in dogs fed a homecooked diet is the potential to develop vitamin D deficiency since dogs are unable to produce vitamin D cutaneously unlike many other mammals. Consequently, they need to obtain an adequate amount of vitamin D in their diet to avoid hypocalcaemia and skeletal complications.10 12 Commercial pet food diets are commonly supplemented with vitamin D.12 The metabolically active vitamin D metabolite 1,25 dihydroxyvitamin D3 (1,25(OH)2D3), alongside parathyroid hormone (PTH) is responsible for increasing serum calcium, in health. Skeletal pathologies, such as rickets, can develop in growing dogs with sustained vitamin D deficiency.13 Vitamin D has a number of wider ranging roles and most notably has been shown to profoundly influence immune function.14

Dogs fed nutritionally incomplete diets are also at risk of developing other multiple vitamin and mineral deficient states.9 For example, dietary intake of vitamin A precursors, most notably betacarotene, is essential, if liver stores are insufficient.15 Vitamin A is required for adequate immune function in the dog.16 skeletal growth in puppies,17 epithelial integrity, visual and reproductive function.18 19 Adequate dietary intake of iodine is important to ensure normal thyroid function. Hypothyroidism is a common endocrine disease in dogs which is typically caused by autoimmune destruction of the thyroid gland although nutritional causes of hypothyroidism have been reported in dogs.20 21

This case report describes a seven-month-old bulldog with severe generalised osteopenia and hypocalcaemia secondary to hypovitaminosis D with secondary hyperparathyroidism. Further investigations also revealed hypovitaminosis A and hypothyroidism. These findings are suspected to be linked to a nutritionally incomplete diet which consisted of a home-prepared mixture of raw meat and cooked cereals and vegetables from four months of age. The severe clinical presentation demonstrates the potential sequelae of feeding an incomplete diet to juvenile dogs and the importance of taking a dietary history.

CASE PRESENTATION
A seven-month-old, male entire, English Bulldog presented for investigation of a three-week history of progressive exercise intolerance, pelvic limb muscle atrophy, pelvic limb gait abnormalities, inability to posture normally to defecate, reduced appetite and moments of abnormal behaviour which were suspected to be pain related. No previous illness had been reported in this dog and he was up to date with vaccinations and anti-parasite treatment. The owner showed a video at four months old demonstrating adequate growth with a normal body shape and gait.

The puppy was one of a seven puppy litter and was still in the care of his breeder. Four out of seven puppies had died over the last seven months, one of
which was diagnosed with hydrocephalus at postmortem examination. The bitch had been fed a homemade diet consisting of raw meat, collected weekly from an abattoir, boiled rice, broccoli and other vegetables. It had received a commercial puppy diet in the last trimester. The puppies were fed by the bitch initially until an undiagnosed illness resulted in them being converted onto a commercial milk replacement. At weaning, they were transitioned onto a commercial puppy mousse and subsequently age appropriate dry food pellets. From approximately four months of age the remaining puppies had been transitioned onto the owners’ homemade diet that the bitch had received previously.

Table 1  Abnormal clinical pathology results

| Analyte (units)                       | Result | Reference range |
|--------------------------------------|--------|----------------|
| Ionised calcium (mmol/L)             | 0.86   | 1.15–1.5       |
| Total 25-hydroxyvitamin D (nmol/L)   | <4     | 17.2–139.9     |
| Parathyroid hormone (pg/mL)          | 281    | 20–65          |
| Serum total T4 (nmol/L)              | <13    | 15–48          |
| Serum-free T4 (pmol/L)               | <3.9   | 6–40           |
| Serum thyroid stimulating hormone (ng/mL) | 0.846 | 0.00–0.50     |
| Vitamin A (µg/L)                     | 248    | 830–3070       |
| Creatine kinase (U/L)                | 602    | 50–200         |

INVESTIGATIONS

Clinical examination demonstrated a subdied and orthopneic animal with marked stridor and stertor, consistent with severe brachycephalic obstructive airway syndrome. A mass in the ventral cervical region was palpable and was suspected to be a goitre. An abnormal thoracic conformation was noted with lateral bowing of the ribs. Bilateral outward rotation of both elbows and marked tarsal valgus were present. Body condition score was 3/9 and mild muscle loss was noted. Pulsoximetry revealed hypoxaemia with an spO2 of 92 per cent.

Neurological examination revealed ambulatory paraparesis, reduced withdrawal reflexes in the pelvic limbs and marked hyperaesthesia on thoracolumbar, lumbar and lumbosacral palpation.

Investigations included haematology, serum biochemistry (table 1) and diagnostic imaging. Haematology was unremarkable. Serum biochemistry revealed ionised hypocalcaemia and an increased creatine kinase concentration. To define the pathophysiology of the hypocalcaemia, concentrations of serum 25 hydroxyvitamin D (25(OH)D), the vitamin D metabolite which is widely used to assess vitamin D status, and plasma PTH were measured. Serum 25(OH)D concentration was undetectable and the PTH concentration was increased (table 1). Due to the presence of a suspected goitre on examination, total and free thyroxine alongside thyroid stimulation hormone were measured which revealed low total and free T4 and increased concentration of thyroid stimulating hormone (table 1). Hypovitaminosis A was also identified (table 1).

CT was performed to allow rapid assessment of both the paraparesis and the dyspnoea in this critical case. The examination revealed a bilaterally symmetrically enlarged and hypodense thyroid gland (figure 1) (46 Hounsfield units (HU), normal canine thyroid density 107.5 HU),22 generalised increased lung attenuation with maintained volume, bilaterally symmetric fatty infiltration of thoracolumbar epaxial and hypaxial muscles, curvature deformations of the ribs, malformation of several thoracic vertebrae and generalised marked decrease in bone density (figure 2). CT osteodensitometry of the calvarium revealed a bone mineral density of 218.9 mg calcium hydroxyapatite/mL (in house normal average for breed 663 mg CaHA/mL, range 569–750 mg CaHA/mL, n=9) (figure 3).23 Thoracic radiography to assess naso-oesophageal tube placement also revealed lung opacification and generalised osteopenia (figure 4).

TREATMENT

Treatment for suspected pneumonia was started with intravenous amoxicillin-clavulanate (Augmentin; GlaxoSmithKline) 20 mg/kg every 8 hours and oxygen therapy. Over the first 24 hours, some improvement in oxygen saturation and respiratory rate and effort was seen.

To address suspected regurgitation and inappetence antinausea and prokinetic support in the form of maropitant (Prevomax; Dechra) 1 mg/kg intravenously every 24 hours and a metoclopramide (Meprid; Ceva) constant rate intravenous infusion at 2 mg/kg per day were initiated. Analgesia in the form of methadone (Comfortan; Dechra) 0.2 mg/kg intravenously every 4 hours and paracetamol (Perfalgan; Bristol-Myers Squibb) 10 mg/kg intravenously every 12 hours were provided to alleviate the hyperaesthesia. This was subsequently escalated to a continuous rate intravenous infusions of fentanyl (Fentadon; Dechra) at 3 µg/kg per hour and ketamine (Narketan; Vetoquinol) at 0.2 mg/kg per hour, with subsequent reduction in recorded pain scores.
Figure 2  Abdominal CT image showing the heterogeneous hypodensity of the epaxial and hypaxial muscles consistent with fatty infiltration, whereas ventral abdominal muscles appear normal.

A naso-oesophageal tube was placed to ensure nutrition, with a commercial liquid diet (Royal Canin gastrointestinal high energy liquid) given as a continuous rate infusion. Rates were calculated to provide 33 per cent resting energy caloric requirement per day with daily incremental increases of 33 per cent.

Calcitriol (Rocaltrol; Roche) at a dose of 2.5 ng/kg orally once daily was started to address hypovitaminosis D and levothyroxine (Leventa; MSD Animal Health) at 20 µg/kg orally once daily was instigated to address the hypothyroid state.

OUTCOME AND FOLLOW-UP

Despite intensive critical care management of the patient’s multiple comorbidities with intravenous antibiosis, oxygen therapy, enteral nutrition and gastroenteral support, its respiratory function worsened four days after admission with progressive hypoxaemia (spO₂ 90 per cent on 80 per cent inspired oxygen concentration) and worsening dyspnoea. High-flow nasal oxygen therapy was started but only mild improvement in oxygenation status (spO₂ 92 per cent) was seen with no improvement in respiratory effort after several hours. Given the clinical deterioration after five days of intensive management, the owner elected to euthanase the patient.

Figure 3  (A) Head CT image showing a generalised osteopenic skull with a measured bone mineral density of the calvarium of 218.9 mg calcium hydroxylapatite/mL. (B) Head CT image of an eight-month-old male Bulldog with normal calvarial bone density (665.6 mg calcium hydroxylapatite/mL).

DISCUSSION

This case describes a case of profound hypovitaminosis D which resulted in hypocalcaemia, secondary hyperparathyroidism and low bone density. The most plausible explanation for the low vitamin D status was the feeding of a vitamin D deficient diet. Hypovitaminosis D and hypocalcaemia have been reported in animals following insufficient dietary intake.10

Clinical symptoms include pathological fractures, pain on palpation of bones, facial swelling and mandibular flexibility (due to osteopenia), seizures and muscle weakness (due to hypocalcaemia) and rickets (due to hypovitaminosis D causing impaired mineralisation of physeal and epiphysial cartilage during growth).13 24–26

Dogs are dependent on dietary intake of vitamin D due to an inability to synthesise sufficient quantities in their skin.12 27 Skeletal development is dependent on the interactions of vitamin D and PTH as part of calcium homeostasis. 1,25-dihydroxy-vitamin D₃ and calcium are both necessary for growth plate development with both osteoclasts and chondrocytes expressing vitamin D receptors.13 Hypovitaminosis D results in hypocalcaemia due to decreased intestinal absorption, thus decreasing the calcium pool available for mineralising osteoid and newly formed cartilage.13 Furthermore, hypocalcaemia stimulates parathyroid gland hyperplasia and subsequent hyperparathyroidism, with resultant calcium reabsorption from bone.13 Hypocalcaemia in this case may have been further exacerbated if the diet was deficient in calcium. The combined effects of hypovitaminosis D, hypocalcaemia and secondary hyperparathyroidism likely resulted in the severe osteopenia seen in this case.

An interesting feature of this case is the presence of primary hypothyroidism and a goitre. Again, the most plausible explanation for this abnormality is the nutritionally inadequate diet in which low intake of iodine resulted in a thyroxine deficient state. Nutritional causes of hypothyroidism are rare in dogs.21 28 Conversely, iodine deficiency in people is a common cause of goitre development.29 A case series of hypothyroidism due to a suspected iodine deficient diet was reported in dogs fed a predominantly meat or meat-only diet.20 Dietary sources of iodine include iodised salt fish and fish products,20 all of which were absent from this patient’s diet. As such the early-onset hypothyroidism in this case was suspected to be due to iodine deficiency. Plasma iodine levels were not sampled before the patient receiving an iodine-based contrast medium as part of the protocol for the CT scan; therefore, it was not possible to ascertain an accurate plasma iodine concentration. However, the hypodense thyroid on CT likely reflects a lower than normal concentration of iodine within the tissue.22

Myosteatosis was an unexpected observation on the CT images. This condition has not been reported in dogs and the
aetiology of the fat deposition in the muscle is unclear. However, it may be a consequence of the nutritionally inadequate diet. This possible explanation is supported by murine model studies which found that vitamin D supplementation resulted in improvement in myosteatosis that was induced by feeding a high fat high sugar diet.\(^\text{30}\)

Fish oil supplementation has been shown to reduce myosteatosis in a rodent model of neoplasia, possibly suggesting that omega 3 fatty acid deficiency may be causing this finding.\(^\text{31}\)

Further studies are required to assess whether the hypovitaminosis D, omega 3 fatty acids or other deficiency seen in this case could have contributed to the myosteatosis seen in this patient.

Hypovitaminosis A was also documented in this case. Dogs can produce vitamin A from sources of beta-carotene such as carrots and green leafy vegetables or directly from liver. Deficiencies can result in visual impairment, dermatoses, poor embryonic skeletal development\(^\text{32}\) and suppressed immune function, especially within the respiratory tract.\(^\text{16}\) Similarly, vitamin D is associated with ability of the innate immune system to handle microbes with the vitamin D receptor being present on most immune cells.\(^\text{33}\) No visual impairments or dermatoses were documented in this case; however, the patient did present with diffuse pneumonia. Although this is suspected to be secondary to regurgitation and aspiration in this brachycephalic breed, the severe presentation and poor response to medical management could have been exacerbated by its concurrent poor nutritional status.

A limitation of this report is the lack of dietary analysis. The long-term nutritional profile of the diet was difficult to ascertain before feeding to dogs.

In summary, this case documents marked hypovitaminosis D, hypocalcaemia and secondary hyperparathyroidism with severe osteopenia alongside hypothyroidism and hypovitaminosis A. This is most likely due to the feeding of a nutritionally incomplete homecooked diet. This case highlights the need to fully assess patients’ dietary history and demonstrates the merits of ensuring that homecooked diets are nutritionally balanced before feeding to dogs.

Learning points

- This case highlights the severe clinical sequelae of feeding a nutritionally incomplete diet to a juvenile dog.
- Marked skeletal complications may result from of feeding a diet with low vitamin D to a growing animal.
- Patients fed homecooked diets may have other deficiencies such as early onset hypothyroidism due to iodine deficiency, or hypovitaminosis A.
- Full dietary history should always be acquired with dietary analysis performed.

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REFERENCES

1. Connolly KM, Heinze CR, Freeman LM. Feeding practices of dog breeders in the United States and Canada. J Am Vet Med Assoc 2014;245:669–76.
2. Lafframme DP, Abood SK, Fasceetti AJ, et al. Pet feeding practices of dog and cat owners in the United States and Australia. J Am Vet Med Assoc 2008;232:687–94.
3. FDA website pet food recalls [Internet]. Available: https://www.fda.gov/animal- veterinary-safety-health/recalls-withdrawals
4. Mellanby RJ, Mee AF, Berry JL, et al. Hypercalcaemia in two dogs caused by excessive dietary supplementation of vitamin D. J Small Anim Pract 2005;46:334–8.
5. Freeman LM, Chandler ML, Hamper BA, et al. Current knowledge about the risks and benefits of raw meat-based diets for dogs and cats. J Am Vet Med Assoc 2013;243:1549–58.
6. Finley R, Ribble C, Aramini J, et al. The role of salmonelae shedding by dogs fed Salmonella-contaminated commercial RAW food diets. Can Vet J = La Rev Vet Can 2007;48:69–75.
7. Lefebvre SL, Reid-Smith R, Boerin P, et al. Evaluation of the risks of shedding salmonelae and other potential pathogens by therapy dogs fed RAW diets in Ontario and Alberta. Zoosens Public Health 2008;55:470–80.
8. Schmidt VM, Pinchbeck GL, Nuttall T, et al. Antimicrobial resistance risk factors and characterisation of faecal E. coli isolated from healthy Labrador retrievers in the United Kingdom. Prev Vet Med 2015;119:31–40.
9. Dillitzer N, Becker N, Kienzle E. Intake of minerals, trace elements and vitamins in bone and RAW food rations in adult dogs. Br J Nutr 2011;106:553–6.
10. Streiff EL, Zwischenberger B, Butterwick RF, et al. A comparison of the nutritional adequacy of Home-prepared and commercial diets for dogs. J Nutr 2002;12:1695–700.
11. Polizopolou ZS, Kazakos G, Patsikas MN, et al. Hypervitaminosis A in the cat: a case report and review of the literature. J Feline Med Surg 2005;7:363–8.
12. Cline J. Calcium and vitamin D metabolism, deficiency, and excess. Top Companion Anim Med 2012;27:159–64.
13. Dittmer KE, Thompson KG. Vitamin D metabolism and rickets in domestic animals: a review, vol. 48, veterinary pathology. SAGE PublicationsSage CA: Los Angeles, CA 2011:389–407.
14. Mellanby RJ. Beyond the skeleton: the role of vitamin D in companion animal health. J Small Anim Pract 2016;57:175–80.
15. Wolf G. Multiple functions of vitamin A. Physiol Rev 1984;64:873–937.
16. Cane NJ. Immunology and Nutrition. In: Stephen I, Ettinger SJ, Feldman EC, eds. Textbook of veterinary internal medicine. 5th edn. Philadelphia: W.B. Saunders Ltd, 2000: 809–13.
17. Russell WC. Morris ml. vitamin A deficiency in the dog. 1. experimental production of the vitamin A deficient condition. J Am Vet Med Assoc 1939:95:316–20.
18. Elle MH, Cullum ME. The function of vitamin A: current concepts. Exp Biol Med 1982;172:139–52.
19. Kumar S, Pandey AK, Mutha Rao M, et al. Role of β carotene / vitamin A in animal reproduction. Vet World 2010;3:236–7.
20. Nuttall WO. Letters to the editor: Iodine deficiency in working dogs. vol. 34. New Zealand Veterinary Journal 1986;72.
21. Castillo VA, Pizazz MA, Lalia JC, et al. Nutrition; commercial diet induced hypothyroidism due to high iodine: A histological and radiological analysis. Veterinary Quarterly 2001;23:218–23.
22. Taeymans O, Schwarz T, Duchateau LUC, et al. Computed tomographic features of the normal canine thyroid gland. Vet Radiol Ultrason 2008;49:13–19.
23. Park S, Oh J, Son K-Y, et al. Quantitative computed tomographic assessment of bone mineral density changes associated with administration of prednisolone or prednisolone and alendronate sodium in dogs. Am J Vet Res 2015;76:28–34.
24. de Fornel-Thibaud P, Blanchard G, Escoffier-Chateau L, et al. Unusual case of osteopenia associated with nutritional calcium and vitamin D deficiency in an adult dog. J Anim Hosp Assp 2007;43:52–60.
25. Taylor MB, Geiger DA, Saker KE, et al. Diffuse osteoporosis and myelopathy in a puppy fed a diet composed of an organic premix and RAW ground beef. J Am Vet Med Assoc 2009;234:1041–8.
26. Hutchinson D, Freeman LM, McCarthy R, et al. Seizures and severe nutrient deficiencies in a puppy fed a homemade diet. J Am Vet Med Assoc 2012;241:477–83.
27. How KL, Hazewinkel HAW, Mol JA. Dietary vitamin D dependence of cat and dog due to inadequate cutaneous synthesis of vitamin D. Gen Comp Endocrinol 1994;96:12–18.
28 Graham PA, Refsal KR, Nachreiner RF. Etiopathologic Findings of Canine Hypothyroidism. Vol. 37, Veterinary Clinics of North America - Small Animal Practice 2007:617–31.
29 Lamberg BA. Iodine deficiency disorders and endemic goitre. Eur J Clin Nutr 1993;47:1–48.
30 Benetti E, Mastrocola R, Chiazza F, et al. Effects of vitamin D on insulin resistance and myosteatosis in diet-induced obese mice. PLoS One 2018;13:e0189707.
31 Almasud AA, Giles KH, Miklavcic JJ, et al. Fish oil mitigates myosteatosis and improves chemotherapy efficacy in a preclinical model of colon cancer. PLoS One 2017;12:e0183576–34.
32 Zile MH. Function of vitamin A in vertebrate embryonic development. J Nutr 2001;131:705–8.
33 Remillard RL. Homemade diets: attributes, pitfalls, and a call for action. Top Companion Anim Med 2008;23:137–42.