Osteopenia and other radiographic signs in canine hyperadrenocorticism

The specificity of conventional radiography in assessing canine hyperadrenocorticism was evaluated by comparing the incidence of related radiographic findings in 24 hyperadrenocorticoid, 15 diabetic and 20 hypothyroid dogs. Hyperadrenocorticoid dogs showed significantly more perihilar bronchial mineralisation than other groups. There was no significant variation between the disease groups with respect to obesity, hepatomegaly, contour of the caudoventral hepatic margin, peripheral bronchial mineralisation or osteopenia. Adrenal mineralisation and calcinosis cutis were rare findings observed only in hyperadrenocorticoid dogs. The effect of obesity on the radiographic appearance of bone was studied using a dissected lumbar spine from a canine cadaver. An osteopenic effect could be demonstrated by superimposition of a 10 cm-thick fat block. The low specificity of almost all common signs in canine hyperadrenocorticism and the low incidence of characteristic findings demonstrate the limited potential of radiography in assessing this condition. Radiographic assessment of bone density is unreliable because of artefactual osteopenic effects of high kVp settings necessary in obese dogs.

T. Schwarz, C. K. Störk, D. Mellor and M. Sullivan

Department of Veterinary Clinical Studies, University of Glasgow Veterinary School, Bearsden Road, Bearsden, Glasgow G61 1QH

C. K. Störk's current address is Service de Chirurgie des Petits Animaux, Université de Liège, Boulevard de Colonster, 20-B44, B - 4000 Liège, Belgium

INTRODUCTION

The metabolic effects of canine hyperadrenocorticism have long been recognised as causing multiple morphological changes. Resulting radiographic features include osteopenia, adiposity, hepatomegaly, adrenomegaly and mineralisation of the adrenal glands, pulmonary interstitium, bronchial walls, cutis and other soft tissue structures. Although the radiographic findings in hyperadrenocorticism have been described, specificity has not been addressed (Ticer 1977, Huntley and others 1982, Peterson 1984, Penninck and others 1988).

Obesity, or redistribution of body fat to the abdomen, is a very common manifestation in hyperadrenocorticoid dogs (Peterson 1984). It is an accepted fact that radiographic contrast decreases with the increased kVp settings necessary to penetrate greater body thickness (Curry and

others 1990). Consequently, some authors have argued that increased body thickness could produce a spurious radiographic osteopenia, but without providing supporting evidence (Huntley and others 1982, Lamb 1990, Owens and Biery 1999).

The purpose of the present study was to investigate the specificity of conventional radiography in the assessment of canine hyperadrenocorticism by comparing the occurrence of related radiographic findings to those in dogs with other obesity-inducing conditions. In addition, the effect of obesity on the radiographic appearance of bone was studied on a canine cadaver specimen.

MATERIALS AND METHODS

Clinical study

In a retrospective study, abdominal and thoracic radiographs from 59 dogs referred to the University of Glasgow Veterinary School were evaluated by two reviewers. Twenty-four of the dogs were hyperadrenocorticoid, 15 were diabetic and 20 were non-congenital hypothyroid dogs; none of the dogs in the last two disease groups were hyperadrenocorticoid, and the two reviewers had no knowledge of the diagnosis. Assessment results which differed between the reviewers were re-evaluated until agreement was achieved.

Films were examined for the presence of adrenomegaly, adrenal and pulmonary mineralisation, calcinosis cutis, hepatomegaly, contour of the caudoventral hepatic margin, obesity, and perihilar and peripheral bronchial mineralisation. Adrenal mineralisation, adrenomegaly and calcinosis cutis were scored as present or absent. Hepatomegaly and obesity were scored as absent, mild, marked or very severe, the appearance of liver lobe edges as sharp, blunt or round, and bronchial mineralisation as absent, mild or marked.

The radiographic bone density of lumbar vertebral bodies was assessed subjectively as normal, mildly or markedly decreased using the following criteria: increase in transparency, increase in cortico-

medullary contrast, loss of trabecular bone pattern, presence of cortical lamellation, thinning and deformity. A similar assessment was made of the ribs, pelvis and at least one long bone.

The Statistix V4.0 programme was used to perform statistical analyses. Analysis of variance (ANOVA) was used to investigate differences between the groups with respect to bodyweight and age. Kruskal-Wallis one-way ANOVA by ranks was used to compare categorical parameters relating radiographic findings between groups.

Cadaver specimen study

Dorsoventral and lateral radiographs of a dissected lumbar spine with attached lumbar soft tissue structures (muscles, fat and skin) of a skeletally mature German shepherd dog, euthanased for medical reasons and with no evidence of hyperadrenocorticism, were taken with an extremity cassette with high detail screens (Ultravision, speed 100; Dupont/Sterling) and used as standard (1). To assess the effect of obesity, the spine was then re-radiographed with a 10 cm-thick fat block superimposed on top of the spine (2). To evaluate magnification, the object-film distance was increased by 10 cm by placing the same fat block beneath the spine (3). Conditions (1), (2) and (3) were repeated using a high speed screen cassette normally used for abdominal radiography (Quanta Fast Detail, speed 200; Dupont/Sterling). All pictures were taken with a stationary grid and using the same type of film. Exposure settings were always adjusted using a step wedge to achieve spinal opacity equivalent to the standard film.

RESULTS

Clinical study

The three groups of dogs were comparable statistically with regard to the distribution of age, gender and bodyweight.

Decrease in radiographic bone density was present in all disease groups, but no statistically significant difference was found in the profile of alteration (Fig 1). There was no significant variation between the disease groups with regard to obesity,
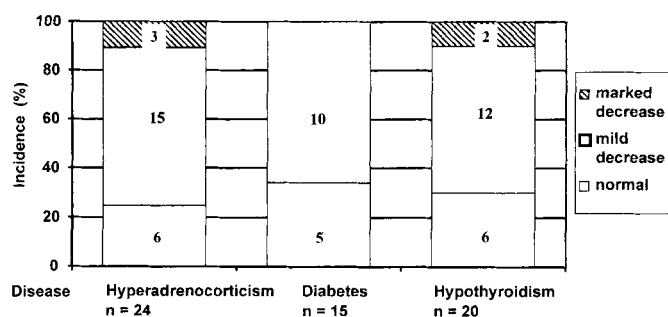

FIG 1. Distribution of bone opacity in disease groups. Numbers of affected animals are given within the columns
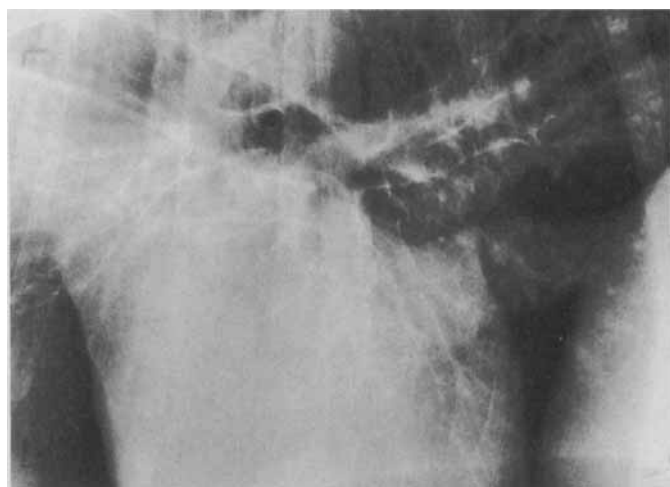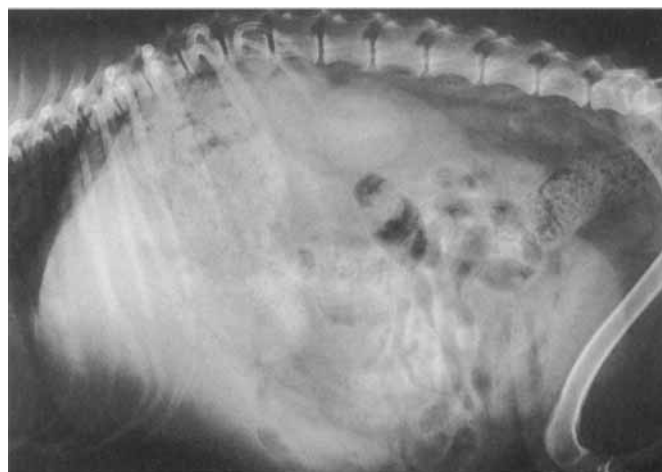

FIG 2. Lateral abdominal radiograph of a hyperadrenocorticoid dog. Note the pendulous abdomen, abdominal adiposity and marked hepatomegaly with a rounded caudoventral hepatic margin. These common radiographic findings in hyperadrenocorticism are non-specific

FIG 3. Close-up lateral chest radiograph of a hyperadrenocorticoid dog. There is marked perihilar and peripheral bronchial mineralisation
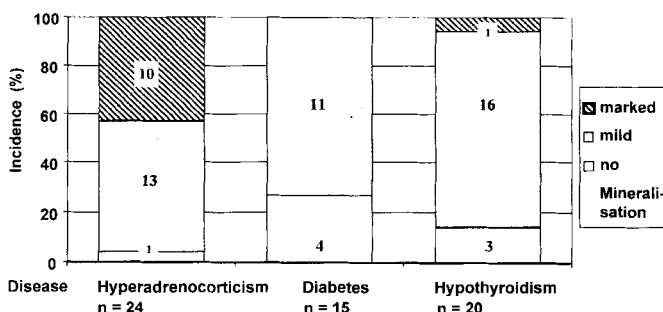

FIG 4. Distribution of perihilar bronchial mineralisation in disease groups. Numbers of affected animals are given within the columns

FIG 5. Close-up dorsoventral abdominal radiograph of a hyperadrenocorticoid dog showing an enlarged and mineralised left adrenal gland (arrows). These changes are very rare and were also detected by ultrasonography

FIG 6. Close-up view of the sacrococcygeal region of a hyperadrenocorticoid dog. Note the superficial linear mineralisation (arrows) due to calcinosis cutis, a rare sign in advanced hyperadrenocorticism

hepatomegaly, contour of the caudoventral hepatic margin and peripheral bronchial mineralisation (Fig 2). However, significantly more hyperadrenocorticoid dogs had perihilar bronchial mineralisation compared with the other two groups (P<0·001) and this was significantly more marked in hyperadrenocorticoid dogs (Figs 3 and 4). Adrenal mineralisation and calcinosis cutis were noted rarely, and only in hyperadrenocorticoid dogs (2/24 and 3/24, respectively) (Figs 5 and 6). Adrenomegaly was present in two hyperadrenocorticoid dogs, but was also

misdiagnosed in one diabetic dog. No pulmonary mineralisation was found.

Cadaver specimen study

In both dorsoventral and lateral radiographs of the cadaver specimen, an increase in vertebral transparency, increase in corticomedullary contrast and loss of the trabecular bone pattern became apparent when fat was superimposed on the spine. A more severe loss of bone density occurred when the object-film distance was increased by interposing the fat (Figs 7 and 8). On radiographs taken with high

FIG 8. Dorsoventral radiographs of the third lumbar vertebra of a cadaver specimen under different conditions. A stationary grid was used in all views. In (A) a detail screen was used. Note the decrease in bone density and loss of contrast from (A) to (B) caused by a faster screen and the superimposition of a 10 cm-thick fat block on top of the spine in (B). Note the decrease in sharpness and loss of definition from (B) to (C) caused by interposition of the same fat block between the spine and table with the same fast screen, resulting in magnification. Decreased radiographic bone density is apparent as a loss of trabecular bone pattern and reduced bone-soft tissue contrast
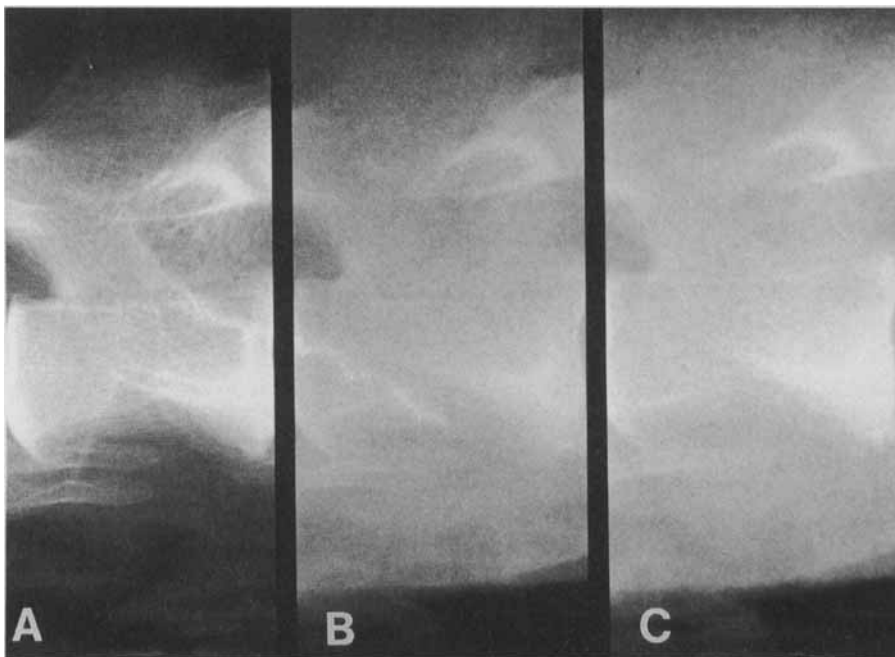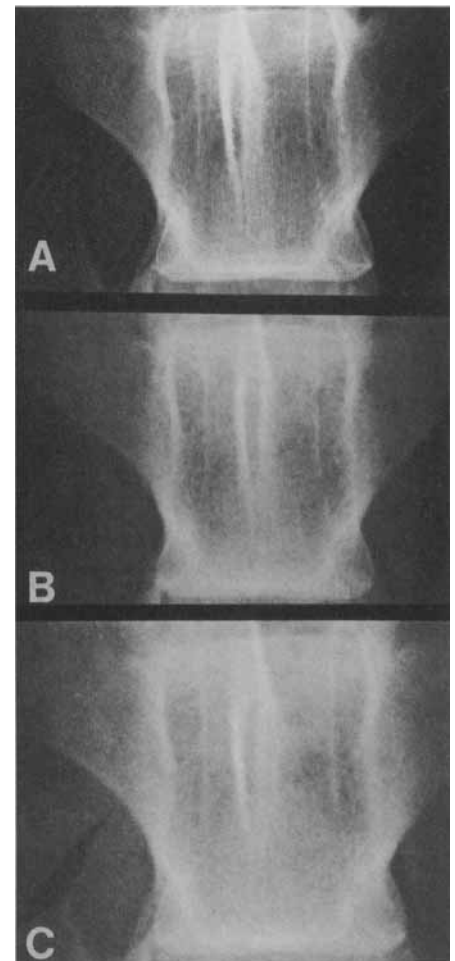
FIG 7. Lateral radiographs of the third lumbar vertebra of a canine cadaver specimen under different conditions. A stationary grid was used in all views. In (A) and (B) a detail screen was used. Note the decrease in bone density and loss of contrast from (A) to (B) caused by the superimposition of a 10 cm-thick fat block in (B). Note the further decrease in bone-soft tissue contrast from (B) to (C) caused by the use of a faster screen in (C). Loss of radiographic bone density is apparent as increased vertebral translucency and loss of trabecular bone pattern

speed screens, the radiographic detail was reduced compared with those achieved with the extremity cassette. With superimposed fat, bone density decreased compared with normal views taken with high speed screens and, furthermore, if the fat block was interposed. Thus, the highest bone detail was achieved with the standard set-up (extremity cassette). The poorest detail was achieved when fast screens and an interposed fat block were combined.

DISCUSSION

In this study, diabetic, hypothyroid and hyperadrenocorticoid dogs showed no significant difference in the degree of manifestation of obesity, hepatomegaly and peripheral bronchial mineralisation. The caudoventral hepatic margin did not show a characteristic shape in any of the disease groups. There might have been a difference if a comparison had been made with dogs with congestive hepatomegaly. However, other authors have found a wide variation in liver size and shape in normal dogs (Lee and Leowijuk 1982). Cockett (1986) established normal hepatometric criteria, but these were only specific for the German shepherd dog breed.

Perihilar bronchial mineralisation was significantly more common in the hyperadrenocorticoid dogs of the present study. However, this feature is not pathognomonic in the diagnosis of hyperadrenocorticism, as it occurs frequently in dogs as an age-related change and in chronic bronchitis (Mantis and others 1998). As mild mineralisation was particularly common in all disease groups in the present study, only very marked changes should be regarded as a significant finding. A generalised increase in unstructured interstitial pulmonary opacity with diffuse mineralisation has been described in hyperadrenocorticoid dogs, but was not noted here (Berry and others 1994).

Generalised osteopenia is commonly diagnosed radiographically in hyper-adrenocorticoid dogs (Huntley and others 1982, Penninck and others 1988, Lamb 1990). Osteopenia is a radiographic description of bone loss, regardless of cause. Osteoporosis, a loss of bone tissue due to negative turnover, can be induced by hyperadrenocorticism, where it is most noticeable in ribs and vertebrae (Dämmrich 1959, 1962, Norrdin and others 1988). Although in the present study many hyperadrenocorticoid dogs did show decreased bone density, this did not differ significantly from other obese dogs.

Non-congenital hypothyroidism is not known to cause radiographically detectable osteopenia in dogs (Panciera 1998). In humans, diabetes mellitus can cause localised osteonecrosis and thereby locally decreased bone density due to diabetic angiopathy (Emmrich and Reisert 1967), but these changes are never generalised and also have not been described in dogs. The fact that all three disease groups in the present study showed a radiographic decrease in bone density is therefore more likely to reflect increased body thickness than changes specific to the disease process. This potential source of misinterpretation has been noted previously (Huntley and others 1982, Lamb 1990, Owens and Biery 1999) and the present cadaver study has demonstrated that superimposition and, in particular, interposition of fat leads to decreased radiographic bone density.

Owing to the relatively high kVp settings necessary to penetrate increased body thickness, the Compton effect results from the dominating interaction of X-rays with irradiated tissues. Compton interaction creates an attenuation of the beam independent of the atomic number of the penetrated tissue and thus decreases radiographic contrast between bone, soft tissue and fat. The Compton effect is also responsible for scattered radiation which further decreases image contrast. Grids are used to limit scattered radiation reaching the film, but do not eliminate it entirely. High speed screens are used in radiography to achieve

sufficient blackening of the film with thick body parts such as the abdomen. Because of the higher intensification factor of these screens, there is reduced definition on the radiographic image, which decreases the detectability of the fine trabecular pattern of the bone, a sign currently associated with osteopenia.

With greater body thickness, the distance between the spine and film will also increase and result in magnification and reduced definition of the image. This effect is marked if dorsoventral rather than ventrodorsal abdominal views are taken. Bearing in mind several experimental studies, which have shown that between 30 and 50 per cent of bone mass loss is necessary before osteopenia is radiographically detectable (Ardran 1951, Bachman and Sproul 1955, Lachman 1955, Edelstyn and others 1967), it is also much more likely that technical factors contribute substantially to the commonly diagnosed radiographic finding of 'osteopenia'.

Huntley and others (1982) suggested the use of film densitometry as a more accurate means of assessing osteoporosis. However, this cannot distinguish the contribution of the different factors to the resulting density of the film. Choosing bony structures with less surrounding soft tissue, such as the appendicular skeleton, would eliminate artefactual osteopenic effects of radiographic technique, but hyperadrenocorticoid osteoporosis occurs less frequently and less severely at such a location.

Special attention has been drawn to structural changes associated with osteopenia, such as cortical thinning, deformation and cortical lamellation (double cortical line sign) as rare but reliable manifestations of the process (Lamb 1990). None of the dogs in the present study showed these signs. Loss of fine trabecular pattern is another structural pattern of osteopenia. In humans, Siffert (1967) showed that in any generalised osteoporosis, the fine trabeculae disappear first, leaving the more coarse ones. Even on recovery, these fine trabeculae are not rebuilt. However, scat-

tered radiation and high penetration have a similar effect on the visible trabecular pattern. It is important to note that, despite the relatively distinct osteoporosis in many hyperadrenocorticoid dogs, no radiographic diagnosis of osteopenia is safe in any obese dog, unless very drastic and rare changes are present.

Several authors have highlighted the value of rare radiographic findings in canine hyperadrenocorticism, such as adrenomegaly, adrenal mineralisation and calcinosis cutis (Huntley and others 1982, Penninck and others 1988). Although the specificity of such radiographic findings is high, the sensitivity of conventional radiography is very low. Only 56 per cent of adrenal masses were diagnosed on radiographs of cases where marked adrenomegaly and calcification was present (Penninck and others 1988).

On the other hand, abdominal ultrasonography has become the gold standard for adrenal imaging in only one decade. Standards for normal and enlarged adrenal glands are established (Grooters and others 1994, Barthez and others 1995, Hoerauf and Reusch 1995) and even the detection of atrophied adrenal glands has been shown recently (Hoerauf and Reusch 1999a,b). Consequently, ultrasonography is superior to radiography for imaging the adrenal glands and should therefore be regarded as the imaging modality of choice. Computed tomography is an alternative and equally reliable method which offers the additional opportunity to image pituitary macroadenomas, but requires general anaesthesia (Bailey 1986, Emms and others 1986, Reusch and others 1999).

Conclusions

Abdominal radiography has only a limited potential in the diagnostic work-up of suspected hyperadrenocorticoid dogs. It may be used if abdominal ultrasonography is unavailable or not suitable, owing to large amounts of intestinal gas. Clinicians should be aware of the lack of specificity of radiographic findings in endocrine conditions and obesity. Radiographs will rarely help to distinguish such conditions.

References

ARDRAN, G. M. (1951) Bone destruction not demonstrable by radiography. British Journal of Radiology 94, 107-109

BACHMAN, A. L. & SPROUL, E. E. (1955) Correlation of radiographic and autopsy findings in suspected metastasis in the spine. New York Academy of Medicine 31, 146-148

BAILEY, M. Q. (1986) Use of X-ray-computed tomography as an aid in localisation of adrenal masses in the dog. Journal of the American Veterinary Medical Association 188, 1046-1049

BARTHEZ, P. Y., NYLAND, T. G. & FELDMAN, E. C. (1995) Ultrasonographic evaluation of the adrenal glands in dogs. Journal of the American Veterinary Medical Association 207, 1180-1183

BERRY, C. R., ACKERMAN, N. & MONCE, K. (1994) Pulmonary mineralization in four dogs with Cushing's syndrome. Veterinary Radiology & Ultrasound 35, 10-16

COCKETT, P. A. (1986) Radiographic anatomy of the canine liver: simple measurements determined from the lateral radiograph. Journal of Small Animal Practice 27, 577-589

CURRY, T. S., DOWDEY, J. E. & MURRY, R. C. (1990) The radiographic image. In: Christensen's Physics of Diagnostic Radiology, 4th edn. Philadelphia, Lea & Febiger. pp 196-218

DÄMMRICH, K. (1959) Ein Beitrag zur Osteoporose endokrinen Ursprungs beim Hund. Berliner und Münchner Tierärztliche Wochenschrift 72, 340-343

DÄMMRICH, K. (1962) Die Beeinflussung des Skeletts durch Hormone der Nebennierenrinde unter besonderer Berücksichtigung des 'Morbus Cushing' beim Hund. Berliner und Münchner Tierärztliche Wochenschrift 75, 331-343

EDELSTYN, G. A., GILLESPIE, P. J. & GREBBELL, F. S. (1967) The radiological demonstration of osseous metastases: experimental observations. Clinical Radiology 18, 158-162

EMMRICH, J. & REISERT, P. M. (1967) Das Röntgenbild der Osteopathien endokriner Genese. Röntgen-Blätter 20, 1-13

EMMS, S. G., WORTMAN, J. A., JOHNSTON, D. E. & GOLDSCHMIDT, M. H. (1986) Evaluation of canine hyperadrenocorticism, using computed tomography. Journal of the American Veterinary Medical Association 189, 432-439

GROOTERS, A. M., BILLER, D. S., MIYABAYASHI, T. & LEVEILLE, R. (1994) Evaluation of routine abdominal ultrasonography as a technique for imaging the canine adrenal glands. Journal of the American Animal Hospital Association 30, 457-462

HOERAUF, A. & REUSCH, C. (1995) Darstellung der Nebennieren mittels Ultraschall: Untersuchungen bei gesunden Hunden, Hunden mit nicht-endokrinen Erkrankungen sowie mit Cushing-Syndrom. Kleintierpraxis 40, 351-360

HOERAUF, A. & REUSCH, C. (1999a) Ultrasonographic characteristics of both adrenal glands in 15 dogs with functional adrenocortical tumors. Journal of the American Animal Hospital Association 35, 193-199

HOERAUF, A. & REUSCH, C. (1999b) Ultrasonographic evaluation of the adrenal glands in six dogs with hypoadrenocorticism. Journal of the American Animal Hospital Association 35, 214-218

HUNTLEY, K., FRAZER, J., GIBBS, C. & GASKELL, C. J. (1982) The radiological features of canine Cushing's syndrome: a review of forty-eight cases. Journal of Small Animal Practice 23, 369-380

LACHMAN, E. (1955) Osteoporosis: the potentialities and limitations of its roentgenologic diagnosis. American Journal of Roentgenology 74, 712-715

LAMB, C. R. (1990) The double cortical line: a sign of osteopenia. Journal of Small Animal Practice 31, 189-192

LEE, R. & LEOWIJUK, C. (1982) Normal parameters in abdominal radiology of the dog and cat. Journal of Small Animal Practice 23, 251-269

MANTIS, P., LAMB, C. R. & BOSWOOD, A. (1998) Assessment of the accuracy of thoracic radiography in the diagnosis of canine chronic bronchitis. Journal of Small Animal Practice 39, 518-520

NORRDIN, R. W., CARPENTER, T. R., HAMILTON, B. F. & BREWSTER, R. D. (1988) Trabecular bone morphometry in beagles with hyperadrenocorticism and adrenal adenomas. Veterinary Pathology 25, 256-264

OWENS, J. M. & BIERY, D. N. (1999) Spine. In: Radiographic interpretation for the Small Animal Clinician, 2nd edn. Baltimore, Williams & Wilkins. pp 127-146

PANCIERA, D. L. (1998) Canine hypothyroidism. In: BSAVA Manual of Small Animal Endocrinology, 2nd edn. Eds A. G. Torrance and C. T. Mooney. Cheltenham, BSAVA. pp 103-114

PENNINCK, D. G., FELDMAN, E. C. & NYLAND, T. G. (1988) Radiographic features of canine hyperadrenocorticism caused by autonomously functioning adrenocortical tumors: 23 cases (1978-1986). Journal of the American Veterinary Medical Association 192, 1604-1608

PETERSON, M. E. (1984) Hyperadrenocorticism. Veterinary Clinics of North America: Small Animal Practice 14, 731-749

REUSCH, C. E., STEFFEN, T. & HOERAUF, A. (1999) The efficacy of L-deprenyl in dogs with pituitary-dependent hyperadrenocorticism. Journal of Veterinary Internal Medicine 13, 291-301

SIFFERT, R. S. (1967) Trabecular patterns in bone. American Journal of Roentgenology 99, 746-755

TICER, J. W. (1977) Roentgen signs of endocrine disease. Veterinary Clinics of North America 7, 465-486