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Age Determination in young Keeshound Puppies Using a simple Radiographic Study of the Radius, Ulna and Carpus

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Abstract

Radiographic features in the normal development of the radius, ulna and carpal bones from birth to maturity in medium size dogs are reported in order to have an important tool for determining a dog's age from radiographs. Eight (male and female) Keeshounds from the ages of one day to eleven months were studied to determine the normal radiographic development of the radius, ulna and carpal bones. At birth, diaphyses of the radius and ulna are present. The epiphyses and carpal bones are absent radiographically because they are composed of cartilaginous tissue. Two weeks later, ossification centers of the accessory carpal bone and lateral humeral condyle can be seen radiographically. At three weeks of age, the ossification center of the proximal radial epiphysis is barely seen. At one month, the ossification center of the medial humeral condyle is present. At six weeks (1 ½ months), the ossification center of the distal ulnar epiphysis is present (21 days later than the distal radial epiphysis). By eight weeks of age (two months), all four epiphyses are radiographically present. At fourteen weeks of age (3.5 months), the distal ulnar epiphysis is completely developed. By twenty weeks (five months), the radius and ulna are approximately the same diameter at the level of the mid diaphysis.

Key words: Development, ulna, radius, age, radiographycally.

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Determinación de la edad en cachorros jóvenes *Keeshound* utilizando un estudio radiológico simple del radio, ulna y carpo

Resumen

Las características radiográficas en el desarrollo del radio, ulna y huesos carpeanos desde el nacimiento hasta la adultez en perros de raza de mediano tamaño son reportadas con el propósito de contar con una herramienta importante para determinar la edad del perro desde el punto de vista radiográfico. Ocho perros (machos y hembras) de la raza *Keeshound* fueron utilizados desde un día de edad hasta los once meses con el propósito de determinar el desarrollo radiográfico normal del radio, ulna y huesos del carpo. Al nacer las diàfisis de la ulna y radio están presentes radiográficamente. Las epífisis y huesos del carpo están ausentes radiográficamente. Los centros de osificación del hueso carpo accesorio y el condilo lateral del húmero se observan radiográficamente. A las tres semanas de edad el centro de osificación de la epífisis proximal del radio se observa levemente. Al mes de edad el centro de osificación del condilo medial del húmero está presente. A las seis semanas de edad el centro de osificación de la epífisis distal de la ulna está presente (21 días mas tarde que la epífisis distal del radio). A las ocho semanas de edad (2 meses) todas las cuatro epífisis están radiográficamente presentes. A las 14 semanas (3 meses y medio) la epífisis distal de la ulna está desarrollada completamente. A las 20 semanas (5 meses) el radio y la ulna son aproximadamente igual en diámetro a nivel de la mitad de sus diafisis.

Palabras clave: Desarrollo, ulna, radio, edad, radiográficamente.

Introduction

The ulna is the longest bone of the dog. In giant dogs its blood supply from the nutrient artery is one straight small artery which gives off very few and very short branches at the level of the distal metaphysis. The nutrient artery enters the ulna in the proximal metaphysis. In contrast, the adyacent radial nutrient artery enters the bone almost at the level of the mid diaphysis and gives off several tortuous branches which serve the distal metaphysis over a broad area [10].

During growth the ulnar diaphysis is located more proximally than the radius in relationship to the carpus; its distal epiphysis has a styloid shape and appears radiographically between 14 to 28 days later than the radial epiphysis. It has to grow faster than the radius if longitudinal growth of these two bones is to be proportional. When some giant breed dogs experience their fastest longitudinal growth rate, the metaphyseal vessels of the ulna are not long enough in comparison with the radius to maintain proportional growth. Anatomically the ulna differs from the radius. The distal epiphysis is conical in shape, long, and grows much more actively than that of the distal radius. The proximal ulnar physis is relatively inactive and contributes very little to the ulnar length. During growth the physes (growth cartilage) are seen as radiolucent lines as they are composed of cartilage which is not a radiopaque tissue [7]. The physis is the part of the bone where length is added. During active ossification the cartilage cells proliferate, form columns, mature, hypertrophy, become calcified, and disintigrate, leaving a straight strip of calcified cartilage matrix where new bone is deposited by the osteoblasts. These new zones of calcified cartilage matrix correspond to the metaphysis. During growth the metaphyses are very radiopaque. The distal metaphyses of radius and ulna are bigger than the proximal ones. They contribute 85% of the total length of the ulna and 70% of the total length of the radius. There is much more active cell proliferation and production of new primary trabeculae in these areas [10].

In the embryo of the dog and cat, bone originates by intramembranous ossification of connective tissue cells or by enchondral bone formation from a hyaline cartilage mold. Bones of the calvarium for the most part arise from intramembranous ossification. Long bones of the body, on the other hand, arise by enchondral formation from cartilage. In the very early stages of ossification centers of bone development may begin from intramembranous ossification and later become enchondral [13, 14, 15].

In the formation of a long bone the hyaline cartilage model develops three centers of ossification: one in the middle of the diaphysis, and one in each of two epiphyses.

The cartilage cells around the centers mineralize and are converted to bone over an everwidening area until the diaphysis is completely ossified. Circumferential growth then continues from the cambium layer of the periosteum but at a much slower rate. Growth is by apposition and resorption, and although this continues throughout life, it is at a far slower pace during maturity. Longitudinal growth is controlled by the growth plates (physes) located between the diaphysis and epiphysis. These remain active throughout the growing period by producing cartilage cells that are in turn converted to bone cells. Eventually the physes become ossified and longitudinal growth of the bone ceases [13, 14].

Some reports in the Veterinary literature have called attention to the normal and abnormal anatomical development, metabolic diseases, abnormal biomechanics, and trauma that have effected the growth and appearance of the forelegs [1, 2, 3, 4, 6, 11]. The approach to the diseases that occur as a result of these abnormalities are best studied by two methods: the x-ray and the microscope. Information on bone growth under normal and abnormal stresses is a subject requiring study in depth [5, 8, 9, 10, 12].

Material and Methods

Eigth (males and females) Keeshound dogs were selected for this study. In this experiment the dogs that were used were medium sized dogs of slow growth rate from the cardiology research center of the School of Veterinary Medicine, University of Pennsylvania. United States of America. They were radiographied at a week interval from birth to maturity with the purpose to make a descriptive study.

Radiographic Examination

A 300 mA/126 kVp and a 200 mA 120 kVp x-ray machines were used for radiography. Craniocaudal and lateral radiographs of the forelimbs were taken using a standardized technique chart. Intensifying screens were used for the live animals. Kodak nonscreen high detail AA Industrial film was used for the post-mortem radiographic studies.

The radiographs were developed in a Kodak X-omat MGN 90 second developing system and in a manual technique. They were interpreted on a conventional view box.

Results

One week of age (Figure 1). In both views lateral and antero-posterior radiographs. The carpal bones and radial and ulnar epiphyses are not visible radiographically as they are composed of cartilaginous tissue. In this medium size breed (Keeshound) the ossified diaphysis of the ulna is a

Figure 1. a, b. one week of age. the epiphyses and carpal bones are not visible because they are composed of cartilage tissue. c, d. two weeks of age. the ossification centers of the accesory carpal bone and lateral humeral condyle are seen.

Figure 2. a, b. three weeks af age. four ossification centers of the carpal bones are visualized. the proximal radial epiphysis is barely seen (arrow). c, d. four weeks of age. ossification center of the medial humeral condyle is present (black arrow).

Figura 3. a, b. six weeks of age. the ossification center of the distal ulnar epiphysis is present (arrow). (21 days later than the distal radial epiphysis). c. magnification of the carpal joint shows the first and second row of carpal bones completely.

much as 0.4 to 0.5cm longer than the radius. The metaphyses of the radius and ulna are wider than the midshaft of the diaphysis. In the ulna the proximal metaphysis is slightly wider than the distal one.

Two weeks of age (Figure 1). The ossification center of the dorsal component of the accessory carpal bone is well seen. The ossification centers of the accessory carpal bone and of lateral humeral condyle (C) white arrows) is barely visible. The metaphyses are more opaque than the diaphyses.

Three weeks of age (Figure 2). The ossification centers of four carpal bones are present: two of the proximal row (radial and accessory (A); two of the distal row (first and fourth (B). The accessory carpal bones is the largest in the proximal row and the fourth the largest in the distal row. The ossification center of the distal radial epiphysis is very well outlined (C,D); the proximal one is barely seen (C). The lateral condyle of the humerus is seen clearly (black arrow (A).

Four weeks of age (Figure 2). (One month). The ossification center of the proximal radial epiphysis is very well outlined. The distal radial metaphysic is much wider than that of the ulna. Very early mineralization of the medial humeral condyle is visible at this time.

Six weeks of age (Figure 3). The ossification center of the distal ulnar epiphysis first becomes visible at this age.

Seven weeks of age (Figure 4). The mineralized nucleus of the distal ulnar epiphysis as a rectangular shape and is about a third of third of its mature length. The caudal ossification center (cap) of the accessory carpal bone is visible.

Eight weeks of age (Two months) (Figure 4). The ossification centers of the proximal ulnar epiphysis as well as the medial epicondyle of the humerus become visible radiographically. At this age (two months) the ossification centers of all four epiphyses are well outlined radiographically.

Ten weeks of age (Figure 5). The distal ulnar epiphysis has a styloid shape and is about two-thirds of its total adult size. Two of the bones from the proximal row of the carpus (radial and intermediate) become partially fused. The two ossification centers of the accessory carpal bone are very well mineralized.

Figura 4. a,b. seven weeks of age. the caudal ossification center (cap) of the accessory carpal bone is barely seen (arrow). c,d. eight weeks of age. the ossification centers of the proximal ulnar epiphysis and the medial epicondyle of the humerus become visible (arrows). all four epiphyses are radiographically present.

Fourteen weeks of age (Figure 5) (3 ½ months). The distal ulnar epiphysis is developed completely. The two ossification centers of the accessory carpal bone are now fully fused as are the radial and intermediate carpal elements.

Sixteen weeks of age (Four months) (Figure 6). The distal tip of the ulnar styloid process is bowed medially and articulates with the ulnar carpal bone. The medial aspect of the distal radial epiphysis extends distally to articulate with the radial carpal bone. The distal ends of the radius and ulna are located at the same level.

Twenty weeks of age (Five months) (Figure 6). The radius and ulna are approximately the same diameter at the level of the mid diaphysis.

Six to seven months. 80 to 90% of the bone length is present. The ulnar mid-diaphysis is much thinner than the radius.

Ten to eleven months (Figure 7). The full length of the bones is present. The metaphyses have remodelled. All four physes are closed. The metaphyses have the same density as the remainder of the bone.

Figura 5. a, b. ten weeks of age. the two ossification centers of the accessory carpal bone are very well outlined (arrows). the radial carpal bone and the intermediate carpal element are partially fused. c,d. fourteen weeks of age. the distal ulnar epiphysis is completely developed. the accessory carpal bone ossification centers as well as the radial carpal bone are fused.

The mature dog. At 11 months the mid-diaphyseal diameter of the mature radius is almost twice that of the mature ulna. During rapid growth (the first 3 ½ months) the ulna is greater in diameter than the radius.

During growth the physes (growth plates) are seen as radiolucent lines as they are composed of cartilage which is not a radiopaque tissue. The physis is the part of the bone where length is added.

These new zones of calcified cartilage matrix correspond to the metaphysic. During growth the metaphyses are very radiopaque. The distal metaphyses of the radius and ulna are bigger than the proximal ones. They contribute 85% of the total length of the ulna and 70%of the total length of the radius. There is much more active cell proliferation and production of new primary trabeculae in these areas. Bone specimens were observed under ultraviolet light 2 months after the injection of tetracycline. No fluorescence was noted.

Figura 6. a, b. sixteen weeks of age (4 months). the styloid process of the ulnar epiphysis is bowed to articulate with the ulnar carpal bone. the radius and ulna are about the same diameter. c,d. five months of age. the radius and ulna are similar in diameter. the radius, ulna, and carpal bones are very well aligned to prevent any type of rotation.

Figura 7. Eleven months of age (adult dog). all the physes are closed (arrow), the full length of the bones is present. the ulna is much thinner than the radius.

Discussion

A radiographic record of the anatomical development of the canine radius, ulna and carpal bone has been described from birth to maturity in medium size dog. An attempt should now be made to relate the importance of normal development as an important tool for age determination and others circumstances that lead to the alteration of the straight, graceful appearance of the forelegs. To understand the normal and abnormal appearance, a knowledge of the developmental anatomy and functions of the skeleton is essential. During active ossification the cartilage cells proliferate, form columns, mature, hypertrophy, become calcified, and disintegrate, leaving a traight strip of calcified cartilage matrix where new bone is deposited by the osteoblasts. The radius and ulna because of their rapid growth, are often the first bones to be affected if an abnormality occurs. These two bones differ anatomically and their growth plates develop at different rates.The radiograph is the best tool for demonstrating the contours, density, and others characteristics of the skeleton indicative of disease and injury.

Conclusion

The radiographic features of the front legs of the normal dog, according to chronological development are as follows: At birth, the carpi and epiphyses are compose of cartilage, and are not visible radiographically in all breeds.

At twelve to fourteen days of age the ossification center of the dorsal components of the accessory carpal bone and the lateral humeral condyle appears. By three week of age, the epiphyses are fully out lined radiographically except for the distal ulnar which appears several days later and is completely developed as an styloid shape at 14 weeks of age (3 ½ months). At the height of enchondral ossification (four to five months) the diameter of both the radius and ulna increases remarkably at the metaphyses. In the mature dog the diameter of the radius is twice that of the ulna.

During growth the ulna has a greater diameter than the radius. At six to seven months of age, 90 per cent of the enchondral growth in length has occurred and the radius and ulna are then about equal in diameter. By the ten to fourteen months, the metaphyses have remodelled and the cortices now have extended the full length oh the bones.

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