Use of fetal skeletal mineralization for prediction of parturition date in cats

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Objective—To determine the relationship between parturition date and fetal skeletal mineralization detected radiographically in cats.

Design—Prospective clinical trial.

Animals—31 queens and their 49 pregnancies.

Procedure—Seventeen pregnant queens were radiographed with a computed radiography system every 2 to 3 days from 1 week after pregnancy was identified by abdominal palpation until parturition. Radiographs were evaluated to determine the first identifiable mineralization of 16 bony structures and teeth during each pregnancy. This information was used to establish a table of expected parturition dates on the basis of fetal mineralization. Single radiographs from an additional 32 pregnant cats were evaluated, and predictions of parturition dates were made on the basis of the mineralization table.

Results—Mineralization was first detected 25 to 29 days prior to parturition (dpp). Mineralization was determined for the spinal column (22 to 27 dpp), skull (21 to 27 dpp), ribs (20 to 25 dpp), scapula (17 to 24 dpp), humerus (20 to 24 dpp), femur (19 to 23 dpp), radius (15 to 22 dpp), tibia (15 to 21 dpp), ulna (5 to 21 dpp), pelvis (8 to 20 dpp), fibula (0 to 17 dpp), tail (8 to 16 dpp), metacarpals and metatarsals (3 to 14 dpp), phalanges (0 to 11 dpp), calcaneus (0 to 10 dpp), and teeth (1 to 6 dpp). Date of parturition was predictable within 3 days in 75% of cats.

Conclusions and Clinical Relevance—Identification of bony structures in the fetus is useful in estimating the time to parturition in queens. (*J Am Vet Med Assoc* 2003;223:1614–1616)

Radiography is commonly used for detection of pregnancy in companion animals. It is useful for confirming pregnancy, as well as determining the number of fetuses. Radiographs may also be used to detect fetal death and completion of parturition. Knowledge of gestational age is often important in breeding programs. This may allow preparation for parturition, including scheduling of Caesarian sections and preventing nursing in kittens at risk for neonatal isoerythrolysis. Although guidelines for estimating date of parturition on the basis of fetal skeletal mineralization are available for use in dogs, the authors are unaware of similar guidelines for cats. The purpose of this study was to establish guidelines for estimating time to parturition on the basis of skeletal mineralization of fetuses by radiography.

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Materials and Methods

Cats—Thirty-one queens were included in the study. Both nulliparous (n = 14) and multiparous (17) queens of ages 0.6 to 5 years were included. The cats were housed with a male of proven fertility until pregnancy was identified by use of abdominal palpation, after which they were housed in individual runs. Litter size varied from 2 to 7 kittens/pregnancy.

Procedures—Seventeen colony-bred pregnant domestic shorthair cats were radiographed 3 times/wk until parturition, beginning 1 week after pregnancy was detected via palpation. Cats were gently restrained without sedation in right lateral recumbency for imaging. By use of a computed radiography system,[a] all cats were evaluated with a single technique (table top, film-focal distance 36 inches, 300 mA, 1/300 seconds, 60 kV). Films were evaluated by 2 radiologists (SMN, JPG) who were unaware of the stage of pregnancy. Detectable mineralization of the spinal column, skull, ribs, scapula, humerus, femur, radius, tibia, ulna, pelvic bones, fibula, caudal vertebrae (tail), metacarpals-metatarsals, phalanges, calcaneus, and teeth in any fetus was recorded. Results were expressed as the first identifiable mineralization of these structures in **days prior to parturition (dpp)**. The data were used to construct a table for prediction of parturition date.

Single radiographs of 32 pregnant cats (30 domestic shorthair, 1 Scottish Fold, 1 Maine Coon) were then evaluated by a radiologist (SMN) who was unaware of the actual date of parturition. The date of parturition was predicted via mean dates of mineralization in the table for all visible fetal bones. The correlation of predicted date of parturition to actual parturition date was analyzed by use of the Spearman rank order test. A value of $P < 0.05$ was considered significant.

Results

All of the cats had uterine enlargement at the time of the first radiographs, but none had fetal skeletal mineralization. Skeletal mineralization was first noted at 25 to 29 dpp, but it was not possible to determine which bones were mineralized. The spinal column and skull were the first recognizable features (**Fig 1**), followed by ribs, scapula and humerus, femur, radius, tibia and ulna (**Fig 2**), pelvis, fibula, tail, metacarpal-metatarsal bones (**Fig 3**), phalanges, calcaneus (**Fig 4**), and teeth (**Fig 5**).

First detectable mineralization of the fetus and mineralization of the humerus and femur occurred over the shortest period (4 days) in all pregnancies, whereas mineralization of the ulna was the most variable finding (range, 16 days; **Table 1**). The metacarpals-metatarsals, phalanges, calcaneus, and teeth mineralized last.

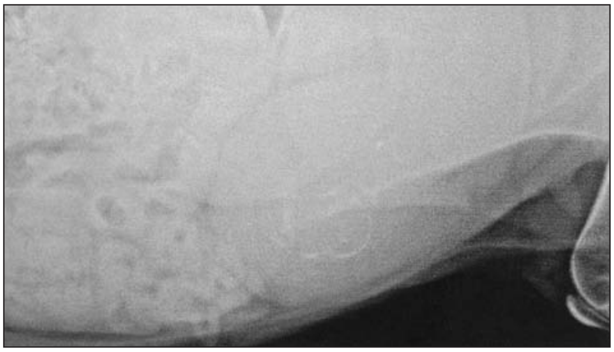

Figure 1—Radiographic appearance of fetal mineralization in a pregnant cat 23 days prior to parturition (dpp). The skull, vertebral column, and humerus are visible in the 3 fetuses.

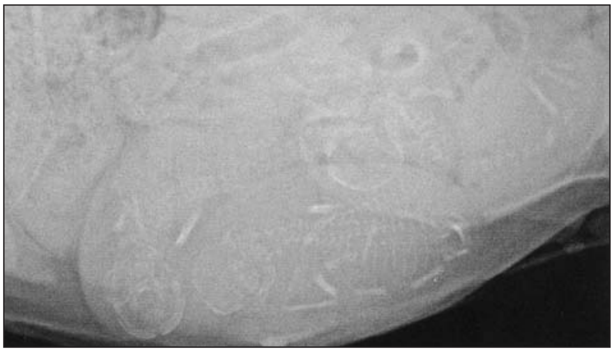

Figure 2—Radiographic appearance of fetal mineralization in a pregnant cat 16 dpp. The ribs, scapula, femur, radius, ulna, tibia, pelvis, caudal vertebrae (tail), and fibula are visible.

Figure 3—Radiographic appearance of fetal mineralization in a pregnant cat 9 dpp. The metacarpals and metatarsals are visible.

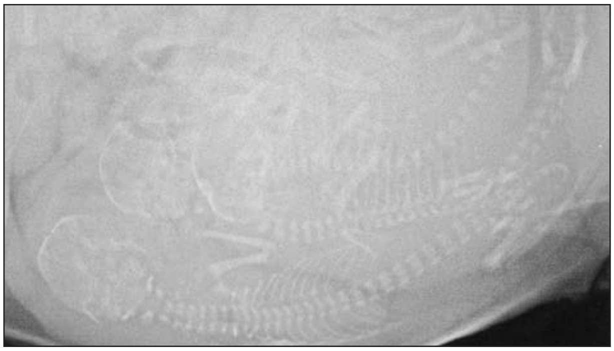

Figure 4—Radiographic appearance of fetal mineralization in a pregnant cat 4 dpp. The calcaneus and phalanges are visible.

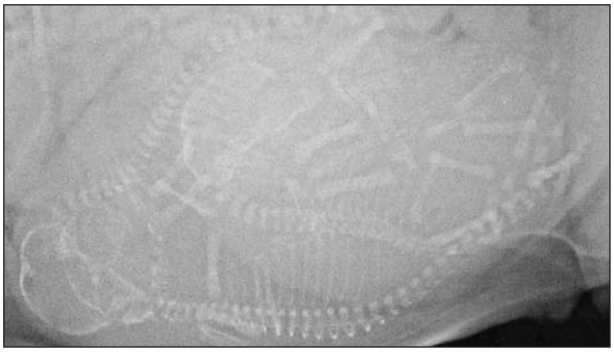

Figure 5—Radiographic appearance of fetal mineralization in a pregnant cat 2 dpp. The teeth are visible.

Table 1—Number of days prior to parturition for first radiographic detection of fetal skeletal mineralization of various bones and teeth in 17 pregnant cats.

	First day of visible mineralization	
Structure	Mean ± SD	Range
General mineralization	26 ± 1	25–29
Vertebral column	24 ± 1	22–27
Skull	22 ± 1	21–27
Ribs	22 ± 2	20–25
Scapula	20 ± 2	17–24
Humerus	20 ± 1	20–24
Femur	21 ± 1	19–23
Radius	19 ± 2	15–22
Tibia	19 ± 1	15–21
Ulna	17 ± 2	5–21
Pelvis	19 ± 1	8–20
Fibula	13 ± 3	0–17
Tail	15 ± 2	8–16
Metacarpals and metatarsals	8 ± 3	3–14
Phalanges	6 ± 3	0–11
Calcaneus	6 ± 3	0–10
Teeth	2 ± 1	1–6

Parturition occurred in 10 cats in which mineralization of the fibula, phalanges, or calcaneus was never apparent.

The schedule of mineralization was used to predict parturition date in 32 pregnant queens. The date of parturition predicted from single computed radiography films was within 3 days of the actual date in 75% of cats and within 7 days in all cats. The correlation of the predicted date to the actual date was significant ($P = 0.001$, $r = 0.78$). Litter size did not affect the accuracy of parturition prediction ($P = 0.8$).

Discussion

Estimation of parturition date in cats on the basis of breeding dates is problematic because of the variability in the duration of gestation (56 to 71 days)[1,2] and behavioral estrus (1 to 21 days).[2] Cats are induced ovulators, and it is believed that multiple copulations increase the peak of the luteinizing hormone surge, which ultimately triggers ovulation.[2] If allowed, queens may breed many times during behavioral estrus, and it is not possible to determine which copulatory events are associated with ovulation and conception. Thus, the observation of breeding is not necessarily a reliable indicator of conception.

The radiographic identification of certain bony structures was useful for predicting parturition date, while the development of other structures was more variable. Mineralization of the humerus and femur developed over the narrowest range, whereas the ulna, fibula, and pelvic bones had the most variable mineralization times and were not good indicators for predicting parturition. The fibula, calcaneus, and phalanges never mineralized in some pregnancies; reliance on mineralization of these structures could lead to overestimation of parturition date in late gestation.

Previous reports[3,4] have estimated gestational age on the basis of radiographic findings. However, none evaluated cats with a known date of parturition. In 1 study,[3] euthanatized pregnant queens were radiographed, fetuses were removed, and crown-rump length measurements were used to estimate gestational age. The uterus was visibly enlarged from days 25 to 35 of gestation, and the first visible mineralization occurred at 38 days. The bones of the vertebral column, skull, scapula, humerus, and femur appeared first, followed by the radius, ulna, and pelvis. On estimated day 49 of gestation, the metacarpal and metatarsal bones became visible, followed by the phalanges and teeth. This is the same general sequence of mineralization observed in our study; however, no direct comparison can be made, since neither breeding date nor date of parturition were available in the previous report.[3] In a second report,[4] cats with known breeding dates were serially radiographed during early pregnancy. Uterine swellings were first apparent on day 17 and visible in all cats by day 21. Mineralization was first detected on day 38 of pregnancy, but the pattern of bony development was not described, nor was any correlation made with date of parturition.

Detection of pregnancy and prediction of parturition by ultrasonography have also been reported in cats.[5,6] Compared with radiography, which relies on fetal mineralization to confirm pregnancy, ultrasonography is more sensitive during early pregnancy. In 1 study,[5] uterine enlargement was detected 4 to 14 days after breeding, and gestational sacs were observed by 11 to 14 days, but no attempt was made to correlate ultrasonographic findings with date of parturition. In a subsequent study,[6] ultrasonographic measurement of fetal head and body diameters predicted the date of parturition within 2 days in 7 of 8 cats examined.

Detectable mineralization in cats was earlier than reported in dogs, in which skeletal elements were first identified 20 to 21 dpp.[7,8] The sequence of mineralization of feline bony structures was similar to that reported in dogs. In Beagles, the vertebral column, skull, and ribs appeared first (20 to 22 dpp), followed by the scapula, humerus, and femur (15 to 18 dpp); radius, ulna, tibia, and pelvis (9 to 13 dpp); fibula, tail, calcaneus, and feet (2 to 9 dpp); and teeth (3 to 8 dpp).[8] Although the order of mineralization was comparable in cats and dogs, mineralization of equivalent bony structures was visible from 6 to 11 days earlier in cats. It is unknown whether mineralization actually develops earlier in feline fetuses, the smaller size of cats makes radiographic detection of mineralization possible at earlier stages, or the computed radiography system used in this study was more sensitive for fetal mineralization than conventional film-screen systems used in a previous study.[9]

The nutritional status, size, and positioning of patients may affect the radiographic identification of skeletal structures in the fetus. In 1 study,[4] it was reported that pregnancy was identified earlier in younger, thinner cats than in older, fatter individuals, in which uterine swellings were obscured. Results of a study of radiographic pregnancy detection in dogs suggested that fetal bony structures appeared later in dorsoventral radiographic views than in lateral views because of the increased radiopacity of the abdominal contents in the dorsoventral views.[7] Only lateral views were obtained in our study.

It should also be considered that breed and litter size may affect fetal development and prediction of parturition date. Nearly all of the cats used in this study were colony-bred domestic shorthairs; only 2 were purebreds. Although litter size did not affect accuracy of parturition prediction in this study, large litters may complicate identification of individual bones because of overlapping of the fetuses.

Parturition date can be accurately predicted within 3 days on the basis of the identification of key fetal structures in most cats. The sequence of mineralization of the cat fetus is similar to that of dogs but becomes radiographically apparent approximately 1 week earlier.

[a]Fuji computed radiography system, FujiFilm Medical Systems, USA Inc, Elmsford, NY.

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