Original Article

Fetal Head Diameter in Dogs and Cats Measured by Radiography and Ultrasonography

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Abstract

In abdominal radiography, the measurement of fetal biparietal diameter or head diameter (HD) and maternal pelvic diameter are commonly used to predict risk of dystocia due to relatively oversized fetus. Besides fetal viability, fetal head measurement is also easy to perform with ultrasound. However, fetal HD measured from both techniques has never been compared. The objectives of the study were to compare and to find the correlations of fetal HD measured by both techniques at the last trimester of pregnancy in dogs and cats. Twenty four dogs and sixteen cats diagnosed for near-term parturition at Emergency Surgery Unit, Kasetsart University Veterinary Teaching Hospital during the period 2017-2018 were included in the study. Fetal HD was measured by both techniques on the same day. The correlations between the two techniques and linear regressions of HD were statistically analyzed. Radiographic measurements of fetal HD were larger than those measured by ultrasonography in both dogs ($p<0.0001$) and cats ($p<0.0001$). The correlations between the results of skull heads from abdominal radiographs and ultrasonogram were significantly correlated ($r = 0.73$ in dogs and $r = 0.94$ in cats, $p<0.0001$). Linear regression formulas were $y = 1.08x+0.13$ ($R^2 = 0.73$) in dogs and $y = 0.96x+0.30$ ($R^2 = 0.88$) in cats (y = HD by radiography and x = HD by ultrasonography). In conclusion, the formulas above can be used to estimate fetal HD between radiography and ultrasonography.

Keywords: cat, dog, fetal head diameter, radiography, ultrasonography

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Introduction

Radiography is a routine diagnostic technique in small animal practice. Radiographic diagnosis of pregnancy is possible after fetal mineralization, which occurs after approximately 43 days of pregnancy in dogs (Rendano *et al*., 1984), and 38 days in cats (Haney *et al*., 2003). This technique is limited, but can be used accurately in late pregnancy to detect the fetal skeleton. Radiography is not only for fetal skeletal detection in normal pregnancy, but it is also for dystocia evaluation. Dystocia can occur through maternal or fetal causes, such as fetal malposition, monstrosity, or anatomic abnormalities of the maternal pelvic canal. However, several causes of dystocia are not detected by imaging such as primary or secondary uterine inertias, fetal viability and early fetal death (Kinns and Nelson, 2018). It is also unable to detect fetal viability signs such as a heart beat or fetal movement unless long term fetal death has occurred, causing an abnormal or overlapped head (Spalding's sign), gas accumulation, or fetal skeleton deterioration.

Ultrasonography is another useful diagnostic tool available in small animal practice, including for use in obstetric cases. It is not only a valuable tool for pregnancy diagnosis, but it is also for monitoring the fetal development (Yeager *et al*., 1992; Zambelli *et al*., 2002) and assessing fetal viability. This is a reliable method for early pregnancy detection. Early pregnancy can be detected at 20-24 days after the last breeding day in dogs (Yeager *et al*., 1992), and at 15-20 days in cats by embryonic sac presentation (Hecht, 2008). Moreover, ultrasonography is used to determine time of parturition based on inner chorionic cavity and head diameter (HD), which provide accurate gestational timing in the first (between 19-37 days after LH peak) and second half (after 37 days) of pregnancy, respectively (Luvoni and Grioni, 2000; Beccaglia *et al*., 2016). Fetal HD was measured at biparietal diameter, and there have been some studies which predicted gestation day (GA) using fetal HD. The formulas used for small breed (up to 10 kg) and medium breed dogs (11-25 kg) are GA = [HD (mm)−25.11]/0.61 day before birth (Mattoon and Nyland 1995; Luvoni and Grioni, 2000; Lopate, 2008; Beccaglia *et al*., 2016), and GA = [15×HD (cm)] + 20 or GA = 21.08 + [14.88×HD (cm) – (0.11×HD^2)] (Mattoon and Nyland 1995; Luvoni and Grioni, 2000; Lopate, 2018), respectively. In fact, the ultrasonographic technique can be used to count the numbers of fetuses, but it may not be as accurate as radiography in the last trimester of pregnancy. Moreover, pelvic canal diameter cannot be measured by ultrasonography.

At the present time, there is no data available to compare fetal HD measured by radiography and ultrasonography. If there is a correlation of fetal HD measurement between both techniques, fetal HD measured from ultrasonography might help to estimate fetal head size when it is compared to pelvic inlet diameter measured from radiography, especially when fetal HD cannot be visualized, or proper HD cannot be measured from radiography.

The purposes of the study were to compare and find the correlation of fetal HD measured by radiography and ultrasonography in the last trimester of pregnancy in dogs and cats.

Materials and Methods

The study was conducted as a retrospective study. The data was collected from the Emergency Surgery Unit, Kasetsart University Veterinary Teaching Hospital during the period 2017-2018 including cases diagnosed with dystocia and receiving surgical treatment. In most cases the dogs and cats were diagnosed by radiography and ultrasonography within 24 hours before parturition. Breed, body weight (BW), litter size were recorded. From radiography, each fetal HD was measured at the widest portion of the parietal bone with both orbits visible to ensure that the image was symmetric either from the maternal ventro-dorsal (VD) or lateral views (Fig 1). The pelvic inlet is pointed at horizontal distance between the two medial tubera ischiadica on VD view (Eneroth *et al*., 1999) (Fig 2). Fetal HD and pelvic inlet diameters were radiographed with a 100-cm (40-inches) focal film distance (FFD) and 1.2 focal spot by digital radiographic machine (KXO_80S/EBT100A/DST 1000A, Toshiba™), and the scales were measured from diagnostic radiology imaging software Infinite™ program. Data was averaged from two measurements, and the percentage of fetal HD measured from each view was reported.

Transabdominal ultrasonography with a 9-13 MHz linear transducer (LOQIC E9, GE™) was performed on the dogs and cats in dorsal recumbency for fetal HD measurement. Preparation of the abdomen involved clipping the hair and applying acoustic coupling gel on the skin. The markers were placed at the widest portion of each fetal parietal bone with both orbits visible to ensure that the image was symmetric (Lopate, 2008) and biparietal diameter was measured as fetal HD. Both radiography and ultrasonography of each dog and cat were performed on the same day (Fig 3).

Fetal HD from dogs and cats were presented as mean±SD and compared with Wilcoxon signed rank test. The correlations and linear regression of fetal HD in dogs and cats between the two techniques were analyzed by RStudio Version 1.0153-©2009-2017. The significant difference was considered when p-value was less than 0.05.

Results

Twenty four dogs were included in the study. The breeds were Chihuahua (8), Pomeranian (4), French bulldog (3), Crossbreed (3), Shih Tzu (2), English bulldog (1), Poodle (1), Shiba (1) and Yorkshire (1). There were sixteen cats in the study, which were domestic shorthair (10), Maincoon (3), Persian (2) and Scottish Fold (1). Eighty four puppies from twenty three dogs, and fifty four kittens from fifteen cats were born. The data of total fetal numbers in one dog and one cat were missing. The mean±SD of BW, litter size, pelvic inlet diameter, fetal HD from two techniques, and percentage of fetal HD measured from VD and lateral views of abdominal radiograph were presented (Table 1). Data of BW in two dogs and one cat were missing.

Fetal HD measured from radiography were larger than those measured by ultrasonography in both dogs and cats ($p<0.0001$). The correlations were significance ($r = 0.73$ in dogs and $r = 0.94$ in cats, $p<0.0001$). Linear regression graphs and formulas from both techniques in dogs and cats were presented (Fig 4).

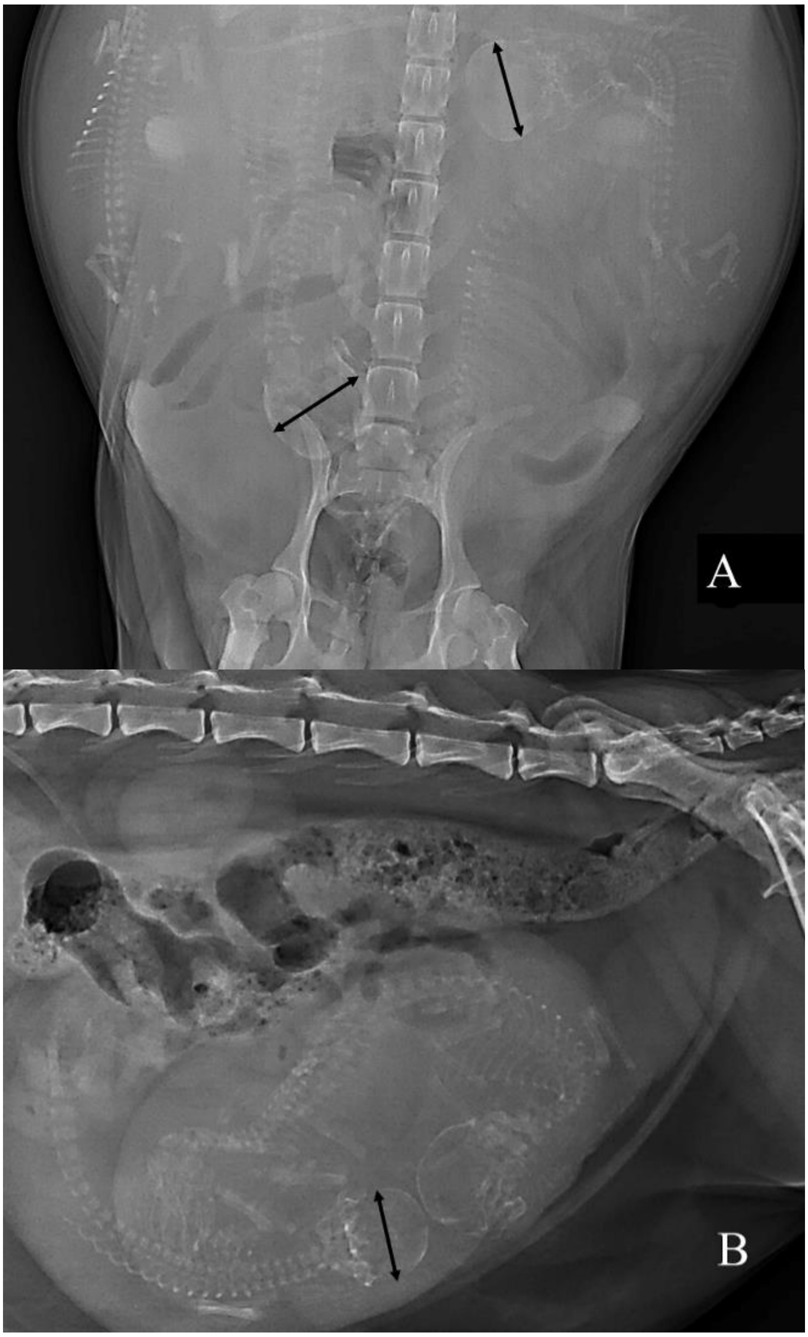

Figure 1 Fetal head diameters were measured at the widest portion of the parietal bone with both orbits visible in the last trimester of pregnancy from abdominal radiograph. Abdominal ventro-dorsal view in a dog (A), and lateral view in a cat (B) were demonstrated fetal HD measurements.

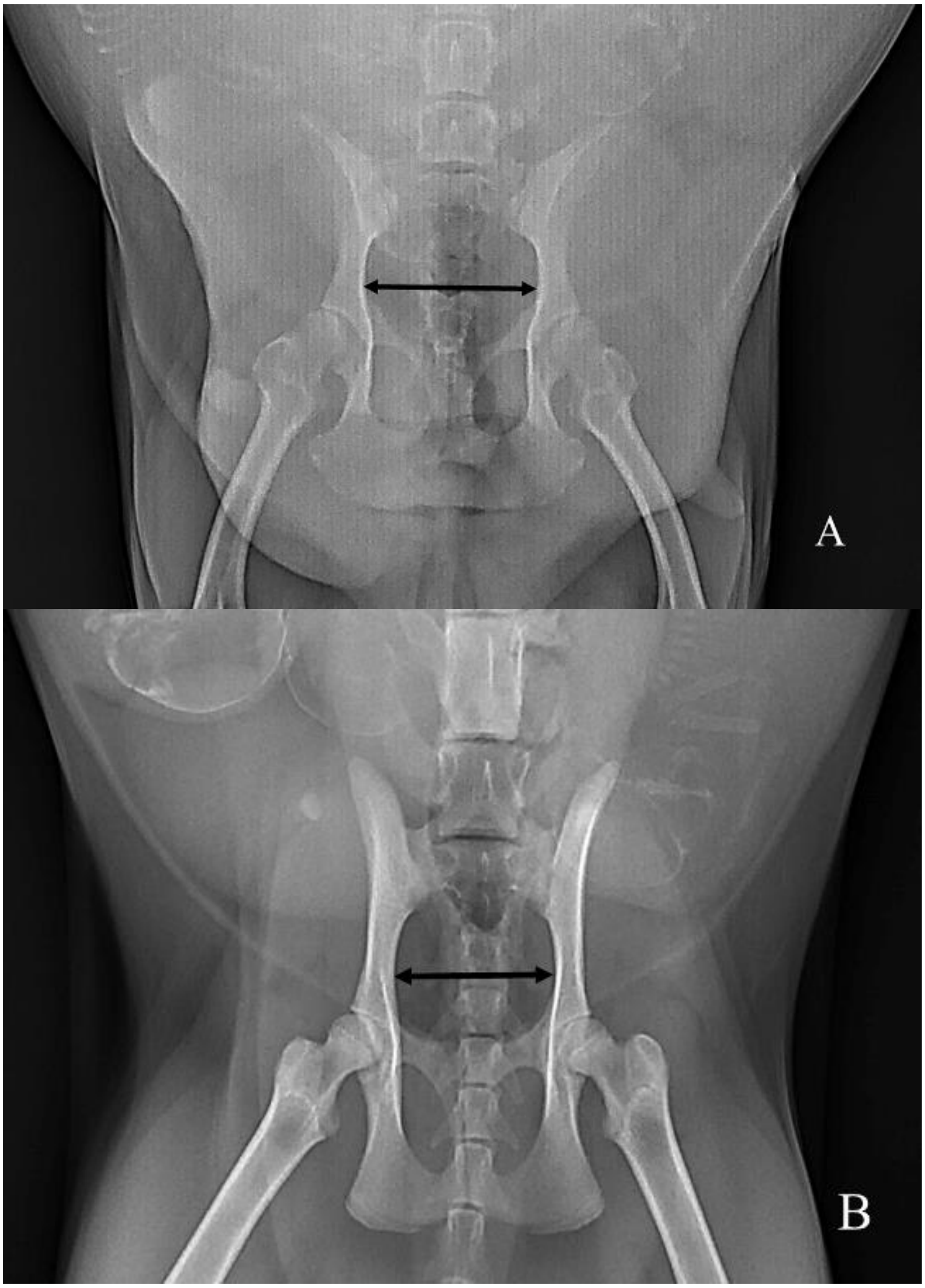

Figure 2 Pelvic inlet diameter measurement from a French bulldog (A) and a domestic shorthair cat (B) were pointed at horizontal distance between the two medial tubera ischiadica at pelvic on ventro-dorsal view of abdominal radiograph.

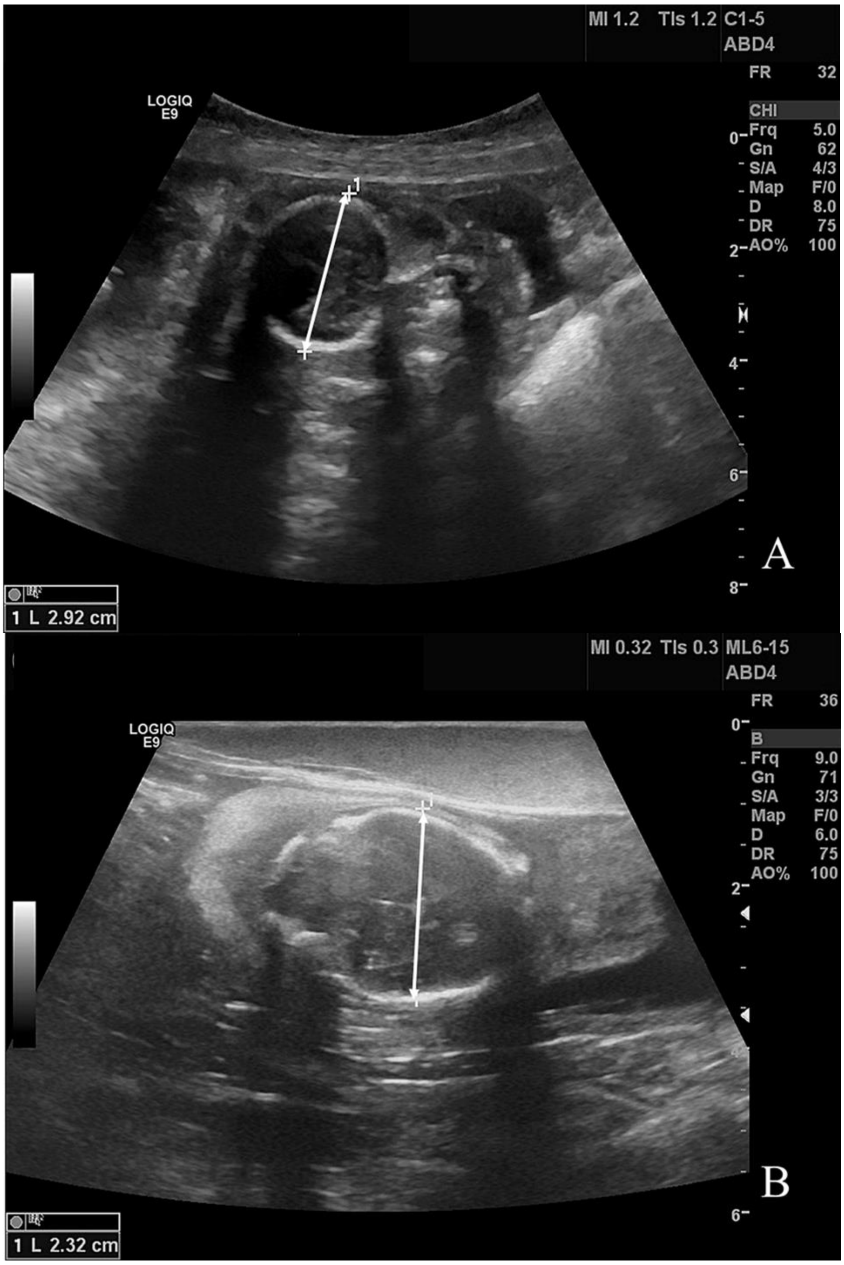

Figure 3 Fetal head diameters from a dog (A) and a cat (B) were measured on ultrasonogram at the widest portion of the parietal bone with both orbits visible in the last trimester of pregnancy.

Table 1 Mean±SD of body weight (BW), litter size, pelvic inlet diameter measured from radiography (XR), fetal HD from XR and ultrasonography (US) and percentage of fetal HD measured from VD and lateral views of XR from the last trimester of pregnant in dogs and cats were presented. Numbers of sample (n) from each parameter were shown in parenthesis.

Species	BW (kg)	Litter size	Pelvic inlet diameter (cm)	Fetal HD (cm)		Percentage of fetal HD measured from VD and lateral views of XR	
				XR	US	VD view	Lateral view
Dog	6.63±5.80 (n=22)	3.62±1.25 (n=23)	3.81±0.57 (n=23)	2.83±0.37 (fetal n=43)	2.50±0.29 (fetal n=47)	82.61% (19/23)	62.50% (15/24)
Cat	4.34±1.27 (n=15)	3.60±1.20 (n=15)	2.92±0.23 (n=16)	2.31±0.29 (fetal n=20)	2.09±0.28 (fetal n=31)	50.00% (8/16)	66.70% (10/15)

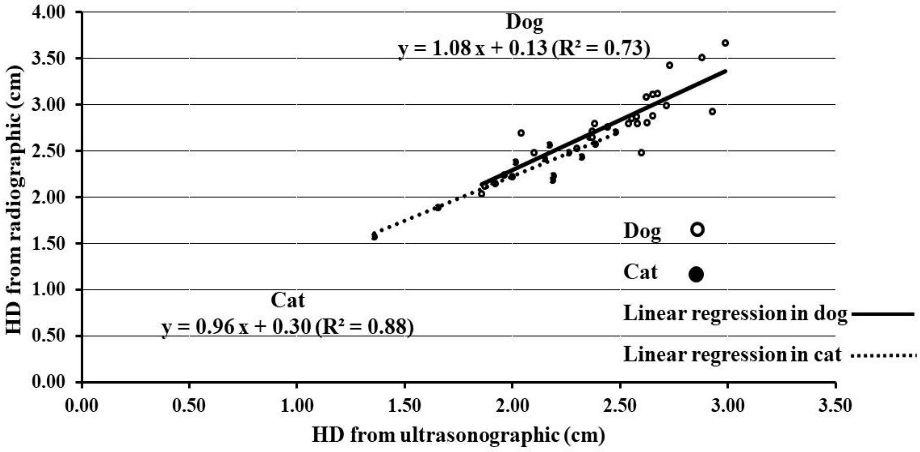

Figure 4 Linear regression graphs and formulas in dogs (bold line) and cats (dot line); y = fetal HD measured by radiography and x = fetal HD measured by ultrasonography were presented.

Discussion

The data of this study mostly represents small breed dogs (16/24) and brachycephalic breed (4/24), dog types which are commonly predisposed to dystocia (Johnston *et al.*, 2001). This study shows that an oversized-fetal head is not the main cause in emergency cesarean section in both dogs and cats (Table 1). This result relates to one retrospective study of 182 cases of canine dystocia. The cause of dystocia was from maternal origin in 75.3% of the cases, mainly due to uterine inertia. An oversized fetus causing dystocia only occurred in 6.6% of cases for dogs (Ekstrand and Linde-Forsberg, 1994). In a retrospective study of 155 dystocia-feline cases, 67.1 % of dystocia cases were also due to uterine inertia, and only 1.9% of cases were due to an oversized fetus (Darvelid and Linde-Forsberg, 1994).

The percentage of fetal heads that could be detected, counted and measured from VD and lateral radiographic images from the maternal pelvic were 82.61% and 62.50% in dogs, and 50.00%, and 66.70% in cats, respectively (Table 1). From radiographic images, some fetal heads could not be measured due to fetal postures, not due to the quality of the radiographic picture because the radiographic setting was set according to species, part of body, distance, and BW by standard digital radiographic machine. In some cases, VD and lateral radiographs may not be suitable to visualize the fetal head for the proper HD measurement. The oblique view can be added in those cases if needed. On the other hand, ultrasonography was more reliable to access fetal head measurement because the ultrasound probe was flexible for searching for a good fetal posture. However, ultrasonography is limited on high echogenic objects, especially bone (Kealy *et al.*, 2011), so this technique could not scan for the details if the fetus was under the pelvic. A way around the problem, in case HD could not be detected by both VD and lateral radiographic, the correlation HD from the ultrasonographic may be used to compare with the pelvic inlet diameter from the radiographic, using the formulas from the study.

From this study, fetal HD from 82.61% (19/23) of dogs and 68.75% (11/16) of cats were measured within 24 hours of the day of surgery. There were four dogs and five cats which were diagnosed over 24 hours before parturition. So, fetal HD measurements were mostly collected from full term fetuses. Mean±SD of fetal HD by ultrasound in dogs (2.50±0.29 cm) was closer to the small breed formula [HD (mm) − 25.11]/0.61 days before birth (Mattoon and Nyland 1995; Luvoni and Grioni, 2000; Lopate, 2008; Beccaglia *et al.*, 2016) than the prediction of the parturition formula [15×HD (cm)] + 20 = GA (Mattoon and Nyland 1995; Luvoni and Grioni, 2000; Lopate, 2018). This might be because most data from the study was collected from small breed dogs. When the data is focused on 14 toy breed dogs (BW <5 kg), mean±SD of fetal HD obtained from abdominal radiograph and from ultrasonogram changed from 2.83±0.37 to 2.64±0.26 cm, and from 2.50±0.29 to 2.39±0.27 cm, respectively. The prediction for fetal HD from ultrasonography transferred to fetal HD from radiography following linear regression y = 1.08x+0.13 (R^2 = 0.73) was relatively accurate. The correlation and linear regression formula in dogs from this study was suitable to apply to toy breed dogs (BW <5 kg).

Fetal HD measurement from abdominal radiographs was larger than fetal HD measured from transabdominal ultrasonogram in both dogs and cats because of the difference of imaging between the two techniques. Radiographs were imaged from x-rays through the object and transferred into a detector. Fetus position in the maternal abdomen may cause increasing distance between each fetal head and cassette, which could possibly effect the head size in the image (Kealy *et al.*, 2011).

There are many factors that cause the magnification effect in radiography such as object-film distance (OFD), focal-film distance (FFD), and focal spot size (Thrall and Widmer, 2013). Object-film distance is the distance from object to the film radiograph. Focal film distance (source-to-image detector or focal-receptor distance) is the distance from the focal spot to the film radiograph. Focal spot is the area on the anode target of an x-ray tube that is struck by electrons and from which x-rays are emitted (Muhlbauer and Kneller, 2013). Object-film distance of fetal HD is the main factor affecting magnification because FFD and focal spot size were standard set with 100-cm (40-inches) and 1.2, respectively in both dogs and cats. However, the fetal HD measurement by radiography was measured compared to the pelvic inlet diameter without regard to the magnification effect because the distance of the fetus in the abdomen and the pelvic bone to the film (OFD) are more or less similar to each other. In contrast, ultrasonography was generated from echogenicity, the hyperechoic line from head border was presented.

The parameters tested by two techniques were correlated. Regression squared (R-squared) for cats ($R^2 = 0.88$) was higher than for dogs ($R^2 = 0.73$), although the number of cats (n=16) was less than dogs (n=24). The variable of breed and BW of dogs might have had an effect on R-squared because the higher BW and higher body condition score may have led to greater OFD. Therefore, the regression equation of this study can be used, but it should be used with caution.

Since the information was obtained within 24 hours before surgical cesarean section, the fetal head was nearly full-term. The radiograph of dogs and cats were also obtained within 24 hours which the dog or cat may have been classified in dystocia. Therefore, radiographic pelvic canal diameter measurements derived on the day of parturition may have been affected by relaxin. Relaxin is known to remodel pelvic connective tissue and increase the elasticity of the symphysis pubis joint and pelvic ligaments and allowing expansion of the pelvic outlet, subsequently affecting pelvic canal diameter in several species during pregnancy (Kristiansson *et al*., 1996). Further study should be conducted to compare significant increase in pelvic inlet between non-pregnant stage and parturition phase, due to the relaxin effect.

A larger sample size with various dog breeds and adjusted magnification factors of digital x-ray should be considered which may provide more accurate information (Conn *et al*., 2002; Heep *et al*., 2012). This correlation might be useful in case of using ultrasonography to monitor fetal viability and fetal HD in order to predict parturition date. Fetal HD measured from ultrasonography might be able to compare to pelvic inlet from the previous films of dogs and cats in case radiography is not taken during near term.

Fetal HD from both techniques should be compared to actual fetal HD after birth in order to find the best method to evaluate fetal HD in dogs and cats. Furthermore magnetic effect including FFD, focal spot size and OFD are also important concerns in the different radiographic protocols (Heep *et al*., 2012).

In conclusion, monitoring parturition date and dystocia in dogs and cats should combine both techniques for parturition prediction and dystocia diagnosis. For good quality images in both techniques, animals should be prepared before examination, such as by fasting and defecation in order to prevent gastric and intestinal contents effecting fetal observation.

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