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# Reliability of Two Formulae Employing Foetal and Extra Foetal Parameters in Predicting Whelping Dates

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## ABSTRACT

**Background:** Predicting whelping is crucial because solely depending on the gestation period calculated from the first day of mating does not provide an accurate estimation of the expected delivery date in female dogs. The study aimed to determine the accuracy of predicting the whelping dates in different sized dogs based on the formulas of foetal (BPD) and extrafoetal (ICC) calculations developed.

**Methods:** Ultrasonographic foetometry is utilized to forecast the parturition date in dogs, opening up new avenues for improved obstetrical care in canines. For this, the whelping predictions with these two formula calculations were compared to the real whelping dates. A total of 62 ICC and 52 BPD measurements were taken from 114 healthy female dogs.

**Result:** The range of prediction accuracy for ICC extended between 43.5% and 100% (± 2 days), whereas for BPD, it varied from 21.2% to 100% (±2 days). Comparing the prediction accuracy of formulas proposed by Luvoni and Grioni (2000) with those by Mattoon and Nyland (2002) revealed a statistically significant difference. Greater accuracy in prediction was reported in dogs with normal or medium litters than compared to dogs with high or low litters.

**Key words:** Dog, Fetal parameters, Parturition, Pregnancy, Ultrasound.

## INTRODUCTION

The popularity of pedigree dogs has significantly increased in the last two decades, particularly in urban areas, leading kennel owners to pay high prices for importing rare breeds. Additionally, modern lifestyles and the prevalence of nuclear families have contributed to a rise in dog ownership, resulting in strong emotional connections with these pets (Bharathy and Gunaseelan, 2016). These factors have expanded the opportunities for canine breeding, making it a highly profitable and commercialized industry.

Precise estimation of the date of delivery is crucial for the best possible care throughout pregnancy and whelping. To reduce the losses of offspring, prompt management in the event of dystocia or a protracted pregnancy is necessary, which requires careful observation of the pregnant bitch throughout the perinatal period (Kim *et al.,* 2007).

Predicting whelping is of utmost importance because relying completely on the timing of gestation from the first day of mating would not accurately predict the expected day of delivery (EDD) in bitches (Simon *et al*., 2022). The duration of pregnancy in dog is 65±1 days from the luteinizing hormone (LH) preovulatory surge. The ability to determine gestational age and to predict the time of EDD would be a considerable advantage in breeding establishment for bitches with multiple or uncertain mating times or where the periovulatory determinants are not performed.

The expected date of delivery can be determined by conducting ultrasonographic measurements of relevant structures and using specific mathematical formulas. Prior research reported that the inner chorionic cavity diameter (ICC) and biparietal diameter (BP) measurements were more useful. Calculation formulas by Luvoni and Grioni (2000) and Mattoon and Nyland (2002) are now available for determining whelping date using ICC and BP measurement. This study evaluated the accuracy of these formulas in predicting parturition day in dogs with different body weights in clinical settings. The present paper aimed to compare actual whelping dates with predicted ones based on ICC and BPD measurements using the formula proposed by Luvoni and Grioni (2000) and Mattoon and Nyland (2002).

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## MATERIALS AND METHODS

The study was performed on 114 healthy female dogs between one to eight years of age, brought for pregnancy diagnosis to the Gynaecology units at TVCC, Mannuthy and UVH, Kokkalai during January 2022 to January 2024. The study included bitches of various breeds and body sizes. All dogs were divided into three groups based on body weight, *viz.* small breeds (< 10 kg), medium breeds (10-25 kg) and large breeds (> 25 kg) (Beccaglia and Luvoni, 2012). For bitches with unknown and known breeding dates, ultrasonographic examinations were conducted with MyLab 70 Vet XV (Esaote, Italy) ultrasound machine. For the majority of examinations, multi frequency microconvex (3-9 MHz) transducer was used. In some instances, to calculate certain foetal parameters especially, in small breeds a linear array (1-8 MHz) transducer was employed.

### Inner chorionic cavity (ICC)

A total of sixty-two ICC measurements were taken. The measurement of each of ICC was determined by taking the mean of two ICC diameters made at 90° angles from one side of the trophoblastic decidual reaction to the other (Fig 1). The ICC measurements were used for prediction when the anechoic structure retained a spherical form with clearly defined boundaries. For this, the measurements were specifically carried out between fourth week of gestation. The Gestational age (GA) was calculated using the formula GA = (6×ICC in cm)+ 20 (Matton and Nyland, 2002). The days before parturition (DBP) was calculated as follows: DBP in small breeds = ICC in mm-68.68/1.53 and DBP in medium and large size breeds = ICC in mm-82.13/1.8 (Luvoni and Grioni, 2000) wherever applicable.

### Biparietal diameter (BPD)

BPD measurements were taken when the parietal bones were parallel (Fig 2) so that distance between them could be measured correctly. DBP was calculated using formulae DBP = (BP in mm - 29.18)/0.7 in medium and large sized bitches and DBP = (BP in mm - 25.11)/0.61 in small sized bitches (Luvoni and Grioni, 2000), wherever applicable. The GA was calculated using the formula GA = (15 × HD in cm) + 20 (Mattoon and Nyland, 2002) and DBP = 65-GA.

To assess the accuracy of the formulas by Luvoni and Grioni (2000) and Mattoon and Nyland (2002) using the ICC and BPD parameters in predicting the parturition day in dogs, the predicted whelping dates using the two were cross referenced with actual delivery dates, using two levels of accuracy (±1 or ±2 d). The day of whelping was determined as the day the first foetus was expelled.

### Statistical analysis

The frequency distribution of each combination of categories for the variables was assessed using cross-tabulation (crosstabs). The categorical data was tested for statistical significance as per the Fisher's exact test. The values were considered significant at $p<0.05$. The entire statistical analysis was conducted using Statistical Package for the Social Sciences version 26.0 (IBM Corp., New York, USA).

## RESULTS AND DISCUSSION

The prediction data of whelping based on ICC measurements using the Luvoni and Grioni (2000) and Mattoon and Nyland (2002) formula are presented in Table 1. The overall predictive accuracy of ICC measurements, irrespective of the breed size was better for the formula of Luvoni and Grioni (2000) than Mattoon and Nyland (2002), the precision being lower for all the breed sizes at EDD and two levels of accuracy with latter. For EDD ±2d, the accuracy was 100% using Luvoni and Grioni formula for all the breed sizes, in contrast to 82.30% for Mattoon and Nyland formula. Regardless of the formula used, the prediction accuracy at EDD±1 d was statistically significant ($P<0.05$) across various breed sizes, except for medium and large breeds using the Mattoon and Nyland formula. The comparison between Luvoni and Grioni (2000) equations with Mattoon and Nyland (2002) in small, medium and large breeds based on ICC is also presented. The Luvoni and Grioni formula demonstrated greater prediction efficiency for whelping compared to the Mattoon and Nyland formula, as evidenced by ICC measurements. However, this difference was found to be statistically significant only for medium-sized breeds at EDD and EDD ±1 d. These findings emphasize the importance of utilizing the Luvoni and Grioni

Fig 1. Inner Chorionic Cavity (ICC).


**Fig 2:** Bi parietal diameter (BPD).

formula for whelping prediction based on ICC measurements over the alternative formula for all breed sizes and in particular, medium sized breeds.

The prediction of whelping based on BPD measurements with the Luvoni and Grioni (2000) and Mattoon and Nyland (2002) are presented in Table 2. The predictive accuracy of whelping with BPD was significantly varying between different sized breeds only at EDD± 1 d with Luvoni and Grioni formula while, it varied significantly at EDD±1 d and ±2 d with Mattoon and Nyland formula. The comparison between Luvoni and Grioni (2000) and Mattoon and Nyland (2002) in small, medium and large breeds based on BPD is presented. The formula Luvoni and Grioni (2000) delivered significantly higher (P<0.05) prediction efficiencies compared to those of Mattoon and Nyland (2002) for small breeds at EDD, EDD ±1 and EDD ±2 days. For medium breeds its during EDD ±2 d and for large breeds during EDD and EDD ±2 d similar observations are recorded.

A comprehensive comparison was conducted between two formulas regardless of the breed size. The study revealed that the Luvoni and Grioni (2000) formula exhibited higher predictive accuracy for whelping compared to the Mattoon and Nyland (2002) formula, particularly at EDD, EDD ±1d and ±2d based on ICC and BPD. The statistical significance of difference between the two formula in prediction was only observed at EDD based on ICC, while significance was noted at EDD, EDD ±1d and ±2d based on BPD, emphasizing the superior accuracy of the Luvoni and Grioni formula in whelping prediction.

The impact of litter size on precision of prediction derived from individual parameters was also examined. The accuracy of prediction of day of parturition on basis of litter size and ICC is presented in Table 3, respectively. Based on ICC measurements, regardless of formula employed Fisher's exact test indicated superior prediction efficiency for medium litter sizes compared to low and high litter sizes across EDD, EDD ±1d and ± 2 d, based on ICC regardless of the formula employed.

The accuracy of prediction of day of parturition on the basis of litter size and BPD is presented in Table 4, respectively. The impact of litter size on predictive accuracy for whelping based on BPD measurements showed higher results for medium-sized litters in comparison to high and low-sized litters, similar to the finding on the impact of litter size based on ICC measurements precision. However, While applying Luvoni and Grioni (2000) formula significant

**Table 1:** Prediction of whelping based on ICC measurements.

| | Small (n=28) | Medium (n=17) | Large (n=17) | Overall (n=62) | P value |
|---|---|---|---|---|---|
| **Based on Luvoni and Grioni (2000)** | | | | | |
| EDD | 12/28 (42.90%) | 11/17 (64.70%)$^{X}$ | 4/17 (23.50%) | 27/62 (43.50%)$^{X}$ | NS |
| EDD ± 1 | 22/28 (78.60%)$^{a}$ | 16/17 (94.10%)$^{bX}$ | 10/17(58.80%)$^{c}$ | 48/62 (77.40%) | * |
| EDD ± 2 | 28/28 (100.0%) | 17/17 (100.0%) | 17/17 (100%) | 62/62 (100%) | NS |
| **Based on Mattoon and Nyland (2002)** | | | | | |
| EDD | 5/28 (17.90%) | 0/17 (0.0%)$^{Y}$ | 2/17 (11.80%) | 7/62 (11.30%)$^{Y}$ | NS |
| EDD ± 1 | 19/28 (67.90%)$^{a}$ | 6/17 (35.30%)$^{bY}$ | 6/17 (35.30%)$^{b}$ | 31/62 (50.0%) | * |
| EDD ± 2 | 26/28 (92.90%) | 14/17 (82.40%) | 11/17 (64.70%) | 51/62 (82.30%) | NS |

NS-Non significant;

$^{ab}$Rows bearing different superscripts differ significantly.

$^{XY}$Columns bearing different superscripts differ significantly.

*P<0.05; **P<0.001.

**Table 2:** Prediction of whelping based on BPD measurements.

| | Small (n=16) | Medium (n=12) | Large (n=24) | Overall | P value |
|---|---|---|---|---|---|
| **Based on Luvoni and Grioni (2000)** | | | | | |
| EDD | 5/16 (31.30%)$^{X}$ | 1/12 (8.30%) | 5/24 (20.80%)$^{X}$ | 11/52 (21.20%)$^{X}$ | NS |
| EDD ± 1 | 15/16 (93.80%)$^{aX}$ | 5/12 (41.70%)$^{b}$ | 15/24 (62.50%)$^{c}$ | 35/52 (67.30%)$^{X}$ | * |
| EDD ± 2 | 16/16 (100.00%)$^{X}$ | 12/12 (100.00%)$^{X}$ | 24/24 (100.00%)$^{X}$ | 52/52 (100.00%)$^{X}$ | NS |
| **Based on Mattoon and Nyland (2002)** | | | | | |
| EDD | 0/16 (0%)$^{Y}$ | 2/12 (16.70%) | 0/24 (0.0%)$^{Y}$ | 2/52 (3.80%)$^{Y}$ | NS |
| EDD ± 1 | 0/16(0%)$^{aY}$ | 2/12 (16.70%)$^{b}$ | 10/24 (41.70%)$^{b}$ | 12/52 (50.0%)$^{Y}$ | ** |
| EDD ± 2 | 2/16(12.50%)$^{aY}$ | 6/12 (50.00%)$^{aY}$ | 16/24 (66.70%)$^{bY}$ | 24/52 (46.20%)$^{Y}$ | ** |

NS-Non significant;

$^{ab}$Rows bearing different superscripts differ significantly.

$^{XY}$Columns bearing different superscripts differ significantly.

*P<0.05; **P<0.001.

difference was observed during EDD ±1d and ±2d. Conversely, the formula of Mattoon and Nyland (2002) showed a significant difference only during EDD± 2d.

This research is among the limited studies in the Indian sub-continent that discusses ICC and BPD measurements using Luvoni and Grioni (2000) forumulas to predict parturition time in dog breeds of varying body weights under clinical settings. When determining gestational age in dogs, the Mattoon and Nyland (2002) formula is widely utilized in normal clinical conditions due to its simplicity and applicability across different breeds. Only few studies have compared the usefulness and dependability of different formulas for predicting whelping. This study focused on practical aspects that are important in veterinary practice and involved a significant number of pregnant dogs. The breeding dates were not considered in this study, as gestation length in dogs can vary greatly based on breeding dates (Socha and Janowski, 2014). To date, breed specific formulae were developed by Milani *et al*. (2013), Groppetti *et al*. (2015) and Socha and Janowski (2017). In this study, surprisingly, the non-specific formulae of Luvoni and Grioni (2000) for medium sized bitches yielded results comparable with that of specific formula developed by Groppetti *et al.* (2015) for GSD.

Accurate prediction of the parturition date in dog is important to manage pregnant bitches and to prepare for the delivery. Research on predicting parturition dates in dogs is scarce due to the unique reproductive characteristics of dogs compared to other mammals. There have been many attempts to predict the delivery dates of various pregnant animals using ultrasonographic measurements. As dogs vary in size, there is a need to develop accurate formulae to measure and monitor foetal development according to breed. In this study we evaluated the reliability of two formulae to predict the EDD in dog breeds of different sizes based on ICC and BPD measurements obtained through USG.

To predict EDD in dogs both ICC and BPD are equally reliable indicators in early and late pregnancy, respectively (Beccaglia and Luvoni, 2006). On 4$^{th}$ week after last crossing embryonic vesicles were visualized as a spherical structure with clearly defined margins. According to Beccaglia and Luvoni (2012), the embryonic vesicles were typically spherical with clearly defined edges during week 4 of gestation and after that the accuracy of measurement will be affected by initial elongation of chorionic cavity. In the current study, the accuracy rates for estimating EDD using the Luvoni and Grioni (2000) formula, based on ICC measurements, were found to be 43.20%, 77.40% and 100% for EDD within one day and two days of precision, regardless of breed size. When using BPD measurements, the accuracy rates were 21.20%, 67.3% and 100% respectively. The obtained results were concurrent to findings of Kutzler *et al.* (2003): Beccaglia and Luvoni (2006), Lopate (2008) and Simon (2015) with ICC measurements and with BPD measurements same authors reported partially lower prediction accuracy compared to present study. In contrast, the Mattoon and Nyland (2002) formula yielded lower

**Table 3:** Accuracy of prediction of day of parturition on basis of litter size and ICC measurements.

| Litter size | Low (1-2) | Medium (3-9) | High (>10) | P value |
|---|---|---|---|---|
| **Based on Luvoni and Grioni (2000)** | | | | |
| EDD | 4/27 (14.81%)$^{a}$ | 18/27 (66.66%)$^{b}$ | 5/27 (18.51%)$^{a}$ | * |
| EDD ± 1 | 13/48 (27.08%)$^{a}$ | 30/48 (62.5%)$^{b}$ | 5/48 (10.41%)$^{a}$ | * |
| EDD ± 2 | 15/62 (24%)$^{a}$ | 34/62 (54.8%)$^{b}$ | 13/62 (17.7%)$^{a}$ | * |
| **Based on Matton and Nyland (2002)** | | | | |
| EDD | 1/9 (11.1%)$^{a}$ | 8/9 (88.88%)$^{b}$ | 0/9 (0%)$^{a}$ | * |
| EDD ± 1 | 7/32 (21.87%)$^{a}$ | 20/32 (62.5%)$^{b}$ | 5/32 (15.62%)$^{a}$ | * |
| EDD ± 2 | 12/62 (19.3%)$^{a}$ | 30/62 (48.38%)$^{b}$ | 10/62(16.12%)$^{a}$ | * |

NS-Non significant; *P<0.05; **P<0.001.

**Table 4:** Accuracy of prediction of day of parturition on basis of litter size and BPD measurement.

| Litter size | Low | Medium | High | P value |
|---|---|---|---|---|
| **Based on Luvoni and Grioni (2000)** | | | | |
| EDD | 3/8 (37.5%) | 4/8 (50.0%) | 1/8 (12.50%) | NS |
| EDD ± 1 | 6/29 (20.68%)$^{a}$ | 20/29 (68.96%)$^{b}$ | 3/29 (10.34%) | * |
| EDD ± 2 | 15/52 (28.8%)$^{a}$ | 25/52 (48.07%)$^{b}$ | 12/52 (23.07%)$^{a}$ | * |
| **Based on Matton and Nyland (2002)** | | | | |
| EDD | 0/2 (0%) | 1/2 (50.00%) | 1/2 (50.00%) | NS |
| EDD ± 1 | 1/14 (7.14%) | 8/14 (57.14%) | 5/14 (35.71%) | NS |
| EDD ± 2 | 3/24 (12.5%)$^{a}$ | 16/24(66.66%)$^{b}$ | 5/24 (20.83%)$^{a}$ | * |

NS-Non significant; *P<0.05; **P<0.001.

accuracy rates of 11.3%, 50% and 82.30% for EDD, within one day and two days of EDD based on ICC measurements and even lower rates 3.80%, 23.10% and 46.20% based on BPD measurements. This was contrary to Simon (2015) who reported higher accuracy of about 24.14%, 75.86% and 93.10% accuracy with ICC measurements during EDD, EDD±1d and EDD±2d respectively and 23.68%, 44.74% and 71.42% with BPD measurements with Mattoon and Nyland (2002) formula during EDD, EDD±1d and EDD±2d. This might be due to differences in breeds used for two studies.

The study provided additional evidence that ICC measurements can enhance the accuracy of prediction outcomes during mid-gestation, as they allow for precise assessment until the embryonic vesicles exhibit regular spherical shape with clearly defined margins. Conversely BPD measurements may yield less accurate results due to potential influences from skull differences between breeds (Kutzler *et al.,* 2003).

The overall data suggests that the Luvoni and Grioni is superior to Matton and Nyland formula after a thorough comparison between the two. While applying ICC measurements, higher prediction accuracy is observed in medium sized breeds with Luvoni and Grioni (2000) formula and no difference in prediction accuracy is observed between two formulas when used for small and large breeds. On application of BPD measurements, higher prediction accuracy is observed for small breeds through Luvoni and Grioni (2000) than Mattoon and Nyland (2002) formula.

When dogs were grouped into low (1-2), medium (3-9) and high litter (10 and above) size groups, significant difference existed in accuracy of prediction on the basis of ICC and BPD with both Luvoni and Grioni (2000) and Matton and Nyland (2002) formulae. In the current study, higher accuracy was obtained in normal litters (medium) when compared to low and high. This was in agreement with the findings of Beccaglia and Luvoni (2006) and Mir *et al.* (2011) who obtained higher accuracy in normal litters. Elitz *et al.* (2005) reported similar findings that the accuracy of predicting whelping can be affected by an extended gestational length when there are four or fewer foetuses in a litter. This is especially true for BPD measurements taken in late gestation, as individual growth variability can impact accuracy. Therefore, for smaller litter sizes, ICC measurements in mid-gestation are more precise for prediction, as they are less likely to be influenced by litter size and breed factors. For large litter size, overlapping multiple foetuses in the same ultrasound image field can affect the accuracy of BPD measurements. However, Simon (2015) did not get any significant difference on prediction accuracy when comparison was made between above average and below average litter size (Avg. litter size being 6).

An interesting aspect of our study was also the observation regarding the difference between two ultrasonographic measures (ICC and BPD) and formulae tested in this paper. We confirmed that ICC formula of Luvoni and Grioni (2000) can be used effectively in all types of dogs rather than opting for use of breed specific formula of Gropetti *et al.* (2015) in German Shepard dogs and Socha and Janowski (2017) in miniature breeds who reported similar findings.

The statistical comparison of formulae used for studied population of dogs demonstrated a low compatibility of Mattoon and Nyland (2002) for small breeds with the other tested ones suggesting a low precision date prediction using these models for BPD.

## CONCLUSION

Ultrasonographic foetometry performed using ICC and BPD measurements proved to be useful and effective tool for prediction for date of parturition. Results suggest a better practicability of using ICC measurements rather than BPD. Litter size has an effect on accuracy in prediction of parturition with higher accuracy in normal litters than compared to low and high litters. But in late gestation, when BPD measurements are alone available for whelping prediction, Luvoni and Grioni (2000) formula had a significant advantage over Mattoon and Nyland (2002) formula, especially for small breeds.

### Conlict of interest

All authors declare that they have no conflict of interest.

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