

Is the biparietal diameter of fetuses in late gestation too variable to predict readiness for cesarean section in dogs?

K G M De Cramer^{1*}, J O Nöthling¹

^{1*}*Corresponding author. Department of Production Animals, Faculty of Veterinary Science, University of Pretoria, South Africa, kdramer@mweb.co.za*

² *Department of Production Animals, Faculty of Veterinary Science, University of Pretoria, South Africa, Johan.Nothing@up.ac.za*

**Current address of corresponding author. Tel +27 0116603110. P.O. Box 704, Rant en dal, 1751, Mogale city, South Africa. Email address: kdramer@mweb.co.za. Rant en Dal Animal Hospital, 51 Cecil Knight Street, Mogale City, Gauteng, South Africa*

Highlights

- The biparietal diameter and bodyweight was measured in two breeds.
- Biparietal diameter was measured after birth using a digital caliper.
- Measurements were attained in over 660 puppies and 94 litters.
- Variability in biparietal diameter varied more than previously reported.
- Biparietal diameter seems unsuited to predict readiness for cesarean section.

Abstract

Correct assessment of readiness for cesarean section is essential for timing elective cesarean section during late pregnancy in the bitch. In humans, biparietal diameter is sufficiently precise and accurate and used in a clinical setting daily. The objectives of this

study were to determine whether fetal biparietal diameter in late gestation in the dog could be used to predict readiness for cesarean section by having reached a minimum cut-off value and to correlate the biparietal diameter to birth weight. The biparietal diameter of 208 puppies in 34 litters from 31 English bulldog bitches and 660 puppies in 78 litters from 70 Boerboel bitches were measured immediately after delivery by cesarean section, performed at full term, using digital calipers. At the same time the birth weight of the same 208 English bulldog puppies and 494 of the same Boerboel puppies in 59 litters from 54 bitches was measured by means of an electronic scale. With a cesarean section, all the puppies in a litter are delivered simultaneously and readiness for cesarean section must be determined for a litter. The minimum, median and maximum biparietal diameter varied from 21.1 to 47.8, 32.9 to 50.0 and 34.2 to 58.2 mm, respectively, among English bulldog litters and from 18.4 to 48.7, 35.5 to 49.7 and 39.8 to 54.3 mm among Boerboel litters. This large variation suggests that biparietal diameter is too variable within and among litters to be useful as a means of determining readiness for cesarean section.

Keywords: cesarean section, bitch, biparietal diameter, birth weight, gestational age, parturition date

Abridged title: Estimating gestational age using biparietal diameter in dogs

1 Introduction

Correct assessment of readiness for cesarean section is essential for timing elective cesarean section during late pregnancy in the bitch and requires more precision compared to merely predicting an approximate parturition date to limit the number of days wherein parturition may be expected to occur. Readiness for cesarean section may precede the time of spontaneous parturition in the bitch by an unknown time interval. For many bitches presented to veterinary clinicians for management of parturition, there is no

information available of events during the peri-estrous period or mid-pregnancy to help estimate gestational age. Today, in contrast to the dog, ultrasound measurement of fetal dimensions (fetal biometric measurements) are widely used for estimating gestational age in pregnant women [1]. The most common fetal biometric measurements in women taken are; biparietal diameter (BPD), crown rump length, head circumference, abdominal circumference and femur length [2;3]. In women, the accuracy of BPD to predict the spontaneous onset of parturition within 14 days was 89.4% (n = 1788, p < 0.001) when measured in the second trimester [4] and in a large meta-analysis, the discrepancy was approximately 21 days [5]. In women, term is a well-defined safe period of four weeks (37 to 41 weeks of gestation), wherein a fetus may be delivered without having increased risk of complications compared to fetuses delivered at the time of spontaneous parturition [6]. This period may be described as the safe period of intervention by cesarean section. Planned term cesarean sections are only possible in a species when the safe period of intervention is known and a method exists to precisely determine that the gestational age of the fetuses has advanced to within that critical period. There is no literature on this safe period of intervention by cesarean section in the bitch and we do not know how long this period is. In dogs, ultrasonographic measurement of the inner diameter of the inner chorionic cavity proved an accurate method to evaluate gestational age and to predict the day of parturition when the bitch is examined for pregnancy diagnosis during early gestation [7-10] but different equations, derived from growth curves from the various breed sizes were required [8;11;12] or correction factors were required for giant breeds [13]. In later studies, attempts at increasing the accuracy of the estimate of the predicted date of parturition were made by separately evaluating biparietal diameter in large and giant breeds [14] or performing breed specific studies [15;16]. In late pregnancy, it was concluded that the BPD of puppies was most accurate in predicting gestational age and

that the crown rump length may be difficult to measure because of fetal flexion and fetal lengths that exceeds the size of the ultrasound image [13]. A study on English bulldogs suggested that cesarean sections can be scheduled safely once the fetal BPD has reached 29.5 mm or above but the author did not put the theory to test [15]. Although numerous studies reported on gestational age estimation in dogs by ultrasonographic assessment of fetal biometric measurements, none explores the safety of using such estimated dates to time cesarean sections [7-17].

Evans and Sack (1973) showed that the growth of dog fetuses is logarithmic, reaching a steady plateau during late gestation. From this, we assumed that the pattern of variation among BPD and birth weight (BW) of neonates would be similar to the pattern occurring in fetuses in late gestation. Given this assumption, the aim of the present study was to determine whether the variability in BPD and BW of new-born puppies in two breeds are sufficiently small to allow veterinary obstetricians to potentially plan cesarean sections based on these measurements having reached a minimum value as suggested before [15].

2 Materials and Methods

The protocol was approved by the Animal Ethics Committee of the Faculty of Veterinary Science, University of Pretoria, (Onderstepoort, South Africa) (protocol number V010/14). All experimental animals were housed and fed commercial dry pellets twice daily and had access to ad-lib water. All the bitches were selected from the general obstetric population because of increased obstetric risk. High-risk pregnancies were those in English bulldogs [18] and those in Boerboels with a history of dystocia [19] or a history of having had a prior cesarean section or those known to carry very large litters [20]. A trial of labor (attempt at spontaneous unassisted parturition) was declined by all

the owners of the bitches in the current study. Cesarean section was performed upon the first appearance of any degree of dilatation of the cervix detected when performing vaginoscopy every 6 hours or more frequent. The bitches were anesthetized using an anesthetic protocol previously described [21]. The cesarean section was performed in standard fashion as described before [22].

Starting 15 min after delivery, the puppies were weighed on an electronic scale and the BPD was measured in a transverse plane, with the base of the Vernier calipers dorsal to the skull, making certain that the blades contact the cranium at its widest diameter.

In order to assess the precision of measurement, 28 puppies of three litters (two English bulldog and one Boerboel) were each weighed two times and the BPD of each measured two times. The puppies of each of these three litters were presented for the second measurement of BPD in a different order than was the case for the first. The second measurement of BPD on each puppy was done in a way that the operator could not see the value of the first measurement. All BPD measurements were done by the same operator.

The survival rates at delivery, 2 h and 7 d were recorded for all the puppies delivered.

In 31 English bulldog bitches, 231 puppies were delivered during 36 cesarean sections. Of these puppies, 23 from eight litters were excluded from the study and 208 puppies from 34 cesarean sections from 31 bitches were retained in the study. BPD and BW were measured in each of these 208 puppies. In 70 Boerboel bitches, 673 puppies were delivered during 79 cesarean sections. Of these puppies, 13 puppies from nine litters were excluded from the study whereas 660 puppies from 78 cesarean sections in 70 bitches were retained in the study. BPD were measured in each of these 660 puppies and BW in

494 puppies from 59 litters in 54 bitches. The reason for exclusion of puppies in both breeds included *hydrops fetalis*, dysmaturity, mummified puppies and hydrocephalus.

3 Data analysis

For the 28 puppies that were measured two times each, the difference between the two measurements was determined by subtracting the smaller measurement from the larger. The relative difference was obtained by expressing the difference as a percentage of the smaller measurement.

With a cesarean section in a polytocous species such as the bitch, all puppies in a litter are delivered simultaneously and readiness for cesarean section must be determined for a litter as a whole. Yet, if the decision to perform a cesarean section is based on BPD, it should be taken into account that BPD is measured on individual fetuses within the litter. A two-level multiple linear regression was used to assess the effect of BW and litter size on BPD in the 208 puppies from 34 English bulldog litters and 494 puppies from 59 Boerboel litters in which both, BPD and BW were recorded. We used the `xtmixed` command in Stata 14, specifying BPD (biparietal diameter of individual puppies) as response variable, with BW (birth weight of individual puppies) and litter size as explanatory variables and litter as a second-level grouping variable [23]. Puppies were nested in litters. Litter was considered a random effect. The data of the two breeds were analyzed separately.

Data on BPD were summarized by litter, graphically displayed and assessed by direct visual inspection. We assumed that, if a few fetal BPDs from a fairly large litter are measured during antenatal ultrasound, the probability that the largest measured BPD will be higher than the median is fairly high. (Basic probability theory suggests that the probability is 50%, 75%, 88% and 94% if one, two, three or four BPDs from the litter are

measured). We further assumed that ultrasound during late gestation would enable one to measure fetal BPD to the nearest millimeter. Given these assumptions, we determined the frequency with which the median BPD was at least one millimeter higher than the maximum of another.

All analyses were done with STATA version 14 (StataCorp, 4905 Lakeway Drive, College Station, Texas 77845 USA), with alpha set at 0.05.

4 Results

The mean BW and BPD of the 28 puppies that were weighed two times were 359.8 g (standard deviation 54.0) and 38.2 mm (standard deviation 3.80). The mean difference between the two measurements in each puppy was 1.92 g (standard deviation 1.27) for BW and 0.53 mm (standard deviation 0.30) for BPD, with mean relative differences of 0.54% (standard deviation 0.348) for BW and 1.42% (standard deviation 0.866) for BPD.

In both breeds, BPD depends on the BW of puppies ($P < 0.001$) but not on litter size ($P = 0.18$ and $P = 0.93$, for English bulldogs and Boerboels, respectively). Controlling for litter size, the value of BPD increased by 0.038 mm (95% confidence interval 0.034–0.043) for each one-gram increase in the value of BW of English bull dog puppies and by 0.024 mm (95% confidence interval 0.023–0.026) in Boerboel puppies. Figure 1 shows the positive relationship between BPD and BW in both breeds.

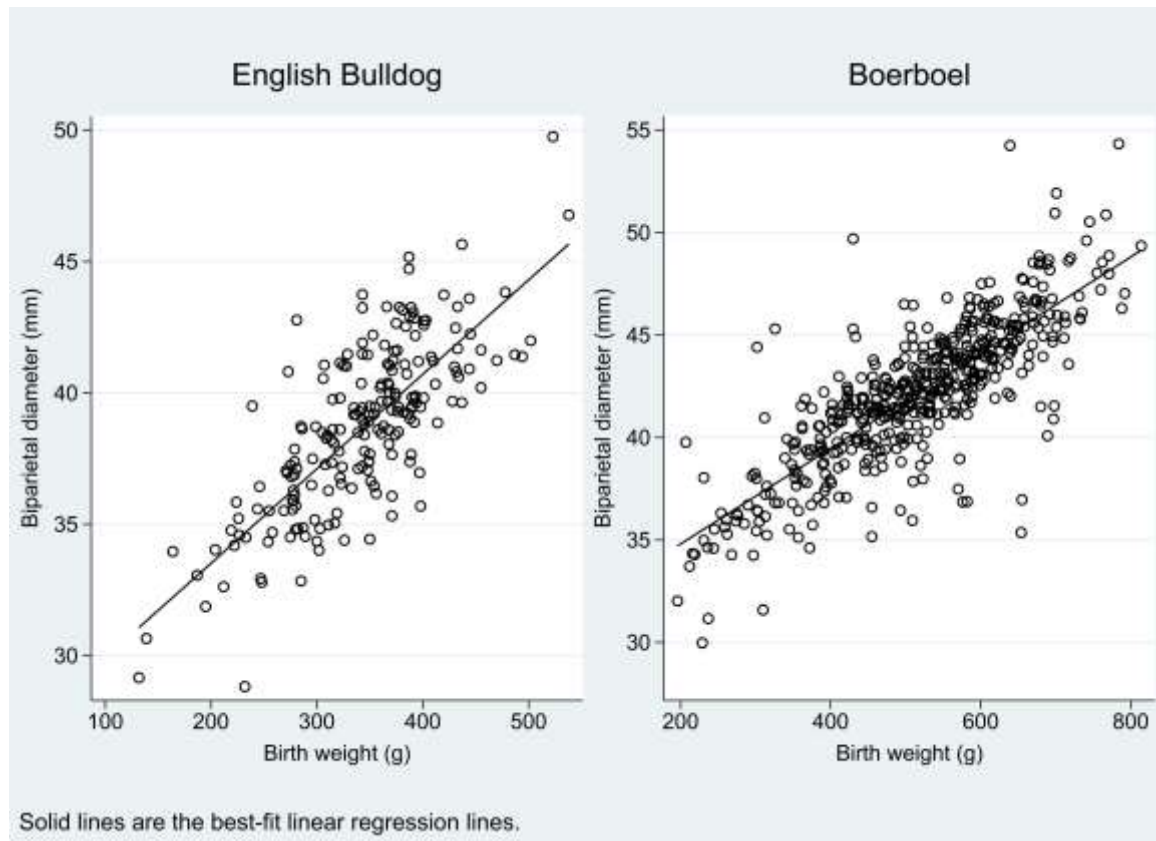


Figure 1: Scatterplot showing that the value of biparietal diameter of English bulldog- and Boerboel puppies increases with the value of birth weight

Figure 2 shows the PBD of all puppies within their litters. Over all puppies, ignoring the fact that the data were clustered in litters, the BPD varied from 28.8 mm to 49.8 mm (mean 38.63 mm, standard deviation 3.20 mm) in the 208 bulldog puppies and from 27.8 mm to 54.3 mm (mean 42.04, standard deviation 3.60) in the 660 Boerboel puppies. The range in BPD among puppies of the same litter varied from 0 mm to 12 mm (mean 4.99 mm, standard deviation 2.78 mm) in the 34 English bulldog litters and from 0 mm to 17.99 mm (mean 7.63 mm, standard deviation 3.61 mm) in the 78 Boerboel litters.

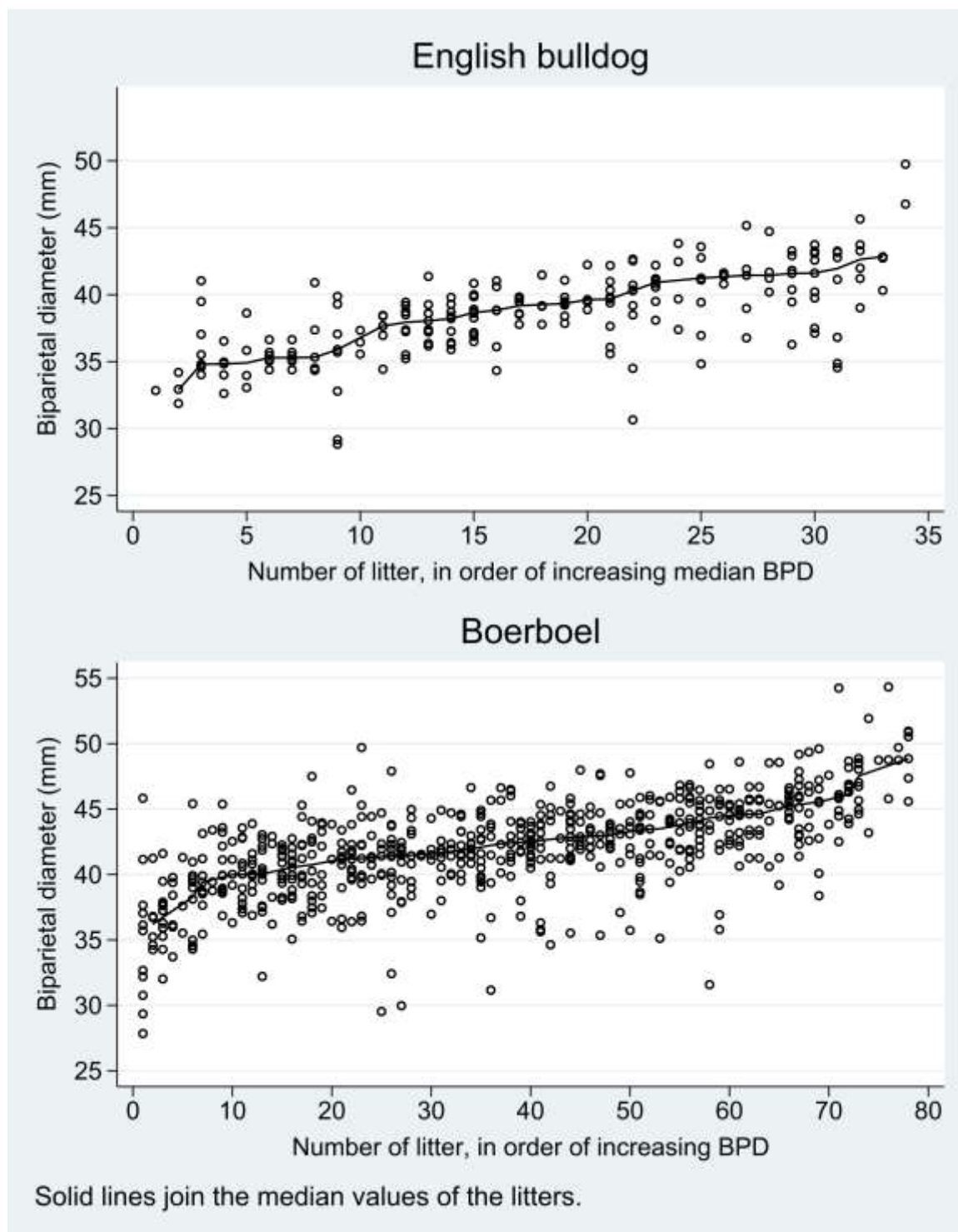


Figure 2: Biparietal diameter of the puppies of 34 English bulldog litters and 78 Boerboel litters

The median BPD of 12 English bulldog litters (Figure 3, solid circles) was 40.9 mm or higher, which is at least 1 mm larger than the maximum BPD of 12 other English bulldog

litters (Figure 3, solid triangles). The median BPD of 15 Boerboel litters (Figure 4, solid circles) was 44.7 mm or higher, which is at least 1 mm larger than the maximum BPD of 15 other Boerboel litters (Figure 4, solid triangles).

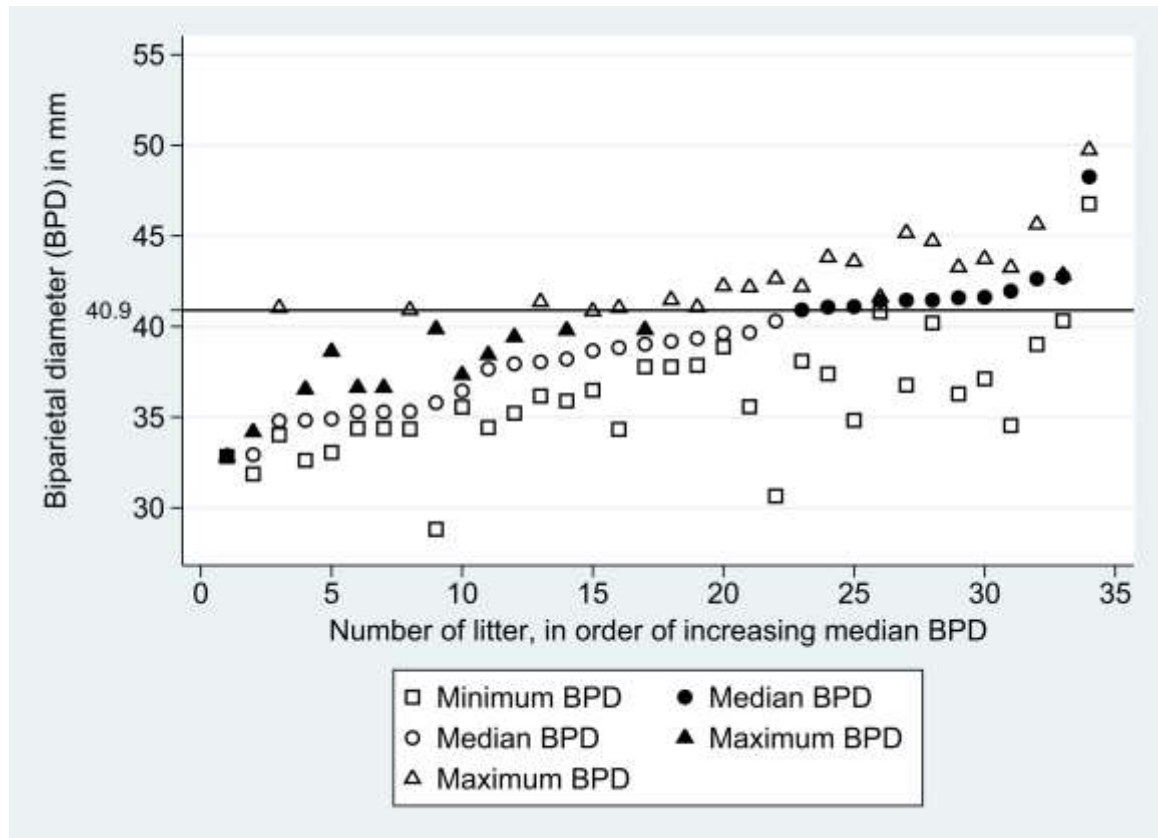


Figure 3: The minimum, median and maximum biparietal diameters of 34 English bulldog litters

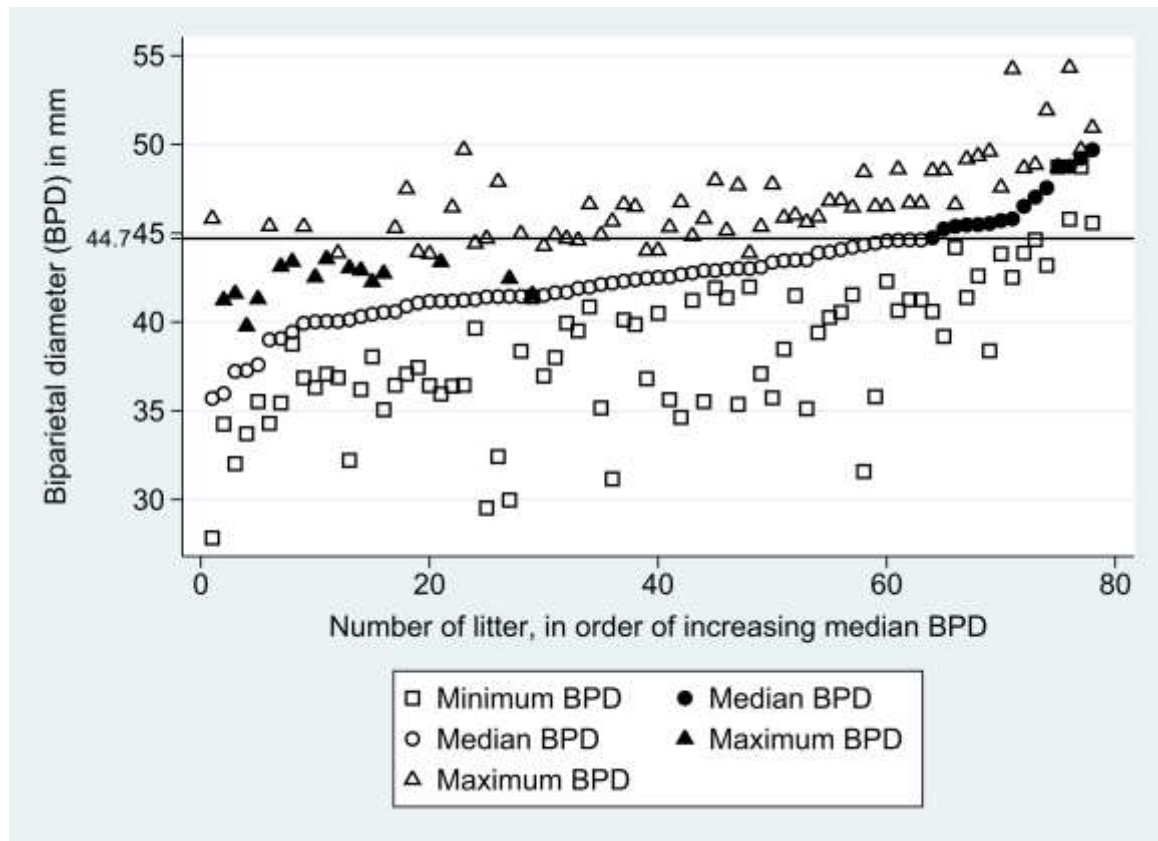


Figure 4: The minimum, median and maximum biparietal diameters of 78 Boerboel litters

Thirty nine of the 231 bulldog puppies from 18 litters died before the age of 7 d, resulting in an overall survival ratio of 0.82. Among the 673 Boerboel puppies, 72 from 43 litters died, resulting in an overall survival ratio of 0.89.

5 Discussion

The precision of measurement of both the BPD and BW was high. Because, in the current study, there was a low mean difference between replicate measurements of the BPD and large ranges in BPD within litters of both, English bulldogs and Boerboels, it is unlikely that lack of precision of the method of measurement may have influenced our results.

The current study established the normal ranges for BPD for two breeds 15 minutes after delivery by cesarean section at full term. The growth curve of canine fetuses is logarithmic with a steady plateau towards the end [24]. For the purposes of the current study, only the last few days of gestation are of interest. Given the findings of Evans and Sack, we assumed that the variation in BPD measured by Vernier caliper within minutes after birth will accurately reflect the variation in BPD of fetuses measured by ultrasonography during late gestation.

The current study showed large variability in BPD among litters and among litter mates in both breeds. The ranges of the BPD for English bulldog puppies (28.8 mm to 49.8 mm) and for Boerboel puppies (27.8 mm to 54.3 mm), found minutes after birth were markedly larger than the narrow range found in another study on English and French bulldogs [15]. In that study a mean BPD of 30.8 mm (standard error of the mean 0.1 mm) and a range 29.5 mm to 31.8 mm were reported in 126 fetuses. The current study shows that it is common for the median BPD of English bulldog and Boerboel litters to exceed the maximum BPD of other litters by at least one millimeter in the respective breeds.

Assuming that ultrasound enables one to measure fetal BPD to the nearest millimeter and that the variation in neonatal BPD is similar to the variation in fetal BPD during late gestation, this large variation should also be evident upon ultrasound examination of fetuses during late gestation. The current study showed a much larger variation in BPD when compared to other breed specific studies [14;15]. It may be speculated that this difference may be ascribed to the artificial averaging of BPD is attained when measuring only a few of the fetuses within a litter and also that incorrect growth curves are derived from ultrasonography attained serial measurements of BPD as it cannot be confirmed that the same fetuses were measured over time.

The range in days whereby a method predicts the date of parturition is of clinical importance when such method is intended to establish readiness for cesarean section in the bitch. Based on current knowledge it may be assumed that a fetus can be delivered and remain viable without assistance if it is delivered 48 h or less prior to the onset of spontaneous parturition [25-27]. Therefore, when determining readiness for cesarean section, the method used to predict the date of parturition should be sufficiently accurate and precise to ensure that the pregnancy has advanced to within this critical 48 h period. Beccaglia and Luvoni [28] showed that fetal BPD predicted parturition date to within ± 1 d in 75% and 63% and within ± 2 days in 88% and 81% of small and medium size bitches, respectively, with the precision not affected by litter size or sex ratio. When performing a breed specific study, Groppetti et al. [16] reported improved results by showing that fetal BPD predicted parturition date to within ± 2 days in 91.7% of German shepherd dog bitches. Assuming that the latter results are accurate and representative of all German shepherd dog populations, further studies are required to establish whether BPD can be used to safely predict readiness for cesarean section in dogs?

The lowest median BPD of an English bulldog litter was 32.8 mm and the highest 48.3 mm, constituting a difference in median BPD of 15.4 mm or 47% of the lowest median. Although we did not measure how long it takes for the BPD of English bulldog fetuses to grow from 32.8 mm to 48.3 mm, using Evans and Sack's notion of the nature of the growth curve of dog fetuses, we postulate that it would be more than two days. Given this and assuming for now that all BPDs in a litter are equal—which they are not—we would have a problem in deciding on a cut-off BPD by which to determine when an English bulldog litter is sufficiently mature for delivery by cesarean section: Proposing to use the smallest median BPD (32.8 mm) as the cut-off would most likely have caused us to declare the litter that eventually had a median BPD of 48.3 mm ready for delivery

more than two days before cervical dilatation. Using any value above 32.8 mm as cut-off would have caused us to never declare litters with median BPDs that were below the cut-off at full term as being ready for delivery by cesarean section. To further complicate matters we must acknowledge that BPD varies among new born puppies—and therefore also full-term fetuses—in a litter. Using any cut-off may cause one to declare a litter ready for cesarean section or not yet ready depending on which BPDs of a litter one measures. This problem also presents itself for the Boerboel and perhaps for various if not all other breeds.

England et al. [7] and Lenard et al. [17] failed to accurately determine litter size in pregnant bitches by means of ultrasonography, exemplifying the limitation of using ultrasonography to observe each fetus in a litter, and observing it once only. Being impossible to accurately count the number of fetuses during mid-pregnancy, suggests that it may be more difficult to make fetal biometric measurements of all the fetuses in each litter in late pregnancy. This would be so because fetuses—especially their calcified skeletons—and a gas-filled intestinal tract in the near ultrasonographic field may both obscure fetuses in the distant field. The model used in the current study overcame these limitations of ultrasound by allowing us to obtain measurements of all the puppies in all the litters. This enabled us to accurately assess variability of the BPD and BW among puppies of the same breed and within the same litter. Another limitation that was overcome in the current study was the precision attained in individual measurements of the BPD. This was because the BPD in all puppies could be measured across identical planes. In contrast, the accuracy of ultrasonographically obtained fetal biometric measurements depends on the spatial arrangements of the fetuses within the uterus and ultrasonographic planes [8] and may further be influenced by intra- and inter observer variability [29].

The results of the current study show that the BPD of both breeds were positively correlated to the BW, which also showed large variability. This suggests that the variability of any fetal biometric measurement should be critically evaluated before it may be considered for determining readiness for cesarean section. Due to the large variability in size of dogs of different breeds and within breeds, functional parameters independent of size of the fetus warrant further investigation into usefulness for determining gestational age of fetuses and readiness for cesarean section [30].

The observation that litter size did not influence BPD and BW suggests that the size of the fetus is likely influenced by factors other than litter size, which may include the genotype of the fetuses.

The puppy survival rates at 7 d in the current study compare favorably to the puppies alive at 2 h after cesarean section in non-brachiocephalic breeds (87%) [31] and puppies alive at 2 hours post cesarean section in brachiocephalic breeds (79%) [18]. The high puppy survival rate obtained in the current study not only confirms good timing of the cesarean section and a safe anesthetic protocol, but also that the BPD and BW values obtained are those of mature puppies of generally normal viability.

We assumed that fetuses suffering from *hydrops fetalis* and those that are unusually small or dysmature would be evident on ultrasonography. Not knowing whether their BPDs are representative of the remainder of the litter, they would most likely have been ignored in the clinical setting when estimating whether a bitch is ready for cesarean section or not. It was therefore just to exclude the 23 English bulldog puppies and 13 Boerboel puppies from the current study.

6 Conclusions

Results of this study show that even in breed specific studies and even with the most reliable measurement of BPD or volumetric measurement to estimate BW, their variability among littermates and within litters close to the time of spontaneous parturition is so large that they are not suitable to predict readiness of dog fetuses for delivery by cesarean section.

Conflicts of interest

The authors have declared no conflicts of interest.

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