Ultrasonographic Fetal Biometry and Gestational Age Estimation in Pregnant Mares in Baghdad, Iraq

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Abstract
Background: This research focused on the evaluation of ultrasonographic fetal biometry. Further, it was to develop predictive regression models to calculate gestational age in horses. Methodology: Eight pregnant mares were studied using two ultrasound techniques, trans-abdominally and trans-rectally. These ultrasound examinations measured several parameters including the diameter of the gestational sac (GSD), crown rump length (CRL), thoracic diameter (TD), abdominal diameter (AD) and head diameter (HD). Results: Measurements of GSD and CRL can be used as a reliable indicator of gestational age before Day 60. However, measurements of TD, AD and HD was found to have strong relationship with gestational age after Day 60. High coefficient values for R2 (>0.99) indicated that there are accurate predictions of gestational age by use of regression models.

Keywords: Mare reproduction, Ultrasonography, Fetal biometry, Gestational age, Crown-rump length.

Introduction

The proper management of a mare's reproduction is crucial for enhancing her fertility and creating an effective breeding program. Diagnosing pregnancies at an early stage, and accurately tracking fetal development are both important factors in equine reproductive care. Among many options for diagnosing pregnancies, Ultrasonography has become the most popular option because it is a non invasive method of examination that provides a safe environment for the pregnant mare and can be viewed "live" on screen while providing the veterinarian with the opportunity to visualize all embryonic/fetal development. (1,2,3) Two common measurements taken using this modality throughout the earliest stages of pregnancy include Gestational Sac Diameter (GS), and Crown – Rump Length (CRL); these have been shown to be highly reliable when estimating gestational age. Both GS and CRL measure the growth rate and development of the embryo during the first two weeks of pregnancy. (4) Once the pregnancy reaches later developmental stages, the fetus becomes easier to visualize and thus additional measurements can be made including Thoracic Diameter (TD), Abdominal Diameter (AD), Head Dimensions (HD); these three measurements have proven to be very reliable indicators of fetal development/growth/viability (5).

Bacterial infections of the reproductive tract, especially *Streptococcus equi* and *Streptococcus pyogenes*, may cause failure of fertilization and low conception rate(6). Gastrointestinal tract diseases, joint affections, and blood parasites such as *Theileria equi* can interfere with general body conditions and general health and reduce the conception rate(7,8,9). Earlier studies indicate that fetal biometric parameters in mares follow predictable growth trajectories, and they frequently correlate well with gestational age(10,11). As a result, the present study was conducted to evaluate ultrasonographic fetal measurements at different gestation stages, and to derive .regression equations for prediction of gestational age in mares

Materials And Methods

Study Area and Animals

A study on eight pregnant mares at different pregnancy stages in Baghdad, Iraq, was conducted. This study was done at an equestrian training club and was done between February and December 2025. Besides, the mares were clinically healthy and were reared under normal feeding and management conditions.

Ultrasonographic examinations were performed using a B-mode ultrasound machine equipped with:
A linear transducer for transrectal examination (early pregnancy)
A sector probe for transabdominal examination (mid-pregnancy)
Measured Parameters
The following fetal biometric parameters were recorded:
Gestational sac diameter (GS)
Crown–rump length (CRL)
Thoracic diameter (TD)
Abdominal diameter (AD)
Head diameter (HD)

Measurements were obtained at different gestational days ranging from Day 30 to Day 180.

Ethical approval

This study was approved by the University of Baghdad, College of Veterinary Medicine, with approval number 1307 on 27-5-2025.

Statistical Analysis

Statistical analyses were performed using simple linear regression models to investigate the association between gestational age (dependent variable) and all biometric parameters (independent variables). So, the strength of each model was determined. R^2 or Coefficient of Determination (R^2) was calculated. Standard regression techniques were used for statistical analysis.

Results And Discussions

Ultrasonographic Fetal Biometry (Days 30–180)

Ultrasonographic data from mares in early to midpregnancy (Days 30–180) are shown, including gestational sac (GS) diameter, crown-rump length (CRL), thoracic and abdominal diameters, and head measurements. These parameters serve as critical modalities for assessing normal embryonic and fetal development along with estimating gestational age Table 1. The GS and the CRL (32 mm and 17.3 mm respectively) were measurable byDay 30, with some rapid elongation of the embryo and development of specific embryonic structures. These findings are in agreement with those of (4) had shown that CRL is reliably representative of gestational age fromabout Day 25, as organogenesis advances and the fetal membranes mature.

These mean values at Day 45 are 51 mm and 32 mm for the GS and CRL, respectively. These values are in agreement with previous findings by (10) also recorded exponential growth during this stage, coinciding with heightened placental attachment and early fetal movement. GS and CRL values keep increasing, which indicates the shift from embryo to early fetus development. Starting from Day 60 measurable fetal structures appeared, specifically: thoracic diameter (12 mm), abdomen diameter (19.6 mm) and head size (30 mm). These measurements initiate the so-called fetal biometric phase, in which several parameters serve as reliable markers of gestational progression (4,12). The progressive increase in these diameters over Days 90, 120, 150 and 180 observed supports the linear fetal growth pattern described by (10) as well as (13).

Thoracic, abdominal, and head sizes (30.8 mm, 46.3 mm, and 35 mm respectively) were the most suitable parameters for Day 90 are thoracic and abdominal diameters. These dimensions significantly increased until Day 180, at which point the mean thoracic and abdominal diameters attained respectively 100.6 mm and 120.2 mm. This constant pattern of growth correlates highly with gestational age confirming that the use of these parameters allow for predicting fetal development post Day 60 (5,10).

In summary, these data show that all measurement parameters are informative at the appropriate gestational age stage:

GS diameter is optimal for pregnancy confirmation before Day 60.

CRL is ideal from Days 30-60 for accurate gestational aging.

Thoracic, abdominal, and head diameters are reliable from Day 60 onwards to assess fetal viability and growth rate. This progression reflects the physiological transition from embryonic to fetal stages, corresponding with the development of organ systems and placental attachment. The observed growth trends in this study are consistent with previously established fetal biometry patterns in mares and confirm that ultrasound measurements provide a non-invasive, reliable method for assessing normal pregnancy progression (5,14, 15).

Regression Models for Gestational Age Estimation

(GA) = predicted gestational age in days
(GS) = gestational sac (conceptus) diameter in mm
(CRL) = crown-rump length in mm
(TD) = thoracic (chest) diameter in mm
(AD) = abdominal diameter in mm
(HD) = head diameter in mm

Based on the five most appropriate measurements in table 4-9 the following equations are proposed:

1. Equation based on Gestational Sac Diameter (GS(
2. Equation based on Crown–Rump Length (CRL(
3. Equation based on Thoracic Diameters (TD)
4. Equation based on Abdominal Diameters (AD)
5. Equation based on Head Diameter (HD)

Table 1: Early to Mid-Pregnancy Measurements (Days 30-180).

No. of mares	Gestational Day	Mean of Gestational Sac GS Diameter (mm)	Mean of Fetal Length CRL (mm)	Mean of Thoracic Diameter (mm)	Mean of Abdominal Diameter (mm)	Mean of dimensions headDiameter (mm)	Most Appropriate Measurement
3	30	32	17.3	Not applicable	Not applicable	Not applicable	GS. Crown-rump length (CRL)
8	45	47.5	39	Not applicable	Not applicable	Not applicable	CRL. GS
8	60	63	60.3	10	19.6	30	CRL. Thoracic and abdominal diameter. Head dimensions
8	90	Not applicable	Not applicable	30.8	44.3	35	Thoracic and abdominal diameters. Head dimensions
8	120	Not applicable	Not applicable	53.1	68.2	40.2	Thoracic and abdominal diameters. Head dimensions
8	150	Not applicable	Not applicable	74.3	93.4	Not applicable	Thoracic and abdominal diameters. Head dimensions
8	180	Not applicable	Not applicable	100.6	120.2	Not applicable	Thoracic and abdominal diameters. Head dimensions

Gestational Age via Crown–Rump Length (CRL)

Assumptions / notes: This formula is likely valid only in early gestation (e.g., less than ~60 days), because after that the gestational sac may become harder to measure or plateau.

Linear regression (GA on GS): $GA_{GS} \approx -1.9 + 0.97 \times GS$

Depending on the given data the GS is used early (day 30, 45, 60), assume a linear relationship in that early window:

Gestational Age via Gestational Sac Diameter (GS(

CRL is commonly used in equine and other species to estimate GA. Assume a linear or perhaps polynomial model; but with data of this study (CRL at days 30, 45, 60) linear may suffice:

Linear regression (GA on CRL): $GA_{CRL} \approx 17.9 + 0.70 \times CRL$

The use of crown–rump length (CRL) to estimate gestational age in horses (and other species) is well established. For example, Murase et al. (2014) measured CRL in mares longitudinally and demonstrated its utility.

Equation to estimate gestational age from thoracic diameter (mm) measurements

Notation

)GA) = gestational age (days(

)TD) = thoracic diameter (mm) - chest diameter measured by ultrasound

Data used (from Table 4-9): gestational days 60, 90, 120, 150, 180 with corresponding TD:

GA (days): 60, 90, 120, 150, 180

TD (mm): 10, 30.8, 53.1, 74.3, 100.6

Thoracic diameter (TD) → gestational age

Linear regression (GA on TD): $GA_{TD} = 48.0140 + 1.3491 \times TD$

Valid (derived) measurement range: TD ≈ 10–100.6 mm

Corresponding GA range represented in the fit: 60–180 days

Model fit: ($R^2 = 0.9925$) (very high; indicates excellent linear fit for these data(

Interpretation: each 1 mm increase in thoracic diameter corresponds to ≈ 1.35 days increase in gestational age in this dataset.

In Fetometry in Arabian Horses, (15) developed regression models for abdominal diameter (ABD), chest depth (CHD, analogous to thoracic diameter), and biparietal / head dimensions, all showing very strong linear correlations with gestational age ($R^2 > 0.97$) in their dataset.

Equation to estimate gestational age from abdominal diameter (mm) measurements

Abdominal diameter (AD) → gestational age

)AD) = abdominal diameter (mm) -abdominal diameter measured by ultrasound

AD (mm): 19.6, 44.3, 68.2, 93.4, 120.2

Linear regression (GA on AD): $GA_{AD} = 36.2146 + 1.2224 \times AD$

Valid (derived) measurement range: AD ≈ 19.6-120.2 mm

Corresponding GA range represented: 60-180 days

Model fit: ($R^2 = 0.9955$) (very high).

Interpretation: each 1 mm increase in abdominal diameter corresponds to ≈ 1.22 days increase in gestational age in this dataset. Both TD and AD equations show very high explained variance in this datasets ($R^2 > 0.99$). State breed context: fetal growth rates differ between breeds and management systems; specify breed/management of this study population. Data were analyzed using ordinary least squares linear regression of gestational day (dependent variable) on each biometric (independent variable) using the provided datasets points (GA: 60, 90, 120, 150, 180). Model performance is summarized using coefficient of determination (R^2). Models were restricted to the measurement ranges present in the data (11) also reported that thoracic (chest) and abdominal measurements correlate positively (linearly) with gestational day in mares.

Gestational Age via Head Diameter (HD)

Head diameter (HD) also seems to grow linearly in mid-pregnancy data (e.g., 60 → 30 mm, 90 → 35 mm, 120 → 40.2 mm, etc.). Use a linear model:

Linear regression (GA on HD): $GA_{HD} \approx -116.4 + 5.88 \times HD$

Figure 1: Ultrasonographic image Day 30 pregnancy (normal)

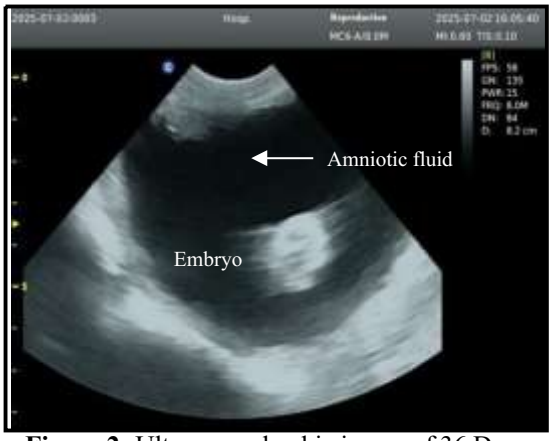

Figure 2: Ultrasonogrhaphic image of 36 Days pregnancy

Figure 3: Ultrasonogrhaphic image of 45 days pregnancy

Figure 4: Ultrasonographic image showing fetal head measurements at 60 days of pregnancy

Figure 5: Ultrasonographic image of 90 days pregnancy showing TD & BD measurement

Figure 6: Ultrasonographic image of 90 days pregnancy showing HD measurement

Figure 7: Ultrasonographic image of 120 days pregnancy showing TD & BD measurement

Figure 8: Ultrasonographic image of 150 days pregnancy showing TD & BD measurement

Figure 9: Ultrasonographic Image of 180 days pregnancy Showing TD & BD Measurment

Conclusions

The findings of this study demonstrate that ultrasonographic fetal biometry is a reliable and non-invasive method for assessing pregnancy progression and estimating gestational age in mares. Gestational sac diameter (GS) is most effective for early pregnancy diagnosis before day 60. Moreover, the crown–rump length (CRL) is the most accurate parameter for the estimation of gestational age between day 30 and day 60. After the day 60 of gestation, the most reliable parameters for the assessment of growth and development of the fetus are thoracic, abdominal and head diameters. The regression models created in this study showed a high accuracy ($R^2 > 0.99$), which approved them for their practical applicability in a clinical and field setting.

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Authors' Contribution

Ahmed Yaseen Mohammed participated in data collection, ultrasonographic examination, statistical analysis and manuscript writing. Nazih Wayes Zaid supervised study design and data interpretation and critically revised manuscript. The manuscript's final version was read and approved by both authors.

Competing Interest

The authors declare that there are no competing interests regarding the publication of this study.

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