10.5005/jp-journals-10009-1515

ORIGINAL RESEARCH

Fetal Foot Length and Its Sonographic Correlation with Gestational Age

[1]Sandhya Hemraj, [2]Devdas K Acharya, [3]Sally M Abraham, [4]US Vinayaka, [5]G Ravichandra

ABSTRACT

Introduction: Accurate assessment of gestational age and fetal growth using ultrasound is imperative in providing good quality antenatal and perinatal care. It provides a noninvasive reliable estimate of the gestational age and serves as a baseline upon which interval fetal growth can be assessed throughout pregnancy.

Aim: The present study was undertaken to assess the relationship between gestational age and fetal foot length and to derive a nomogram correlating gestational age in weeks with fetal foot length.

Materials and methods: This was a prospective, cross-sectional study conducted on 300 pregnant women between 18 and 39 weeks of gestation after obtaining their written informed consent. Our inclusion criteria were women with singleton pregnancies who were certain of their last menstrual periods; who had previous regular menstrual cycles; who had undergone a first trimester dating scan; who had a normal anomaly scan; and with normal amniotic fluid volume. Each patient underwent a detailed antenatal ultrasound study in which, in addition to routine fetal biometry, each fetal foot length was measured. In each fetus, the measurements of the two feet were averaged for analytical purpose. For each gestational age, the fetal foot length was calculated from the raw data and linear regression analysis was used to establish a relationship between sonographic gestational age and fetal foot length. The p value was also calculated to estimate the level of significance.

Results: Our study demonstrated a strong statistically significant linear relationship between gestational age and fetal foot length during the second and third trimesters of gestation.

Keywords: Fetal foot length, Gestational age, Obstetric sonography.

How to cite this article: Hemraj S, Acharya DK, Abraham SM, Vinayaka US, Ravichandra G. Fetal Foot Length and Its Sonographic Correlation with Gestational Age. Donald School J Ultrasound Obstet Gynecol 2017;11(2):141-145.

Source of support: Nil

Conflict of interest: None

[1]Assistant Professor, [2]Professor and Head, [3]Professor, [4,5]Associate Professor

[1]Department of Radiology and Imaging, M.V.J. Medical College & Research Hospital, Bengaluru, Karnataka, India

[2,4,5]Department of Radiology and Imaging, Yenepoya Medical College Hospital, Mangaluru, Karnataka, India

[3]Department of Obstetrics and Gynaecology, Yenepoya Medical College Hospital, Mangaluru, Karnataka, India

Corresponding Author: Sandhya Hemraj, Assistant Professor Department of Radiology and Imaging, M.V.J. Medical College & Research Hospital, Bengaluru, Karnataka, India, e-mail: sandhya.hemraj@gmail.com

INTRODUCTION

The normal growth pattern and accurate age estimation of the developing human fetus have always interested researchers and scientists worldwide. Several methods have been developed over the last century to measure the fetus and study its normal growth; the most notable being the Carnegie staging system which was first described by George L Streeter.[1] Later, obstetric ultrasound became the most widely used noninvasive method for gestational age estimation of the unborn fetus.

The fetal lower limb initially develops as an outgrowth from the distal body stalk of the embryo which is termed as "limb bud" up to 39 days post conception in relation to the Carnegie stages.[1] As the fourth embryonic week ends, three regions develop in the limb bud corresponding to the thigh, leg, and foot.[2] Within the fifth embryonic week, the lower limb bud develops a distinctive morphology with a flat ventral and rounded dorsal surface shaped like a paddle, called the "foot plate."[1,2] It is oriented in a transverse plane with the plantar surface pointing toward the head. Around this time, the first stage of skeletogenesis occurs, termed mesenchymal condensation. The footplate of the lower limb then rotates inward, causing the flexor surface to obliquely face the median sagittal plane of the embryo.[2]

When the embryo reaches a size of about 14 mm, the foot has initially 3 and later 5 primitive toe rays. These toe rays acquire clefts or notches between them and develop a primitive heel.[1,2] At the beginning of the 3rd month, the fetal foot is in equinus, adducted and supinated. During the middle of the 3rd month, the foot dorsiflexes at the ankle. At the beginning of the 4th month, the equinus is corrected; however, mild varus of the metatarsus still persists.[2] The fetal foot undergoes mild pronation which continues to occur during the remainder of intrauterine development and is not yet complete at the time of birth.[2]

In the 1920s, Streeter studied 704 stillborn human fetuses from 50 days post conception until birth and observed a strong linear statistical correlation between gestational age and fetal foot length.[1] Subsequently, several studies were undertaken to study the correlation between fetal foot length and gestational age of the fetus.

The hypothesis which we wanted to test in this study was – is there a relationship between gestational age and fetal foot length? If so, is the relationship statistically significant? Can the fetal foot length measurement be used

as an alternate parameter to assess gestational age during mid and late trimester when the routinely used biometric parameters of biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) are difficult to obtain or inaccurate? Hence, the present study was undertaken at our institution to assess the relationship between gestational age and fetal foot length and to derive a growth chart/nomogram correlating the gestational age in weeks with fetal foot length.

MATERIALS AND METHODS

This was a prospective, cross-sectional study carried out on 300 pregnant women between 18 and 39 weeks of gestation after obtaining their written informed consent. Our inclusion criteria were women with singleton pregnancies who were certain of their last menstrual period (LMP); who had previous regular menstrual cycles; who had undergone a first trimester dating scan; who had a normal anomaly scan between 20 and 24 weeks; and with normal amniotic fluid volume.

Women whose fetuses had or were suspected of having intrauterine growth restriction, chromosomal or structural abnormalities, isolated limb dysplasias, oligo/polyhydramnios, women with pregnancies complicated by any medical, surgical or obstetric disorders during the 18 to 20 weeks scan, and also those fetuses in whom congenital anomalies were detected later on in the gestation were excluded from the study. The reason being we wanted to include only sonographically normal fetuses in this study.

The study was conducted over a 1 year period from March 2013 to March 2014 at Yenepoya Medical College, Mangaluru, Karnataka, India after obtaining approval of the hospital Ethical Committee.

Each patient underwent a detailed antenatal ultrasound study in which, in addition to the routine fetal biometry of BPD, HC, FL, and AC, measurements of each fetal foot length were made. A single radiologist performed these measurements using 2D, real-time, gray scale PHILIPS Envisor C-HD, and GE Voluson 730 Expert ultrasound equipments with 2 to 5 MHz curvilinear transducers.

Fetal foot length was measured from the skin edge overlying the calcaneus to the skin overlying the distal end of the longest toe (the first or second toe) on either the plantar or the sagittal view. In each fetus, the measurements of the two feet were averaged and a single value obtained for the purpose of statistical analysis (Fig. 1).

Normal pregnancy outcome was defined as a healthy mother and a healthy baby with a birth weight of more than 2.3 kg [so as to exclude intrauterine growth rate (IUGR) babies] delivered at term (between 37 and 42 weeks of gestation) by either normal delivery or cesarean section. All the neonates were certified healthy by the pediatrician and the mother was certified healthy by the obstetrician. The birth weight of every baby delivered in the study was recorded immediately after birth and documented.

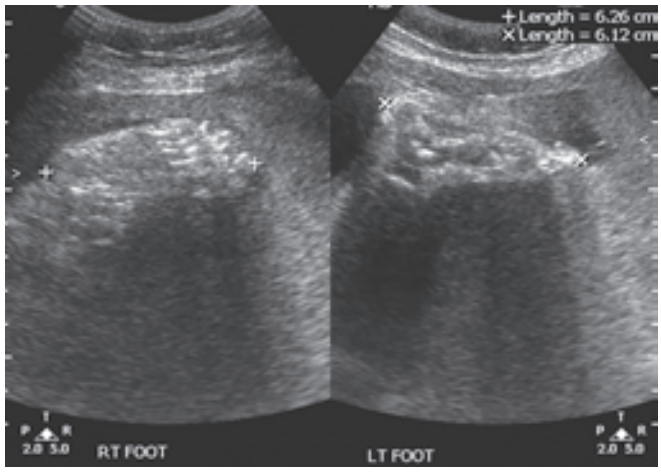


Fig. 1: Measurement technique for fetal foot length

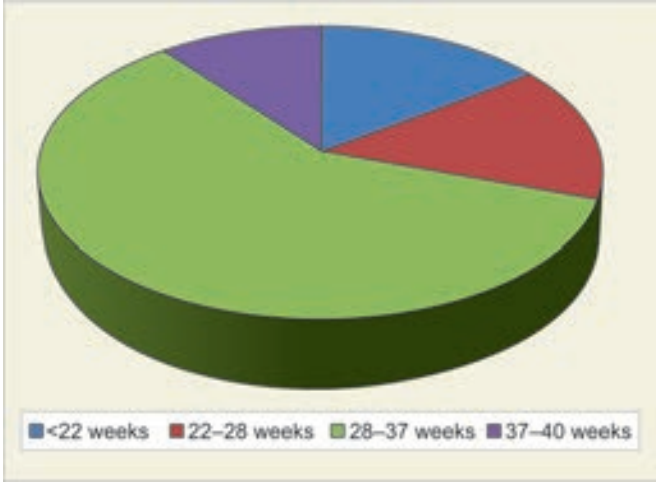
All patients included in the study delivered in Yenepoya Medical College Hospital, Mangaluru, Karnataka, India and the study was conducted.

Statistical analysis was performed using SAS 9.2, Statistical Package for the Social Sciences (SPSS) 15.0, Stata 10.1, Med Calc 9.0.1, Systat 12.0, and R environment version 2.11.1. Graphs and tables were generated using Microsoft Excel. For each gestational age in weeks, the fetal foot length was calculated from the raw data and expressed as mean ± standard deviation (SD). Linear regression analysis was used to establish a relationship between sonographic gestational age in weeks and fetal foot length, and to derive an equation to predict the gestational age in weeks from the fetal foot length measurements. Pearson's correlation coefficient and p value was calculated to estimate the level of significance and a p-value of < 0.01 was taken as strongly significant. Nomograms and growth curves were constructed to correlate gestational age with fetal foot length.

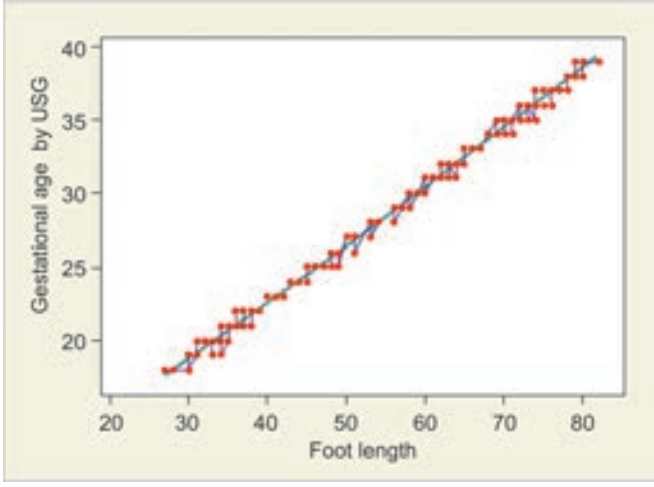
RESULTS

Table 1 and graph 1 shows that 59% of our patients were between 28 and 37 weeks; followed by 15.3% between 22 and 28 weeks; 15% less than 22 weeks; and 10.7% between 37 and 40 weeks of gestation.

Strong significant linear statistical correlation was found between sonographic gestational age and fetal foot length with a p-value of < 0.001 and R^2 value of 99.5%. Also, there was no statistically significant difference between the right and left fetal foot lengths in our study. The changes in fetal BPD, HC, FL, and AC with advancing gestation were as reported previously in other studies (Graph 2).



Graph 1: Total number and percentage of patients of < 22 weeks, 22 to 28 weeks, 28 to 37 weeks, and 37 to 40 weeks of sonographic gestational ages



Graph 2: Scatterplot of sonographic gestational age *vs* fetal foot length in the study

Table 1: Total number and percentage of patients of less than 22 weeks, 22 to 28 weeks, 28 to 37 weeks, and 37 to 40 weeks of sonographic gestational ages

Gestational age (by USG)	*No. of patients*	*%*
<22 weeks	45	15.0
22–28 weeks	46	15.3
28–37 weeks	177	59.0
37–40 weeks	32	10.7
Total	300	100.0

DISCUSSION

Accurate assessment of gestational age and fetal growth using ultrasound is imperative in providing good quality antenatal and perinatal care. It not only provides a non-invasive reliable estimate of the gestational age but also serves as a baseline upon which interval fetal growth can be assessed throughout pregnancy.

The traditional method of gestational age estimation relies on the date of the LMP and uses Naegle's rule. However, this method has its own limitations, especially when women are not able to accurately recall their LMPs or in those who have irregular menstrual cycles. This method is also fallacious when pregnancy occurs during lactational amenorrhea, as a result of oral contraceptive failure, or during chronic anovulation.[3]

The world over, ultrasound is the preferred method of estimating the gestational age during pregnancy. During first trimester, gestational sac diameter, volume and fetal crown rump length are used and during the second trimester, a composite of fetal BPD, HC, AC, and FL are used to estimate the gestational age.[3,4] However, these traditional biometric parameters have certain limitations – for instance, certain cranial malformations affecting the shape of the skull will affect the BPD and HC; some abdominal pathologies, such as ascites in fetal hydrops, and severe intrauterine growth restriction will affect AC measurements, and FL maybe difficult to measure in a deeply engaged breech and inaccurate in limb dysplasias.[5,6] This indicates that there is a need for alternate measurements to assess gestational age in second and third trimesters.[6] Our study focused on the role of fetal foot length measurements in assessment of gestational age.

George L Streeter in 1920 first showed that the fetal foot has a characteristic pattern of normal growth. He proposed that the fetal foot could be used to estimate the gestational age. Goldstein et al found that the fetal heel ossification centers could play an adjunctive role in gestational age estimation.[7] In 1987, Mercer et al performed ultrasound measurements of the fetal foot and concluded that fetal foot length is a reliable parameter for gestational age estimation and is particularly useful when other parameters do not accurately predict gestational age, as in macrocephaly, hydrocephalus, and short limbed dwarfism.[8] Chatterjee et al[7] in 1994 conducted a prospective study in 53 normal pregnant women and demonstrated a statistically significant linear correlation between fetal foot length and gestational age of 15 to 40 weeks. The study by Platt et al[9] also suggests that ultrasound measurement of fetal foot length is highly correlated to the menstrual age of the fetus. Mhaskar et al[5] performed ultrasonographic measurements of foot length in 105 fetuses and demonstrated that fetal foot length is a reliable indicator of gestational age. Similar findings were observed in a cross-sectional study conducted on 100 pregnant women in second and third trimesters by Gameraddin et al.[10]

Campbell et al[11] found that the fetal femur to foot length ratio was approximately unity between 14 and 40 weeks of gestation. They concluded that the fetal femur/

Table 2: Nomogram of the relationship between sonographic gestational age in weeks and fetal foot length in the study

GA by USG (weeks)	*No. of patients*	*% of patients*	*Foot length in mm*
19	8	2.67	31.88 ± 1.55
20	12	4.00	32.92 ± 1.24
21	17	5.67	35.94 ± 1.14
22	11	3.67	38.09 ± 0.94
23	11	3.67	40.91 ± 0.54
24	6	2.00	44.00 ± 0.63
25	11	3.67	46.91 ± 1.38
26	4	1.33	49.75 ± 1.50
27	7	2.33	51.29 ± 1.25
28	5	1.67	54.00 ± 1.22
29	4	1.33	57.00 ± 0.82
30	10	3.33	58.90 ± 0.74
31	11	3.67	61.91 ± 1.58
32	13	4.33	63.85 ± 0.99
33	13	4.33	66.31 ± 0.95
34	28	9.33	69.21 ± 0.92
35	52	17.33	71.37 ± 1.21
36	41	13.67	73.95 ± 0.80
37	19	6.33	76.26 ± 1.10
38	8	2.67	78.75 ± 0.71
39	5	1.67	79.80 ± 1.30
Total	300	100.00	
Regression 1	GA by USG (weeks) = 6.739 + 0.395 *Ft length. R^2 = 99.5%, p < 0.001*		

foot length ratio nomogram is useful to differentiate fetuses who have dysplastic limb reduction from those whose limbs are short due to constitutional factors or IUGR. Joshi et al[4] studied fetal foot length in 800 pregnant women and found linear relationship with high degree of correlation between fetal foot length and gestational age and fetal foot and femur lengths. The fetal femur/foot length ratio was fairly constant throughout gestation; being ≥ 0.9 in 51% of cases and 1 in 40% of cases. A ratio of < 0.92 is a useful indicator of skeletal dysplasias because of the asymmetric limb shortening with relative sparing of the hands and feet which occurs in these conditions.[12]

Hebbar et al[6] created a nomogram of the fetal foot length throughout gestation and found first degree correlation and linear growth function between gestational age and fetal foot length and a statistically significant correlation between foot length and other traditional growth parameters between 16 and 40 weeks of gestation. They also found that fetal foot length increased at the rate of 2.5 mm per week between 16 and 28 weeks and 2.2 mm per week from 29th week till term.

Visualization of the fetal foot is also helpful to detect anomalies like club foot and arthrogryposis. Fetal foot polydactyly has been detected in Trisomy 13.[7] Meirowitz et al[13] in 2000 conducted an ultrasound study of fetal foot length on 5,372 singleton fetuses ranging from 15 to 37 weeks of gestation and observed no significant variation in fetal foot length even in extremes of growth abnormalities, such as IUGR and macrosomia. They concluded that fetal foot length can be used as a reliable indicator of gestational age even in extremes of fetal growth.

Chitty and Altman[14] conducted a prospective, cross-sectional study and measured the foot and long bone lengths of 663 fetuses between 12 and 42 weeks of gestation in order to construct size charts of fetal foot and long bone length against gestational age. They suggested that these charts be used for antenatal diagnosis of skeletal dysplasias. Manjunatha et al[15] conducted a cross-sectional study and found that metrical measurement of fetal foot length postnatally using vernier calipers in both liveborn and stillborn fetuses correlated strongly with the gestational age in second and third trimesters. This is of paramount importance to a forensic pathologist in establishing the precise duration of pregnancy, whenever mandated.

In 2015, Pandey et al[16] conducted a prospective cross-sectional study on 100 pregnant women attending the outpatient department for antenatal ultrasound examination between 15 and 36 weeks of gestation in the Department of Radiodiagnosis in Meerut. They found a strong statistically significant relationship between fetal foot length and gestational age in the North Indian population.

Our study demonstrates that there is a statistically significant relationship between gestational age and fetal foot length during the second and third trimesters of gestation. Estimation of fetal foot length is therefore, a valuable alternate biometric parameter for gestational age estimation during second and third trimesters especially in cases where the traditional biometric parameters play a limited role; for example, in certain cranial malformations affecting the skull shape which will affect the BPD and HC; in macrocephaly, hydrocephalus; abdominal pathologies, such as ascites in fetal hydrops, and severe IUGR which will affect AC measurement, and when FL maybe inaccurate as in limb dysplasias and short limbed dwarfism.

LIMITATIONS

- In this study, IUGR fetuses, fetuses with limb deformity, achondroplasia, oligohydramnios, chromosomal or structural abnormalities have not been included. Hence, the role of fetal foot length measurement in gestational age estimation of abnormal fetuses during second and third trimesters of gestation has not been studied and cannot be applied.
- As earlier described, various researchers have found that the fetal femur/foot length ratio is fairly constant in second and third trimesters; being ≥ 0.9 in 51% of cases and 1 in 40% of cases. This ratio is useful to differentiate fetuses who have dysplastic limb

reduction from those whose limbs are short due to constitutional factors or IUGR. In addition, a fetal femur/foot length ratio of < 0.92 is a useful indicator of skeletal dysplasias.[4,11,12] However, we have not included the fetal femur to foot length ratio in our study. Hence, we cannot comment on the role of this ratio in assessment of fetuses with suspected skeletal dysplasias.

CONCLUSION

Many studies conducted across varied patient populations throughout the world conclusively demonstrate a statistically significant relationship between gestational age and fetal foot length during the second and third trimesters of gestation. Estimation of fetal foot length has also been found to be useful in skeletal dysplasias and detection of congenital anomalies of the foot. We hope that fetal foot length estimation gains widespread acceptance in the medical imaging community and is incorporated into the routine biometric parameters as part of the regular obstetric ultrasound examination.

REFERENCES

1. Lutterodt MC, Rosendahl M, Yding Andersen C, Skouby SO, Byskov AG. Age determination enhanced by embryonic foot bud and foot plate measurements in relation to Carnegie stages, and the influence of maternal cigarette smoking. Hum Reprod 2009 Aug;24(8):1825-1833.
2. Mooney EK, de la Torre JI. Lower limb embryology Gross Morphologic Overview of Lower Limb Development. 2016. [cited 2016 Oct 21]. Available from: http://emedicine.medscape.com/article/1291712-overview.
3. Kaul I, Menia V, Anand AK, Gupta R. Role of fetal kidney length in estimation of gestational age. JK Sci 2012 Apr-Jun;14(2):65-69. Available from: www.jkscience.org.
4. Joshi KS, Marahatta SB, Karki S, Tamrakar S, Shrestha NC. Fetal foot length and femur/foot length ratio: significance in Nepalese context. NJR 2011 Jul-Dec; 1(1):15-22.
5. Mhaskar R, Agarwal N, Takkar D, Buckshee K, Anandalakshmi, Deorari A. Fetal foot length – a new parameter for assessment of gestational age. Int J Gynaecol Obstet 1989 May;29(1):35-38.
6. Hebbar S, Kopal S, Adiga P, Rai L. Fetal foot length throughout gestation: a nomogram. Sri Lanka J Obstet Gynaecol 2013 Jun;35(2):58-61.
7. Molly S. Chatterjee, Luis A. Izquierdo, Bobby Nevils, George J. Gilson, Cesar Barada. 1994-04-27-19 Fetal foot: evaluation of gestational age © Chatterjee www.thefetus.net/.
8. Mercer BM, Sklar S, Shariatmadar A, Gillieson BS, D'Alton ME. Fetal foot length as a predictor of gestational age. Am J Obstet Gynecol 1987 Feb;156(2):350-355.
9. Platt LD, Medearis AL, DeVore G, Horenstein JM, Carlson DE, Brar HS. Fetal foot length: Relationship to menstrual age and fetal measurements in the second trimester. Obstet Gynecol 1988 Apr;71(4):526-531.
10. Gameraddin MB, Salih S, Yousef M. Evaluation of gestational age with fetal foot length using ultrasonography. J Am Sci 2014 Jan;10(1):5-7.
11. Campbell J, Henderson A, Campbell S. The fetal femur/foot length ratio: a new parameter to assess dysplastic limb reduction. Obstet Gynecol 1988 Aug;72(2):181-184.
12. Mital M, Gupta P, Nanda V. Fetal gestational age estimation by fetal foot length measurement and fetal femur to foot length ratio in Indian population – a prospective study. J Evol Med Dent Sci 2014 Mar;3(10):2620-2625.
13. Meirowitz NB, Ananth CV, Smulian JC, McLean DA, Guzman ER, Vintzileos AM. Foot length in fetuses with abnormal growth. J Ultrasound Med 2000 Mar;19(3):201-205.
14. Chitty LS, Altman DG. Charts of fetal size: limb bones. Br J Obstet Gynaecol 2002 Aug;109(8):919-929.
15. Manjunatha B, Nithin MD, Sameer S. Cross sectional study to determine gestational age by metrical measurements of foot length. Egypt J Forensic Sci 2012 Mar;2(1):11-17.
16. Pandey VD, Singh V, Nigam GL, Usmani Y, Yadav Y. Fetal foot length for assessment of gestational age: a comprehensive study in North India. Sch J App Med Sci 2015;3(IC):139-144.