Ultrasonographic correlation of fetal foot length and gestational age (GA) in Indian population.

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Background: Accurate knowledge of fetal weight (FW) and GA help clinicians in the evaluation of fetal growth and predict neonatal outcomes. Fetal foot length can be used as USG parameter for estimating the GA.

Aims: This study aims to determine the correlation between fetal foot length and gestational age.

Materials and Methods: In a prospective study, we investigated measurements of fetal foot length, femoral length (FL), Head circumference (HC), biparietal diameter (BPD) and abdominal circumference (AC) and estimated fetal weight (FW) in 334 pregnant women at 15 to 37 weeks' gestation who attended routine antenatal care. The fetal measurements were examined and compared with foot length.

Results: Fetal foot length correlates with the routine USG parameters like BPD, HC, FL and AC. Correlation coefficient [R] of measured fetal foot length is 0.989, 0.985, 0.994, 0.808 with HC, BPD, FL, AC respectively. Parameters are statistically significant with a 'p' value of <0.001 in all of the above correlations. Fetal foot length showed good correlation with GA with correlation coefficient 0.985 with p<0.001.

Conclusions: Fetal foot length sequentially increases with advancing GA, and correlates well with other biometric parameters, especially femur length (FL). Fetal foot length is an alternative USG parameter useful for the estimation of GA in 2nd and 3rd trimesters of pregnancy. It is a dependable marker for estimation of GA especially when other commonly utilised USG parameters are unreliable to predict GA, as in fetus with dolichocephaly, brachycephaly, hydrocephalus, achondroplasia or other varieties of short-limb dwarfism.

KEYWORDS
Gestational Age, Biparietal Diameter, Head Circumference, Abdominal Circumference, Femur Length, Foot Length, Cumulative USG age.

Conflict of interest: None

I.   INTRODUCTION

Sonography in Obstetrics and Gynecology dates from Ian Donald and his Glasgow team's classic 1958 Lancet paper, which is today recognised as one of modern medicine's great breakthroughs. [1]

Clinical researchers have seized technological advances in USG such as real-time imaging, colour and Power Doppler, transvaginal sonography, and 3/4D imaging to improve patient investigation and management in areas such as foetal growth and wellbeing, screening for foetal anomalies and preterm birth, detection of ectopic pregnancy, evaluation of pelvic masses, and fertility management. [1].

Ultrasonography is safe for fetus when used appropriately and when information about a pregnancy is needed. No reliable evidence of physical harm to growing fetuses from diagnostic ultrasound imaging using current technology. But public health experts, clinicians, and industry representatives agree that casual use of ultrasonography, especially during pregnancy should be avoided [2]. There are no adverse effects or radiation hazard on the pregnant mother or the growing fetus.

Intrauterine growth retardation (IUGR) is one of the major risk factors for perinatal morbidity and mortality [3, 4, 5, 6]. Early detection of IUGR is useful in deciding early neonatal management to avoid perinatal mortality and morbidity [3].

Accurate assessment of gestational age and evaluation of fetal growth is essential to perinatal care. Since clinical data such as menstrual cycle or uterine size often are not reliable for estimation of gestational age, the most precise parameters for pregnancy dating should be determined by the obstetrician by ultrasound. [7] Multiple fetal anatomical measurements have been used in ultrasound for evaluation of gestation. Ultrasound becomes one of the essential primary tools to evaluate fetal growth during pregnancy.

At present the most commonly used biometric parameters are HC (Head circumference),

BPD (Biparietal diameter), FL (Femoral length) and AC (Abdominal circumference).

No single fetal biometric parameter is known to be accurate in estimation of gestational age. Addition of more parameters may reduce the inaccuracy.

BPD measurements would overestimate or underestimate gestational age if the head is unusually rounded (as in brachycephalic) or extremely elongated (as in dolicocephalic). Differences in liver size and subcutaneous tissue width cause variation in AC measures in macrosomic and growth delayed foetuses [8]. Achondroplasia of the femur causes an underestimate of FL and, as a result, an underestimation of gestational age.

Fetal foot length is a reliable parameter for determining gestational age, especially when other parameters fail to reliably estimate foetal gestational age (for example hydrocephalus, anencephaly, and short limb dysplasia). [9]

In the normally developing fetus the fetal foot length increases sequentially with advancing gestational age. [10]

II. AIMS AND OBJECTIVES

- Aim

To determine the correlation between fetal foot length and gestational age.

- Objectives
- A normogram of fetal foot length in 2nd trimester and 3rd trimester vis-a-vis gestational age will be obtained.
- The Standard Deviation of the measurements of foot length, femoral length (FL), Biparietal diameter (BPD), Head circumference (HC) and Abdominal circumference (AC) will be obtained.
- The data will be used to determine correlation of fetal foot length, FL, BPD, HC and AC and gestational age.

III. MATERIALS AND METHODS

The study cohort comprised of 334 pregnant women who referred for routine ante natal USG scan between Nov 2018 to Feb 2020 at a single institution (Command Hospital, Air Force, Bengaluru, Karnataka, India-560007). This is a prospective study wherein in addition to the existing measurements; the fetal foot length was measured. The study was approved by the institutional review board of the institution. Informed consent was taken

from all the patients who were undergoing ultrasound examination. The ultrasound examinations were performed with 5 MHz curvilinear transducers on GE Logiq F8 USG machine. Transabdominal ultrasonography was done for assessment of fetal viability, number, liquor volume etc. Fetal foot length measured in millimeter in sagittal or coronal views. Along with fetal foot length other USG parameters like CRL (Crown rump length), BPD (biparietal diameter), HC (Head circumference), FL (Femoral length) & AC (Abdominal circumference) was made to determine gestational age. Congenital anomalies looked for. The foot length was obtained on planter/sagittal view. It is taken from the skin overlying the calcaneum to the distal end of the longest toe (1st or 2nd toe) [Fig 6].

- Inclusion Criteria
- Singleton live pregnancy.
- Definite about date of Last menstrual period. Regular menstrual cycles with a variation of less than 8 days in the duration of menstrual cycles.
- Established Fetal biometric parameters (CRL, BPD, HC, AC, FL) being within normal range.
- Exclusion Criteria
- Fetus with congenital anomaly on USG scans.
- Ultrasonographic evidence of IUGR / Large for date.
- Oligohydramnios or polyhydramnios.
- Maternal diabetes mellitus and hypertension.
- Maternal and paternal dwarfism or gigantism.

IV. RESULT AND ANALYSIS

Table 1 and graph 1 show that 83.5 % of our pregnant woman's were between 20 to 30 years. Table 2 and graph 2 shows that 32.9% of our pregnant woman's were between 18 to 22 weeks; followed by 23.7% between 32 to 36 weeks; 19.2% between 26 to 32 weeks; and 11.4% up to 18 weeks of gestation. Strong significant linear statistical correlation was found between CUA and fetal foot length with a p-value of < 0.001 and R2 value of 0.985% in table 3. Table 5 shows normogram of fetal Foot length (mm) of our study. Figure 3 line diagram representing correlation between fetal foot length and gestational age. Figure 4 line diagram representing correlation between fetal foot length, femur length and BPD; which advances with advancing gestational age.

Table 1: Age distribution of pregnant woman's studied

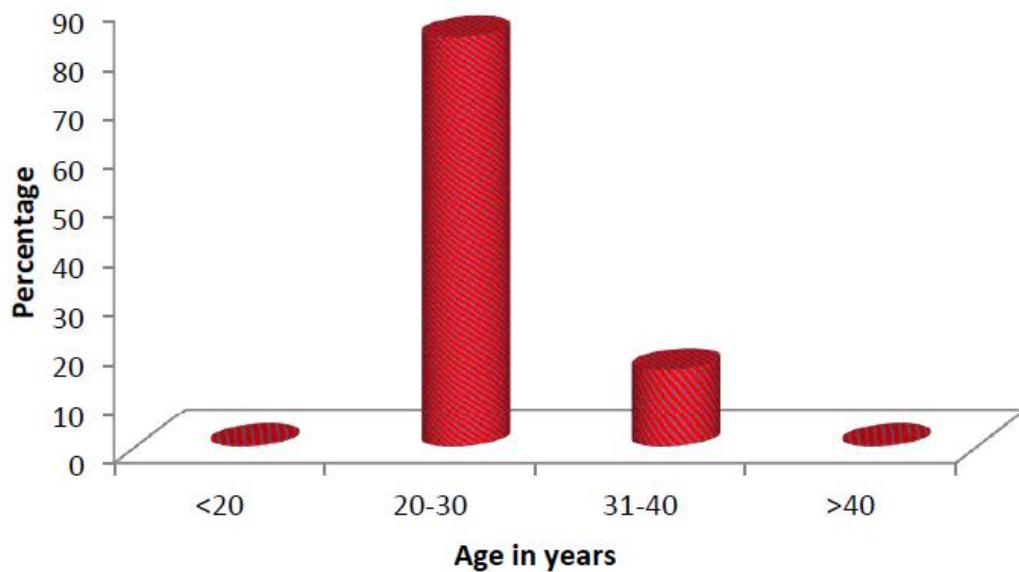| Age in years	No. of patients	%
<20	1	0.3
20-30	279	83.5
31-40	53	15.9
>40	1	0.3
Total	334	100.0

Mean ± SD: 26.72±3.85

Fig 1: Histogram representing age distribution of pregnant woman's studied

Table 2: Gestational Age distribution of pregnant woman's studied

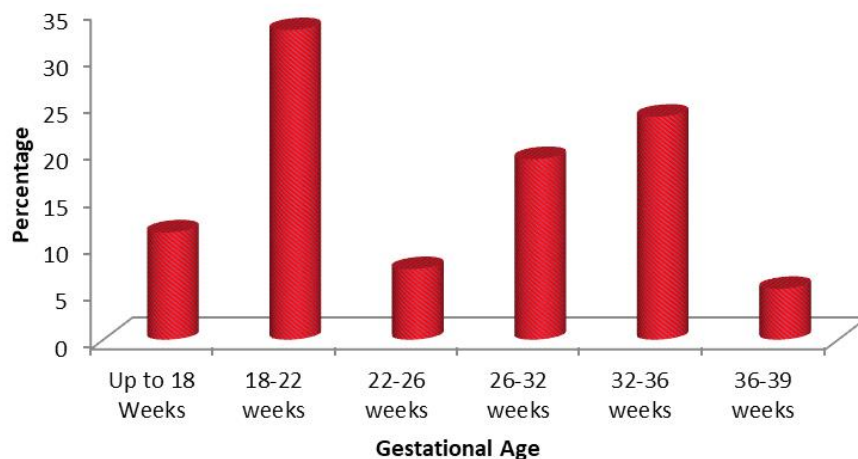| Gestational Age	No. of patients	%
Up to 18 Weeks	38	11.4
18-22 weeks	110	32.9
22-26 weeks	25	7.5
26-32 weeks	64	19.2
32-36 weeks	79	23.7
36-39 weeks	18	5.4
Total	334	100.0

Fig 2: Histogram representing gestational age distribution of pregnant woman's studied

Table 3: Correlation of CUA

	r value	P value
Cumulative USG age (CUA) vs Foot length	0.985	<0.001**
Cumulative USG age (CUA) **vs** Head Circumference	0.990	<0.001**
Cumulative USG age (CUA) **vs** Biparietal diameter	0.988	<0.001**
Cumulative USG age (CUA) **vs** Femur length	0.990	<0.001**
Cumulative USG age (CUA) **vs** Abdominal circumference	0.808	<0.001**

Table 4: A Comparison of foot length (mm), Head circumference (mm), BPD (mm), Femur length (mm) and abdominal circumference (mm) according to gestational age in weeks: Cumulative USG age (CUA)

Gestational age (weeks)	Foot Length	Head circumference	Biparietal diameter	Femur length	Abdominal circumference
14	14.80±0.00	101±0.00	24.90±0.00	14.30±0.00	78.90±0.00
15	20.25±2.9	117.20±1.56	31.95±0.35	17.40±0.00	95.65±1.20
17	25.15±4.45	140.55±5.87	38.80±0.85	23.00±4.24	118.65±1.34
18	28.25±1.81	157.29±4.91	41.84±1.90	28.10±1.25	132.37±5.41
19	31.32±1.58	169.67±4.49	45.72±1.42	30.55±1.24	142.83±7.42
20	33.69±1.89	178.89±4.90	47.56±1.31	32.74±1.12	154.76±4.38
21	37.57±1.65	195.44±4.72	52.12±1.67	36.85±1.19	164.44±6.70
22	40.18±0.91	205.46±4.46	55.64±1.63	39.73±1.34	179.36±8.37
23	42.73±2.05	217.63±6.70	58.41±2.38	41.46±2.14	190.44±3.96

24	48.35±1.20	225.85±1.63	61.15±0.21	44.75±1.06	196.50±9.05
25	49.23±2.40	237.72±3.31	64.20±1.94	47.15±1.92	212.55±6.35
26	53.99±4.50	248.86±9.42	68.22±3.55	50.57±3.17	225.82±11.14
27	51.53±2.12	261.80±8.10	69.43±1.99	52.33±0.81	234.60±5.59
28	57.17±1.60	266.15±5.06	72.98±1.82	55.42±1.77	241.53±11.93
29	58.66±2.72	276.69±5.47	75.04±1.13	56.13±1.47	255.19±3.89
30	60.67±3.31	281.65±7.79	76.73±2.88	58.62±2.22	260.25±13.84
31	62.76±2.66	289.63±6.42	79.92±1.99	60.50±1.74	276.52±9.06
32	65.78±2.18	298.77±5.86	82.66±1.72	62.76±1.08	285.95±10.20
33	66.72±2.52	307.33±5.64	83.63±4.42	65.10±1.84	292.34±10.61
34	68.98±2.67	312.10±5.00	87.05±1.94	67.42±1.88	305.73±7.64
35	70.86±1.19	315.53±3.39	88.64±1.31	69.13±1.23	319.17±9.56
36	71.83±1.49	326.24±2.94	91.43±1.59	71.57±1.44	325.69±12.56
37	73.20±0.84	330.20±1.42	93.08±1.52	73.10±0.65	333.55±2.03
P value	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

Table 5: Normogram of fetal Foot length (mm):

Gestational age (weeks)	Foot Length lower limit (mm)	Foot Length mean (mm)	Foot Length upper limit (mm)
15	17.35	20.25	23.15
17	20.7	25.15	29.6
18	26.44	28.25	30.06
19	29.74	31.32	32.32
20	31.8	33.69	35.58
21	35.92	37.57	39.22
22	39.27	40.18	41.09
23	40.68	42.73	44.78
24	47.15	48.35	49.55
25	46.83	49.23	51.63
26	49.49	53.99	58.49
27	49.41	51.53	53.65
28	55.57	57.17	58.77
29	55.94	58.66	61.38
30	57.36	60.67	63.98
31	60.1	62.76	65.42
32	63.6	65.78	67.96
33	64.54	66.72	68.9

34	66.31	68.98	71.65
35	69.67	70.86	72.05
36	70.34	71.83	73.32
37	72.36	73.20	74.04
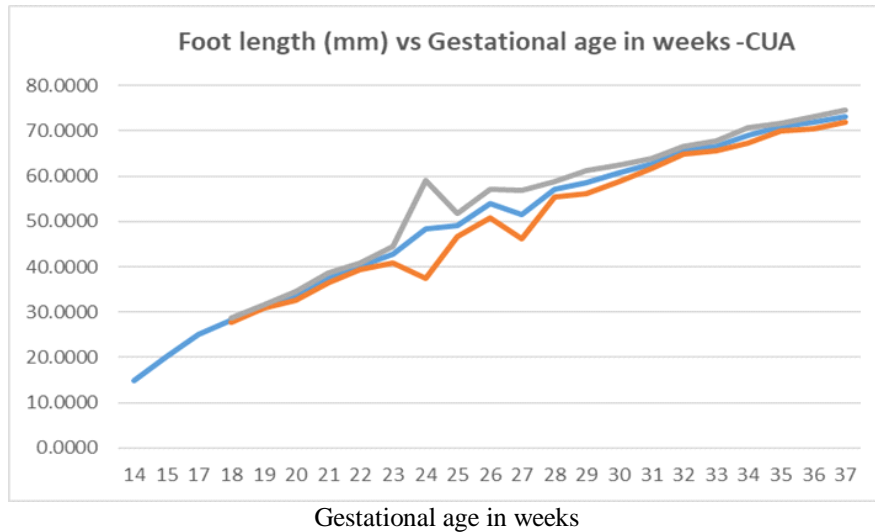
Gestational age in weeks

Fig 3: Line diagram representing correlation between fetal foot length and gestational age

Gestational age in weeks
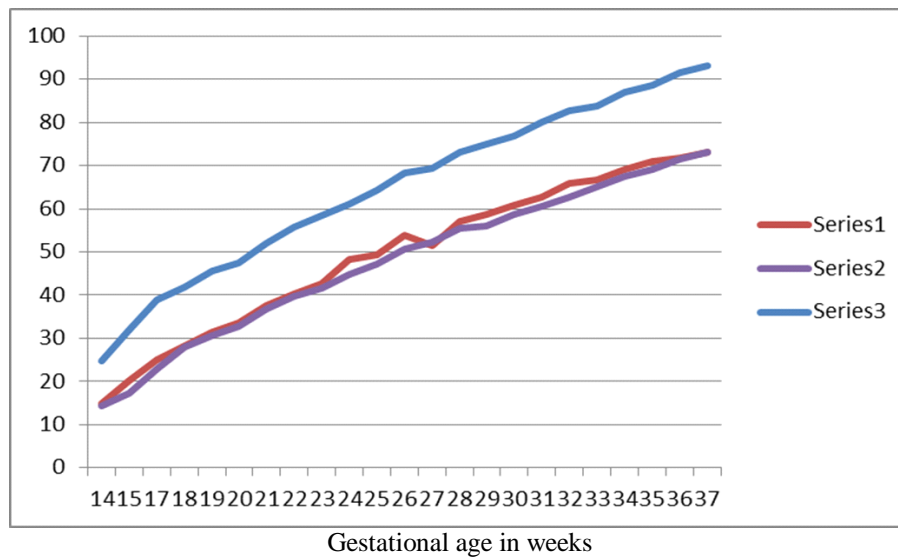
Series1-Foot length
Series2-Femur length
Series3-BPD

Fig 4: Line diagram representing correlation between fetal foot length, femur length and BPD
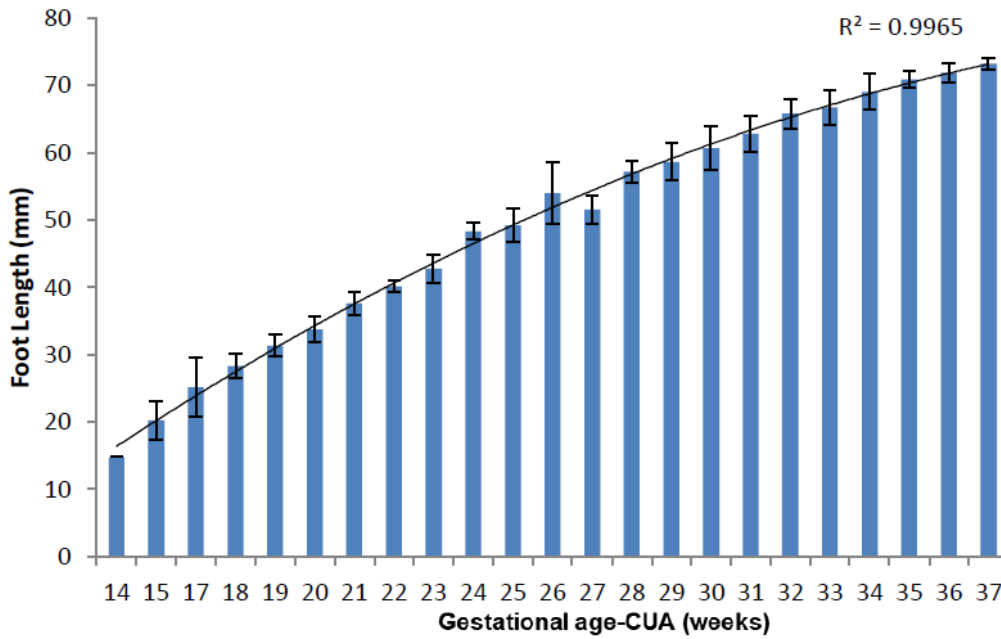
Fig 5: Histogram and line diagram representing correlation between fetal foot length & gestational age and R²
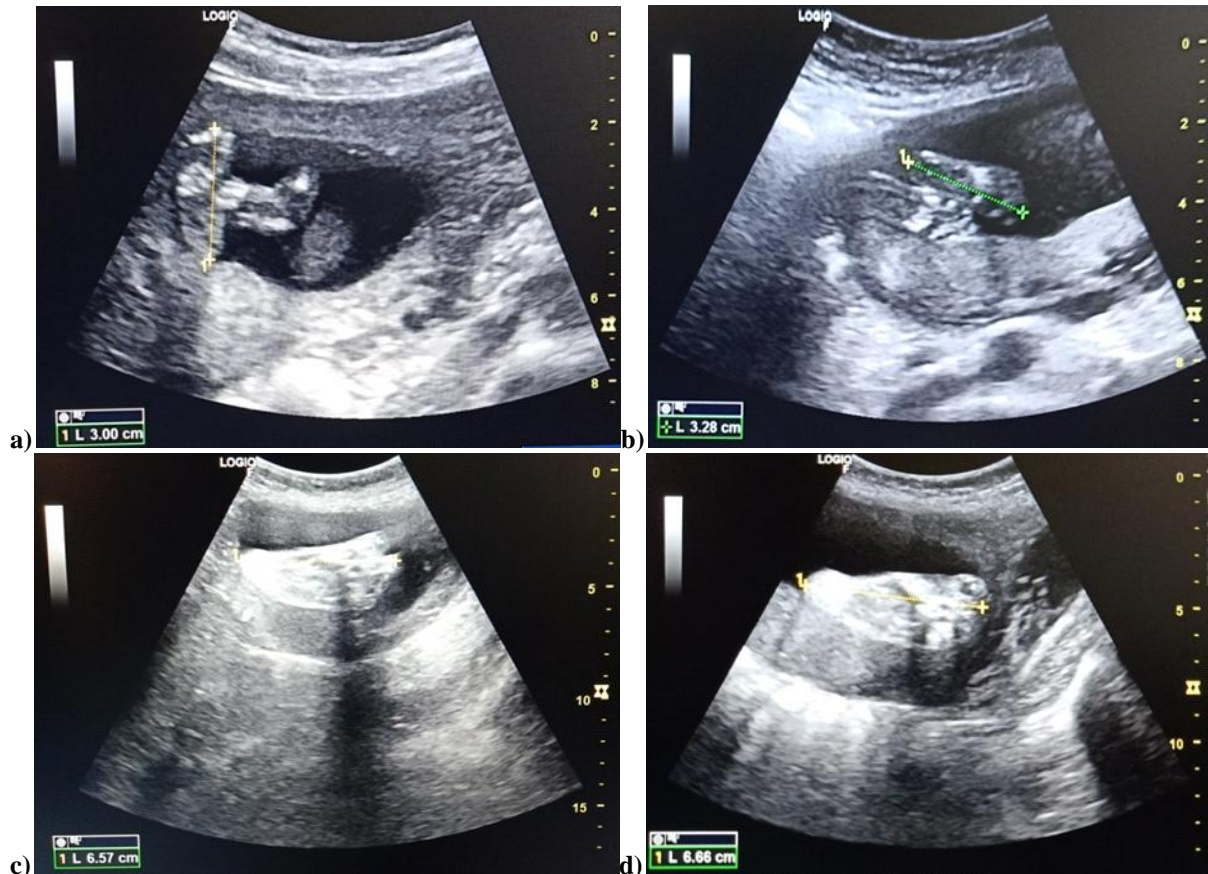
e)   f)

Fig 6 (a,b,c,d,e,f): Representative fetal foot images from six different cases, illustrating ultrasonographic measurement of foot length.

V.   DISCUSSION

In perinatal care, accurate gestational age estimation is essential. Because clinical examinations such as the menstrual cycle or uterine size are not always reliable indicators of pregnancy dating in the early stages of pregnancy. [7]

As a standard prenatal care modality, USG is an accurate and helpful technique for assessing GA in pregnancy; it can have a significant impact on obstetric management and improve prenatal care. Any routine USG parameter [e.g., head circumference, biparietal diameter, femur length, abdomen circumference] is measured based on how easy it is to obtain and how accurate it estimates GA. Measurement that is easily obtained but inaccurate for estimating GA is of less value. It's also not very useful to have a measurement that precisely predicts GA but is quite difficult to collect.

From analysis of our study data with a sample size [n=334], fetal foot length is reliable parameter in estimating the GA. Fetal foot length correlates with the routine USG parameters like biparietal diameter, head circumference, femur length and abdominal circumference. The correlation coefficient [R] of measured fetal foot length is 0.989, 0.985, 0.994, 0.808 with HC, BPD, FL, AC respectively. Correlation of fetal foot length with routine USG parameters are statistically significant with a p value of <0.001 in all of the above correlations.

In our study fetal foot length showed good correlation with GA with correlation coefficient 0.985 with p<0.001. Goldstein I et al. [17] found a significant correlation between fetal foot length and GA (r = 0.9, p<0.0001) and between fetal foot length and femur length (r = 0.9, p <0.0001). Pandey et al (2015) [10] found a significant correlation between fetal foot length and gestational age with correlation coefficient 0.960 and p<0.0001

and between fetal foot length and femur length (r=0.948, p<0.0001); In our study correlation coefficient between fetal foot length and gestational age (r=0.985, p<0.001) and between fetal foot length and femur length (r=0.994, p<0.001) was found to be similar.

Table-6 shows the comparison between the values of Fetal Foot Length of our study with previous studies done by Molly S et al. [12], Andrzej M et al. [13], Rajesh B et al. [14], Family Practice Notebook [16] and Mukta et al [11]. Our study suggests that the measurement of fetal foot length with ultrasound gives a reliable estimation fetal foot length and is highly correlated to the menstrual age of the fetus. R. Mhaskar et al. [15] in 1989 demonstrated a strong correlation on comparison of linear regression of foot length versus gestational age with an r2 value of 0.84 (P < 0.001) which is comparatively much lesser than the present study showing r2 value of 0.9965 (p<0.001). Molly S. Chatterjee et al. [12] in 1994 similarly showed significant linear relationship between fetal foot length and gestational age (R2= 0.89, p<<0.0001). Andrzej M et al. [13] in 2003 found value of the correlation between foot length and femur length was 0.91 and between foot length and fetal age was 0.94 which is close association with our study.

Since our study also compared the foot length with the more recognizable routinely used USG parameters such as head circumference, biparietal diameter, femur length and abdominal circumference, a higher association was found between femur length, head circumference and biparietal diameter with that of gestational age as compared with foot length and abdominal circumference.

In conditions such as abnormal head shape (e.g. microcephaly, hydrocephalus & anencephaly), where HC & BPD measurement is unreliable, fetal

foot length becomes a reliable alternate measuring parameter. In condition such as short limb dwarfism and other skeletal dysplasias, where femur length is unreliable, fetal foot length is a good predictor for gestational age along with other USG parameters.

Table 6: Comparison between Values of fetal foot length (mm) and gestational age (Our Study with Previous Studies)

GA in weeks	Our Study (CUA)	Molly S. Chatterjee et al (1994) [12]	Mukta et al 2014[11]	Family Practice Notebook[16]	Andrzej M. bulandra et al (2003)[19]	Rajesh Bardale et al (2008)[14]
14	14.80±0.00					21.4±8.8
15	20.25±2.9	20		18	19.75	
16		22	21	20	18.94±1.92	
17	25.15±4.45	25	25	23	22.63±2.47	32.1±5.4
18	28.25±1.81	27	27	26	24.70±1.96	
19	31.32±1.58	30	31	29	29.19±2.62	
20	33.69±1.89	32		33	30.90±4.91	
21	37.57±1.65	35	35	36	35.38±2.91	42.6±4.51
22	40.18±0.91	37	38	39	39.01±2.05	
23	42.73±2.05	40	42	42	43.16±3.91	
24	48.35±1.20	42		45	45.80±4.51	
25	49.23±2.40	45			46.25	50.9±2.55
26	53.99±4.50	48	49		52.71±1.99	
27	51.53±2.12	50			51.81±1.33	
28	57.17±1.60	53	54		52.25	
29	58.66±2.72	55			56.75±6.01	58.2±4.95
30	60.67±3.31	58	58		57.50±8.84	
31	62.76±2.66	60	62			
32	65.78±2.18	63	63			
33	66.72±2.52	65	66		56.50	71.0±4.94
34	68.98±2.67	68				
35	70.86±1.19	70	69			
36	71.83±1.49	73	72			
37	73.20±0.84	75	74			75.6±4.17
38		78				
39		80				

Table 7: Comparison with various studies with respect to gestational age:

STUDY	CORRELATION COEFFICIENT [R]	P VALUE
Streeter et al ,1920 [18]	0.98	<0.0001
Joshi et al, 2011 [20]	0.97	0.0001
Platt et al, 1988 [21]	0.94	0.0001
Molly et al , 1994 [12]	0.89	<0.0001
Wozmiak et al, 2009 [22]	0.89	<0.001
Drey et al , 2005 [23]	0.87	0.0001
Pandey et al (2015) [10]	0.960	<0.0001
Our study	0.985	<0.001

VI. CONCLUSION

Fetal foot length sequentially increases with advancing GA, and correlates well with other biometric parameters, especially femur length (FL). Fetal foot length is an alternative USG parameter useful for the estimation of GA in 2nd and 3rd trimesters of pregnancy. It is a dependable marker for estimation of GA especially when other commonly utilized USG parameters are unreliable to predict GA, as in fetus with dolichocephaly, brachycephaly, hydrocephalus, achondroplasia or other varieties of short-limb dwarfism.

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