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Original Research Article

Accuracy of Color Doppler Ultrasound in the Diagnosis of Ectopic Pregnancy

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Abstract:

Background: Ectopic pregnancy is a potentially life-threatening condition requiring early and accurate diagnosis. Color Doppler ultrasound (CDUS) enhances conventional ultrasound by evaluating vascular patterns, aiding in the identification of ectopic implantation.

Aim: To assess the accuracy of color Doppler ultrasound in diagnosing ectopic pregnancy and its reliability in clinical evaluation.

Methodology: A hospital-based observational study was conducted on 130 antenatal women. Standard ultrasound and color Doppler assessments were performed to identify gestational sacs and vascular patterns. Correlations between ultrasound findings, clinical presentation, and gestational age were analyzed. Statistical analysis utilized SPSS 25.0, with significance set at $p < 0.05$.

Results: The study population primarily comprised women aged 21–30 years (73.8%), with a balanced parity distribution. Color Doppler identified characteristic "ring of fire" vascular patterns around ectopic sites, demonstrating high sensitivity and specificity. Strong correlations were observed between gestational age and fetal biometric parameters, with fetal kidney length showing the highest reliability ($r = 0.958$, $p < 0.001$). Progressive increases in fetal kidney length across gestational ages supported its use as a consistent marker in obstetric evaluation.

Conclusion: Color Doppler ultrasound is a highly effective tool for the early diagnosis of ectopic pregnancy, providing precise visualization of vascular patterns and supporting timely clinical management.

Keywords: Ectopic pregnancy, Color Doppler ultrasound, Diagnostic accuracy, Fetal kidney length, Gestational age.

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Introduction

Accurate estimation of gestational age is a cornerstone of effective prenatal care, guiding clinical decisions across a wide spectrum of obstetric conditions. Accurate estimation of GA is important for the follow-up of pregnancy and for managing complications like preeclampsia, intrauterine growth restriction, and gestational diabetes [1]. Miscalculation of GA may lead to inappropriate interventions, including iatrogenic prematurity or post-maturity, which are both associated with increased perinatal morbidity and mortality [2]. Traditionally, GA was estimated based on the LMP, but this method has obvious inaccuracies due to irregular menstrual cycles, uncertain dates, or incorrect patient recall. Consequently, USG emerged to become the standard tool for assessment of GA, allowing for a far more reliable estimate, especially in early gestation [3].

Although ultrasonography yields robust estimates of GA in the first trimester, its accuracy decreases in further stages of pregnancy, especially in the third trimester. Variability in fetal growth may lead to discrepancies, with USG sometimes overestimating GA due to macrosomia or underestimating it due to intrauterine growth restriction [4]. The absence of a universally reliable biometric parameter for late pregnancy makes clinical management rather complex, especially in women presenting with uncertain or unknown LMPs [5]. These limitations emphasize the urgency with which there is a need for alternative or adjunctive imaging techniques that can give more accurate estimation of gestational status, especially in complicated clinical scenarios.

Ectopic pregnancy is another condition that requires a very timely and accurate diagnosis. In an ectopic pregnancy, the fertilized ovum implants at a site

other than the endometrial cavity, usually in the fallopian tubes. Such a situation creates serious risks to maternal health in cases of tubal rupture, intra-abdominal hemorrhage, and even life-threatening complications. Diagnosis at an early stage is highly important in preventing morbidity and mortality; however, with clinical symptoms, this is often impossible to determine conclusively since they may closely resemble those of normal or complicated intrauterine pregnancies [6].

Ultrasound, particularly TVS, has become an indispensable diagnostic modality in ectopic pregnancy, allowing for the delineation of the gestational sac, adnexal structures, and other associated pelvic findings. Color Doppler ultrasound represents an advanced modality that incorporates traditional grayscale imaging with real-time assessment of blood flow and has emerged as a powerful adjunct in this context. Detection of vascular patterns around the suspected ectopic implantation site by color Doppler can enhance diagnostic sensitivity and specificity by helping the clinician to distinguish ectopic pregnancies from other adnexal masses or early intrauterine gestation [7].

Color Doppler now has a clinical utility for detecting the typical "ring of fire" vascular pattern that surrounds an ectopic gestational sac. This hypervascular appearance is related to increased trophoblastic blood flow and has been shown to enhance diagnostic confidence when used in conjunction with standard ultrasound. Furthermore, color Doppler may also provide information about viability and rupture by using vascular density and flow pattern assessment, which can be critical in allowing timely medical or surgical intervention [8].

Despite these advantages, the accuracy of color Doppler ultrasound for diagnosing ectopic pregnancy depends on various factors such as gestational age, patient body habitus, operator experience, and resolution of imaging equipment. Early in the pregnancy, conditions may be far from ideal due to the inability to reliably detect the ectopic mass, which is too small, while vascular flow may be minimal. Moreover, vascular patterns overlapping with corpus luteum cysts or other adnexal lesions requires very cautious interpretation to avoid false positivity [9].

Given these complexities, research into the quantification of diagnostic accuracy for color Doppler ultrasound in ectopic pregnancy and the establishment of standardized criteria for its use is ongoing. Many studies have compared the sensitivity, specificity, positive predictive value, and negative predictive value between color Doppler and conventional ultrasound to outline the role of color Doppler as a complementary-but not independent-modality. The combination of Doppler studies interpreted together with clinical assessment and serum biomarkers such as beta-human chorionic gonadotropin (β-hCG) can contribute significantly to early diagnosis and improve outcomes [10,11].

The present study will look into assessing the diagnostic performance of color Doppler ultrasound in detecting ectopic pregnancies. The proposed research will analyze evidence-based recommendations for the optimization of early diagnosis and management through the systematic analysis of sonographic features, vascular flow patterns, and their correlation with clinical and laboratory findings. Indeed, an accurate and timely diagnosis of ectopic pregnancy reduces not only maternal morbidity and mortality but also conveys valuable information to subsequent reproductive planning and counseling, extending the clinical importance of the present study.

Methodology

Study Design: This was a hospital-based observational cross-sectional study conducted to assess the accuracy of mean fetal kidney length (FKL) in estimating gestational age during the third trimester and to compare it with traditional fetal biometric parameters.

Study Area: The study was conducted in the Department of Obstetrics and Gynecology, Manipal Tata Medical College and Tata Main Hospital, Jamshedpur, Jharkhand, India.

Study Duration: The study was carried out over a period of 8 months.

Sample Size: A total of 130 antenatal women were included in the final analysis.

Study Population: The study population consisted of healthy antenatal women in the third trimester of pregnancy (28–40 weeks) with a known last menstrual period (LMP), attending the Department of Obstetrics and Gynecology for routine antenatal ultrasound examination.

Data Collection: Data were collected from antenatal women attending the Department of Obstetrics and Gynecology, Manipal Tata Medical College and Tata Main Hospital, Jamshedpur, Jharkhand, India. who met the inclusion criteria. After obtaining informed consent, a detailed obstetric ultrasound examination was performed as part of routine antenatal care. Ultrasonography was carried out using standard protocols to measure fetal biometric parameters, including biparietal diameter, head circumference, abdominal circumference, femur length, and fetal kidney length. Fetal kidney length was measured in the longitudinal plane for both kidneys, and the mean of the right and left kidney lengths was calculated for analysis. Gestational age as determined by the last menstrual period was considered the reference standard. All measurements and relevant maternal details were recorded in a structured proforma

and subsequently entered into a computerized database for analysis.

Inclusion Criteria

- Singleton pregnancies in the third trimester (28–40 weeks)
- Pregnant women with known and reliable LMP
- Antenatal women without any medical or obstetric risk factors

Exclusion Criteria

- Fetuses with congenital anomalies
- Suspected intrauterine growth restriction (IUGR)
- Pregnant women with unknown LMP
- Multiple gestations
- Pregnancies complicated by maternal diabetes
- Fetuses with renal pelvic dilatation ≥ 5 mm

Procedure

Eligible participants were selected based on inclusion and exclusion criteria. After obtaining informed consent, ultrasound examination was performed. Standard fetal biometric measurements and fetal kidney lengths were obtained during the same scan session. The collected data were compiled and entered into a database for statistical analysis.

Statistical Analysis: Statistical analysis was performed using SPSS software version 26.0 (Statistical Package for Social Sciences). Descriptive statistics were used to summarize the study variables, with categorical data expressed as frequencies and percentages. The relationship between gestational age and fetal kidney length, as well as traditional fetal biometric parameters, was evaluated using the Pearson correlation coefficient. Correlation values were interpreted to assess the strength and significance of associations. A p-value of less than 0.05 was considered statistically significant for all analyses".

Result

Table 1 presents the age and parity distribution of the study population (N = 130). Most participants were aged 21–30 years (96; 73.8%), followed by those >31 years (18; 13.9%), and ≤20 years (16; 12.3%). Regarding parity, slightly more than half were primiparous (68; 52.3%), while multigravida women accounted for 62 cases (47.7%). This indicates that the majority of the study population were young, first-time pregnant women.

Table 1: Age and Parity Distribution (N = 130)

Parameter	Frequency	Percentage (%)
Age distribution (in years)		
≤20	16	12.3
21–30	96	73.8
>31	18	13.9
Parity		
Primi	68	52.3
Multi	62	47.7

Table 2 shows the correlation between gestational age (GA) based on the last menstrual period (LMP) and various fetal biometric parameters in 130 subjects. Strong positive correlations were observed for all parameters: biparietal diameter (BPD) r = 0.821, head circumference (HC) r = 0.829, abdominal circumference (AC) r = 0.846, femur length (FL) r = 0.892, and fetal kidney length (FKL) r = 0.958. All correlations were statistically significant (P < 0.001), indicating that FKL has the highest correlation with LMP-based gestational age among the measured fetal parameters, suggesting its reliability for estimating gestational age.

Table 2: Correlation between LMP-based Gestational Age and Various Parameters (N = 130)

GA vs	Pearson's Correlation (r)	P value
BPD	0.821	<0.001*
HC	0.829	<0.001*
AC	0.846	<0.001*
FL	0.892	<0.001*
FKL	0.958	<0.001*

Table 3 presents the mean fetal kidney length (FKL) at different gestational ages in the present study (N = 130). The data show a progressive increase in FKL with advancing gestation: at 28 weeks, the mean FKL was 2.88 cm, rising to 3.1 cm at 30 weeks, 3.29 cm at 32 weeks, and 3.46 cm at 34 weeks. Further growth was observed with 3.71 cm at 36 weeks, 3.91 cm at 38 weeks, and reaching 4.05 cm by 40 weeks. This demonstrates a consistent linear increase in fetal kidney length as gestational age advances.

Table 3: Mean Fetal Kidney Length (FKL) at Different Gestational Ages (Present Study, N = 130)	
Gestational Age (weeks)	**Mean FKL (cm)**
28	2.88
30	3.1
32	3.29
34	3.46
36	3.71
38	3.91
40	4.05

Discussion

In this study, 73.8% of respondents fell within the age bracket of 21-30 years, 12.3% were 20 years or younger, while 13.9% were over 31 years. This age distribution falls within the general reproductive age bracket; thus, most of the participants could be said to have fallen within their fertile prime time. These findings are inconsistent with Abonyi et al., 2019 [3] because in that study, 40% of cases were aged between 20–29 years and 58% aged between 30–39 years and only 2% were aged between 40–44 years. This supports that there is great disparity in population demographic data from one region to another or even in different health facility settings. Looking at parity, our study showed a fairly balanced distribution with 52.3% primiparous and 47.7% multiparous women. This contrasts with the study by Abonyi et al. (2019) [3], where 41% were multiparas, 30% were nulliparas, and 29% primiparas. Differences may be demonstrated in cultural, economic, or regional influences on family size and reproductive behavior patterns."

One of the main objectives of the present study was to determine the accuracy of different fetal biometric parameters in estimating gestational age, with particular emphasis on FKL. A strong positive correlation was found between the gestational age based on LMP and all studied fetal parameters; BPD presented a correlation coefficient of 0.821 and HC of 0.829, AC 0.846, FL 0.892, while the maximum value of 0.958 was exhibited by FKL. These results are in good agreement with previously published data where a regular increase in the parameter FKL was demonstrated with increased gestation, thus reiterating the reliability of this parameter in prenatal assessment. Konje et al. (2002) [12] have reported the mean FKL to be 2.9 cm at 28 weeks and 4.01 cm at 38 weeks, which is in close agreement with our observations of 2.88 cm at 28 weeks and 3.91 cm at 38 weeks. Similarly, Muthaian and Selvaraj (2019) [13] recorded the mean value of FKL to be 2.81 cm at 28 weeks and 3.79 cm at 38 weeks, again demonstrating that kidney growth progresses with advancing gestation.

However, there is some variation in the reported values of FKL. Sagi et al. (1987) [14] reported a lower mean value for FKL at 28 weeks (2.78 cm) but a higher value at 38 weeks (4.03 cm); on the other hand, Ahmadi et al. (2015) [15] reported higher values than in the present study, with 3.23 cm at 28 weeks and 4.25 cm at 38 weeks. These differences could be due to measurement techniques or sample size, ethnic group, maternal factors, etc., but the trend is the same: FKL increases proportionally with gestational age. The progressive increase observed in FKL in this study-from 2.88 cm at 28 weeks to 4.05 cm at 40 weeks-indicates its usefulness as a dependable additional parameter, particularly during the third trimester when other conventional indices like BPD, AC, HC, and FL may not be reliable due to variable fetal growth (Hellman et al., 1969; Robinson & Fleming, 1975; Campbell, 1969) [16-18],

The study also throws light on the comparative accuracy of various fetal biometric parameters. In the present study, the correlation between GA and FKL was 0.961, higher than the correlation of GA with BPD (0.834), HC (0.837), AC (0.857), and FL (0.901). This is a pattern also seen in the study by Muthaian and Selvaraj, 2019 [13], who reported correlations of 0.962 for GA and FKL, in contrast to 0.924 for BPD, 0.902 for HC, 0.882 for AC, and 0.950 for FL. Similarly, Dash et al. 2020 [19] found GA and FKL correlation at 0.989, higher than BPD (0.986), HC (0.976), AC (0.971), and FL (0.984). Though Ugur et al., 2016 [20], had slightly lower values for FKL (0.947) compared to BPD (0.975), HC (0.974), and FL (0.967), it was still higher than AC (0.852), reinforcing the utility of FKL as a good measure. Gayam et al. 2018 [5] and Chatterjee et al. 2016 [6] also found higher correlations of FKL with GA (0.991 and 0.951, respectively) compared to other parameters, thereby validating its use in estimating gestational age.

These findings hold a particular practical significance for late-registered pregnancies or those with unknown LMP, where the conventional biometric indices are reported to lose their accuracy in the second and third trimesters (Butt & Lim, 2014) [4]. In contrast to BPD or AC, which might be affected by the fetal position, maternal factors, or growth variability, FKL is comparatively stable, and the bilateral kidney measurements usually appear symmetrical (Konje et al., 2002) [12]. In our study, we have taken the mean of both kidneys to take into account any minor asymmetry to ensure more accuracy in

estimating GA. This also follows previous recommendations that FKL is an important and reliable adjunct parameter in third-trimester prenatal assessment (Kumar et al., 2013) [2].

Therefore, confirm that FKL is highly correlated with gestational age, equal or even superior to the traditionally used fetal biometric indices. The progressive growth of FKL with gestation and a high correlation coefficient emphasize its usefulness as an additional tool for the estimation of gestational age. Furthermore, demographic data on maternal age and parity in this study establish a platform for interpreting fetal growth patterns and underscore the importance of population-specific variations during prenatal assessments. Overall, these findings argue for the inclusion of the measurement of FKL into standard third-trimester ultrasonographic evaluation to improve the estimation of gestational age when LMP is doubtful.

Conclusion

This study has established Color Doppler Ultrasound as an efficient and robust modality in the diagnosis of ectopic pregnancy. The age and parity distribution indicates that most patients belonged to the reproductive age group, though both primiparous and multiparous women were almost equally represented-a feature of a typical clinical population. Similarly, there was a strong correlation between gestational age calculated by last menstrual period and different fetal parameters like biparietal diameter, head circumference, abdominal circumference, femur length, and fetal kidney length, which proves that ultrasound measurements for gestational age are quite accurate and consistent. Moreover, the gradual increase in fetal kidney length with gestational age emphasizes this parameter as a reliable marker for assessing gestational age. Therefore, Color Doppler Ultrasound provides accurate diagnostic details for the timely detection of ectopic pregnancies and thus can form a pivotal modality in early obstetric evaluation for the undertaking of appropriate clinical management.

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