



Research Article

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Three-Dimensional Ultrasonic Volumetric Assessment of Fetal Liver for Determination of Gestational Age: Correlation with Conventional Parameters

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Abstract

Background: Fetal liver volume can be a precise measure of somatic growth. It represents a sizable part of the fetal abdomen and reflects metabolic and hematological activities at different stages during gestation. **Objective:** To analyze the pattern of growth for fetal liver volume (FLV) in pregnancies and its relationship with traditional biometric parameters and gestational age (GA) as a reliable indicator of fetal growth. **Methods:** A cross-sectional observational study involving 100 pregnant women with a potential singleton fetus between 18 and 40 weeks was carried out at Al-Yarmouk Teaching Hospital, Baghdad, Iraq. The FLV was evaluated using the ellipsoid formulation, which is predicated on 3D linear measurements obtained via ultrasound. Standard biometric parameters, including biparietal diameter (BPD), femur length (FL), and abdominal circumference (AC), were established. **Results:** FLV exhibited a robust positive correlation with estimated fetal weight ($r=0.706, p=0.0001$) and gestational age evaluated through BPD, FL, and AC ($r>0.72, p=0.0001$). During late gestation, FLV values remained stable within a narrow range of 356–360 cm³. There were no significant differences noted between male and female fetuses regarding FLV, linear liver dimensions, or birth weight ($p>0.05$), thereby confirming sex neutrality. **Conclusions:** Fetal liver volume is a reliable, gender-neutral measure of fetal growth with high correlation with both abdominal circumference and weight. It can be considered for prenatal assessments to facilitate early identification of intrauterine growth restriction (IUGR) and fetal growth tracking.

Keywords: Fetal liver; Fetal liver volume; Gestational age; Pregnancy.

التقييم الحجمي ثلاثي الأبعاد بالموجات فوق الصوتية لكبد الجنين لتحديد عمر الحمل: الارتباط مع المعايير التقليدية

الخلاصة

الخلفية: حجم كبد الجنين يمكن أن يكون مقياساً دقيقاً للنمو الجسدي. يمثل جزءاً كبيراً من بطن الجنين ويعكس الأنشطة الأيضية والنموية في مراحل مختلفة من الحمل. **الهدف:** تحليل نمط نمو حجم كبد الجنين (FLV) في حالات الحمل وعلاقته بالمعايير البيومترية التقليدية وعمر الحمل (GA) كمؤشر موثوق لنمو الجنين. **الطرائق:** أجريت دراسة مقطعية رصدية شملت 100 امرأة حامل لديهن جنين محتمل بعمر حمل بين الأسبوع 18 و 40 في مستشفى البرموك التعليمي في بغداد، العراق. تم تقييم FLV باستخدام تركيبة الإهليلجية، التي تعتمد على قياسات خطية ثلاثية الأبعاد تم الحصول عليها عبر الموجات فوق الصوتية. تم تحديد معايير قياسية حيوية، بما في ذلك قطر ثنائي الجدار (BPD)، وطول عظم الفخذ (FL)، ومحيط البطن (AC). **النتائج:** أظهر FLV ارتباطاً إيجابياً قوياً مع وزن الجنين المقدر ($r=0.706, p=0.0001$) وعمر الحمل الذي تم تقييمه من خلال BPD و FL و AC ($r>0.72, p=0.0001$). خلال أواخر الحمل، ظلت قيم FLV مستقرة ضمن نطاق ضيق يتراوح بين 356–360 سم³. لم تلاحظ فروق ذات دلالة إحصائية بين الأجنة الذكور والإناث فيما يتعلق ب FLV، أو أبعاد الكبد الخطية، أو وزن الولادة ($p>0.05$)، مما يؤكد حيادية الجنس. **الاستنتاجات:** حجم كبد الجنين هو مقياس موثوق ومحاذ جنسياً لنمو الجنين مع ارتباط عال مع محيط البطن والوزن. يمكن النظر في ذلك لإجراء تقييمات ما قبل الولادة لتسهيل التعرف المبكر على تقييد نمو الرحم (IUGR) وتتبع نمو الجنين.

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INTRODUCTION

The fetal liver volume functions as a precise measure of somatic growth because the liver represents a sizable part of the fetal abdomen and reflects metabolic and hematological activities at different stages in gestation [1]. The quantitative estimation of liver size and quantity improves traditional biometry, in particular the abdominal circumference, which is greatly affected by using hepatic mass. This measurement forms a connection between the growth of the liver and standard fetal weight estimations [2]. Investigations revealed that the left and right lobes showcase almost linear growth from approximately 18 to 40 weeks, therefore strengthening the application of liver measurements for estimating gestational age and



tracking growth [3,4]. Fetal liver morphometrics, which embody lobe dimensions and total volume, show a predictable increase in the course of usual gestation [5]. Anatomical investigations revealed additional statistics on the volumetric trajectories of the fetal liver, organizing normative reference levels that permit statistical modeling of anticipated growth patterns in abnormal pregnancies [6,7]. The 3D ultrasound has reinforced liver volumetry by providing regular, operator-independent measurements that may be associated with the circumference of the abdomen. This development assists in the detection of irregularities from daily growth patterns, as well as the early detection of intrauterine growth restriction, by means of inconsistent reduction in liver volume in relation to

various biometric tests [8,9]. Incorporating the 3D liver volumetry into current procedures gives a treasured approach to improvement curves and raises the surveillance accuracy throughout gestation [10]. The liver plays an essential role in identifying the circumference of the abdomen; therefore, modifications in liver volume regularly precede shifts in common fetal weight, making it a susceptible and early marker for expanded abnormalities [11]. This quantitative relation highlights the importance of incorporating liver quantity assessment into standard biometry, as it improves the precision of growth monitoring and permits the early identification of intrauterine growth restriction in otherwise healthy fetuses. This research aimed to assess the predictive value of fetal liver volume measurements in connection with abdominal circumference for the early identification of intrauterine growth restriction, in addition to quantitatively analyzing fetal liver growth patterns throughout gestational ages in normal pregnancies.

METHODS

Study design and setting

This cross-sectional cohort study was conducted at the radiology department, Al-Yarmouk Teaching Hospital, Baghdad, Iraq, for 6 months from June to December 2025, with 100 pregnant females aged from 16 to 42 years old. Informed consent was acquired from all pregnant women following an explanation of the research's aims and objectives.

Inclusion and exclusion criteria

Pregnant females with a viable singleton fetus of gestational age (18-40 weeks) were included in the study. The study excluded pregnancies complicated by fetal structural anomalies or chromosomal aberrations, such as Down syndrome and Trisomy 21. Furthermore, those who had gestational diabetes, gestational hypertension, twin pregnancy, abnormal amniotic fluid volume, including oligohydramnios or polyhydramnios, abnormal amount of liquor, or any history of previous intrauterine growth restriction pregnancy have been excluded.

Outcome Measurements

Before the examination, sociodemographic data (including sex, age, and body mass index (BMI)), last menstrual period (LMP), and past medical, surgical, and obstetrical history were documented from each patient. The same radiologist examines all included patients. The patient's demographic information, including height, weight, LMP, age, and parity, was collected. The GE LOGIQ S8 ultrasound machine was used to conduct ultrasound exams, using a 4.5 MHZ convex transducer. The participants were examined in either the supine or semi-decubitus position, with a slight leftward tilt to minimize the risk of hypotension resulting from compression of the vena cava. Standard obstetric ultrasonography was performed, and fetal

biometric parameters, including biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL), were obtained following Hadlock's methodology (12–14). At the level of the abdominal circumference, defined as the widest transverse section of the fetal abdomen where the liver, stomach, umbilical vein, and the confluence of the right and left portal veins are visualized, transverse and anteroposterior diameters of the fetal liver were measured according to Vinzileo's technique [15], as shown in Figure 1A. Subsequently, the transducer was rotated longitudinally to acquire sagittal or coronal views and then aligned parallel to the aorta to determine the cranio-caudal liver length, which is measured from the dome of the right hemidiaphragm adjacent to the heart to the inferior margin of the right lobe, as shown in Figure 1B. The fetal liver volume was calculated using the ellipsoid formula: Length $\times$ Thickness $\times$ Transverse diameter $\times$ 0.52. The fetal gestational age and fetal body weight were determined automatically by the ultrasound equipment from the BPD, HC, AC, and FL using Hadlock's approach (16). An ultrasound liver recording is classified as acceptable if the full shape of the liver can be manually delineated. In the event that this requirement was not met, the patient is not included.

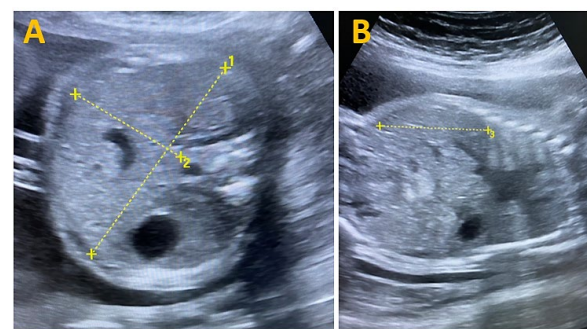


Figure 1: The fetal liver volume measurement. A) The axial plane measures the anterior-posterior diameter (the yellow dotted line 1) and transverse diameter (the yellow dotted line 2), and B) is a sagittal view that measures the cranio-caudal dimension (the yellow dotted line 3).

Ethical considerations

The Helsinki declaration was followed throughout all the study methods. The study protocol was approved by the Ethics Committee in Al Kindy College of Medicine (number 105 on 12/6/2025).

Statistical analysis

Data were analyzed using "Statistical Package for the Social Sciences," IBM SPSS Statistics, Version 29. The descriptive statistics, which included continuous variables (maternal age, BMI, fetal biometric parameters, fetal liver volume (FLV), and birth weight), were tested for normality using the Shapiro-Wilk test. Data were presented as mean $\pm$ standard deviation (SD), range (minimum-maximum), and median. Categorical variables (e.g., fetal sex, weight categories) were presented as frequencies and percentages. The independent samples Student's t-test

was employed for normally distributed data to compare fetal parameters between male and female fetuses. The chi-square test (χ^2) was utilized to examine the proportions of male and female fetuses within various FLV categories. The independent samples Student's t-test was used to evaluate differences in mean FLV between male and female fetuses at particular gestational weeks. This was carried out individually for FLV calculated by BPD, FL, and AC. The strength and direction of the linear relationship between fetal liver volume and ongoing fetal growth parameters were evaluated using Pearson's correlation coefficient (r). A two-tailed p -value of <0.05 was considered statistically significant.

RESULTS

A total of 100 pregnant females were included in this study. Most mothers were aged 25-29 years (33%), followed by 20-24 years (22%) and 30-34 years (21%). Only 7% were younger than 20 years, while 17% were ≥ 35 years. The mean BMI of the included cases was 32.01 ± 5.22 kg/m², with a range of 20.7–43.9 and a median of 31.77 (Table 1).

Table 1: Maternal characteristics of the study population

Characteristic	Result
Maternal age (year)	
	<20(7)
	20–24(22)
	25–29(33)
	30–34(21)
	≥ 35 (17)
Mean and range	27.8 $\pm$ 5.8 (16–39)
Maternal BMI (kg/m ²)	
	<25(9)
	25–29(27)
	30–34(39)
	35–39(14)
	≥ 40 (11)
Mean and range	32.01 $\pm$ 5.22 [20.7–43.9]

Values are presented as frequency, percentage, and mean $\pm$ SD.

Table 2 shows a strong and highly significant positive correlation between fetal liver volume and both fetal body weight and gestational age parameters. Overall, fetal liver volume correlated with body weight ($r=0.706$, $p=0.0001$) and with gestational age assessed by biparietal diameter, femur length, and abdominal circumference, all showing correlation coefficients above 0.72 with p -values of 0.0001. When examined through sex, male fetuses showed barely lower correlation values with body weight ($r=0.656$) and

gestational age measures that ranged from 0.707 to 0.727. On the other hand, for female fetuses, we found a stronger correlation ($0.761 < r < 0.772$) for anthropometric measures such as body weight and gestational age. These results suggest that fetal liver volume can be considered a convenient measure of the degree of fetal growth and maturation, closely related to both frame weight and gestational age according to sex, with the relationship being statistically more significant in females than in males. Cho *et al.* discussed that a positive slope (0.54) indicates that fetal liver volume increases with gestational age by BPD, FL, and AC. The intercept (340) implies the minimum liver volume estimated at a lower gestational age.

Table 2: Correlation between fetal liver volume and fetal growth parameters (BW, BPD, FL, AC) by gender

Variables	Indicator	Fetal liver volume (cm ³)
Fetal BW (grams)	r	0.706
	p	0.0001
GA by BPD	r	0.728
	p	0.0001
GA by FL	r	0.740
	p	0.0001
GA by AC	r	0.740
	p	0.0001
Male		
Fetal BW (grams)	r	0.656
	p	0.0001
GA by BPD	r	0.711
	p	0.0001
GA by FL	r	0.727
	p	0.0001
GA by AC	r	0.707
	p	0.0001
Female		
Fetal BW (gm)	r	0.761
	p	0.0001
GA by BPD	r	0.751
	p	0.0001
GA by FL	r	0.756
	p	0.0001
GA by AC	r	0.772
	p	0.0001

r : Correlation coefficient.

The R^2 of 0.530 indicates that approximately 53% of the variation in fetal liver volume is accounted for by gestational age using BPD as a surrogate marker. The data demonstrating a progressive increase in fetal liver volume with advancing gestational age and its reliability as a surrogate marker of fetal well-being are shown in Table 3.

Table 3: Fetal Liver Volume (cm³) Across Gestational Age Measured by BPD, FL, and AC

Gestational age (week)	Fetal liver volume (cm ³)					
	n	BPD [Mean]	n	FL [Median]	n	AC [Median]
27	3	353.96	2	354.55	2	354.55
28	3	356.45	4	355.39	5	354.90
29	5	356.86	8	356.11	9	356.42
30	6	355.6	3	356.51	4	356.63
31	2	356.39	5	356.65	1	356.01
32	6	357.89	4	359.19	8	357.99
33	7	358.12	8	358.04	13	358.97
34	14	358.91	14	359.05	11	359.04
35	15	359.26	18	359.25	21	359.14
36	20	359.41	16	359.84	12	359.65
37	11	359.90	12	359.75	5	360.38
38	5	360.75	4	360.41	5	360.38
39	3	362.41	2	362.61	4	362.13

The strong association between BPD, FL, and AC measurements indicates that FLV can be accurately interpreted by any of those parameters, thus supporting its applicability in routine prenatal assessments. The tight clustering of these values

across late gestation (weeks 34–39) provides us with a stable reference range for evaluating routine liver growth. Table 4 shows that maternal BMI did not significantly affect the fetal liver volume ($p=0.124$).

Table 4: Correlation of the maternal body mass index (BMI) with the fetal liver volume

Variable	Underweight (<18.5)	Normal ($18.5-24.9$)	Overweight ($25.29.9$)	Obese (≥ 30)	<i>p</i> -value
Maternal BMI (kg/m^2)	35.40 ± 1.85	35.68 ± 1.71	35.92 ± 1.68	6.15 ± 1.97	0.124

Values are presented as mean $\pm$ SD.

DISCUSSION

This study estimated the pattern of growth for fetal liver volume (FLV) in a group of 100 fetuses from 27 to 39 weeks of gestation in the Iraqi cohort. The important findings suggest a strong statistical correlation between FLV and various fetal biometry parameters (BPD, FL, AC) in addition to predicted fetal weight, with fairly substantial correlation coefficients ranging from 0.706 to 0.740. Moreover, although female fetuses showed slightly higher correlation coefficients among FLV and growth parameters, there were no statistically significant differences related to the gender in FLV, which was examined for a long time. The outcomes demonstrate a consistent and innovative increase in the suggestion of FLV as gestational age advances, providing a reference for this population. The observed outcomes of this study, indicating a slow upward push from approximately 354 cm^3 at 27–30 weeks to 362 cm^3 by 39 weeks, align with those established increases in growth and development. The observed quantitative growth patterns for those Iraqi cohorts closely correspond with formerly posted normative records from diverse populations. Chiegwu *et al.* reported a 2D ultrasound investigation with 1,847 Nigerian fetuses between 20 and 41 weeks, reporting a consistent linear increase in FLV from 9.3 cm^3 at 20 weeks to 110.7 cm^3 at 41 weeks, with a strong positive correlation discovered between FLV and both gestational age and estimated fetal weight [17]. It has been found that there is a strong association between the fetal liver volume and the fetal weight ($r=0.706$, $p<0.0001$), encouraging its use as an indicator of fetal development. Okafor *et al.* reported comparable outcomes, showing sturdy relationships among FLV, estimated fetal weight, and GA in healthy Nigerian fetuses [18]. According to the findings of this study, there are strong relationships between FLV and GA for all biometric parameters. Torky *et al.* revealed that liver volume measurements taken during the second trimester were more effective than other second-trimester metrics (HC, AC, FL) in fetal weight for Egyptian participants using 3D ultrasound with the VOCAL system. This finding is particularly pertinent to the current investigation, as the significant correlation identified between FLV and fetal weight indicates that FLV assessment could be a beneficial complement to conventional biometry for estimating weight in Iraqi populations [19]. Additionally, Isaac-Okolo *et al.* found a linear relationship along with a positive correlation between fetal liver length and both

gestational age and fetal weight for 200 Nigerian participants in their third trimester, concluding that liver parameters may serve as a promising tool for estimating gestational age in normal pregnancies [18]. As stated by Szpinda *et al.*, the fetal liver is one of the initial organs affected by abnormal growth, and a 3D estimation provides integral insights into fetal growth patterns [8]. The results of this investigation are associated with the current study of fetal biometry implemented among the Iraqi cohort. Another study carried out by Ali and Mahmoud expanded the gestational age evaluation model, which was tailored to highlight precision for Iraqi fetuses, inspecting 200 pregnant women ranging from 20 to 40 weeks. The findings of their investigation revealed the necessity of population-specific references for fetal biometry in the Iraqi cohort, with $R=0.987$, which is a highly significant correlation coefficient for their gestational age evaluation model (20). Furthermore, the positive correlations detected in this study between FLV and (BPD, FL, AC) were consistent with a study conducted in Mosul by Al Hialy, which demonstrated significant relationships between transverse cerebellar diameter and GA parameters, including BPD, FL, HC, and AC in both normal and reduced fetal growth fetuses. These results are further corroborated by the persistence of these findings between various fetal structures and other Iraqi cities, which adds credibility to the use of ultrasound biometry in monitoring fetal development [21]. The males' FLV vs BW correlation was lower ($r=0.656$), with the females providing stronger correlations between these outcomes (for FLV vs GA by AC, $r=0.772$ for combined gender). Utilizing morphometric measurements of embryonic liver growth, these studies found small-scale differences based on sex, as females generally displayed larger relative livers. Such findings imply that FLV may serve as a more sensitive hepatocellular growth marker in females, possibly due to differences in hepatic glycogen metabolism [22]. Fetal body weight (BW) and fetal liver volume (FLV) showed no statistically significant difference between the female group or male group. The results were comparable for male and female fetuses (male $p=0.54$; female $p=0.12$), supporting a distinct lack of effect of fetal sex on liver growth. Such a finding was consistent with the study of Mousa *et al.*, which states fetal liver volume is a reliable parameter for monitoring fetal growth, especially in cases of intrauterine growth restriction (IUGR) [2]. This cohort study demonstrated that fetal liver volume (FLV) shows a constant value increase from 354 cm^3 at

approximately 34 weeks to 362 cm³ by ~39 weeks, with small traditional deviations at every gestational week. These styles are consistent with the fetal liver growth curves and support the usage of FLV as a gestational age-dependent biomarker rather than a gender-dependent one [23]. The observation of week-by-week FLV statistics tested a gradual, monotonic upward thrust in implied volume as gestation progresses, accompanied by relative stabilization in the latter half of the 1/3 trimester. This sample is consistent with the stated fetal liver growth stages, in which the important issue influencing liver dimensions is gestational age, and as the time approaches closer, volumetric profits slow [24]. The growing dynamics of growth found in this study were in agreement with another investigation, which, as suggested by Szpinda *et al.*, revealed that age liver volumes adhere to predictable pathways. These pathways may be applied to evaluate hepatic increase and facilitate the early analysis of fetal microsomia and macrosomia [6]. Furthermore, Bhadoria *et al.* reported alterations in general fetal morphometric parameters and liver metrics that were directly proportional to the changes in gestational age through a histomorphometric examination of embryogenesis at various gestational stages [25]. It is useful to understand normal liver development. The physiological hypotheses proposed bolster the main conclusions of this study by proposing FLV growth patterns as a function of developmental strategies rather than size artifacts. Fetal liver volume is independent of maternal body mass index, with no significant differences and only a very weak correlation between fetal liver volume across BMI. These findings imply that hepatic development in the fetus is controlled by predetermined mechanisms, such that growth kinetics scale to fetal size rather than to maternal metabolism [26].

Study Limitations

The findings of this investigation must be understood within the framework of several limitations, which might be the pattern length of 100 individuals. Although the sample size was statistically significant for preliminary analysis, it is too small to establish a definitive population, particularly within the gestational age range of 27 to 39 weeks, where the number of individuals is limited. A larger sample length would yield extra reliable percentile estimates. Longitudinal studies, which display the same fetus over time, would deliver more correct insights into individual growth patterns and costs. Additionally, the participant cohort was from a single city (Baghdad), which may also restrict the applicability of the findings to other ethnic or geographic groups. Lastly, while the ellipsoid technique is convenient, it may no longer be as particular as extra sophisticated 3D ultrasonographic strategies, along with VOCAL, that can more accurately account for the liver's abnormal form.

Future Prospects

Future research may focus on confirming the outcomes for larger cohorts to set up more reliable, population-specific normative FLV charts. Longitudinal research is crucial to monitor female or male fetal liver growth and assess its predictive importance for perinatal consequences, consisting of IUGR and occasional birth weight. Furthermore, it is probably beneficial to explore FLV dynamics in high-risk pregnancies (such as those complicated by gestational diabetes or pre-eclampsia) to determine whether or not versions in liver growth appear earlier than other scientific signs of pathology, which potentially may guide targeted therapy such as aspirin administration [27]. Moreover, comparative research that verifies the diagnostic precision of the ellipsoid technique when it comes to more advanced 3D volumetric techniques (such as Virtual Organ Computer-Aided Analysis (VOCAL)) would make contributions to the standardization of measurement protocols for both clinical and research purposes.

Conclusion

This finding suggested that fetal liver volume was strongly correlated with gestational age and general fetal biometric parameters in normal pregnancies and that the absolute length of the liver does not appear to be greatly affected by fetal gender. These findings suggest FLV represents a feasible biomarker of fetal nutritional status and somatic development, warranting future investigation into its potential utility for early detection of growth abnormalities.

Conflict of interests

The authors declared no conflict of interest.

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Data sharing statement

The data that supports the findings of this study are available from the corresponding author upon a reasonable request.

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