

MORPHOMETRIC ASSESSMENT OF THE FETAL LIVER AND ITS INDIVIDUAL LOBES IN RELATION TO GESTATIONAL AGE

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Abstract

Background: The fetal liver is a prominent abdominal organ during prenatal life and undergoes substantial growth throughout gestation. Quantitative assessment of hepatic dimensions may provide useful anatomical reference data for fetal growth assessment and for comparison with prenatal imaging findings.

Objective: To evaluate the morphometric characteristics of the fetal liver and its right, left, caudate and quadrate lobes and to determine their relationship with gestational age.

Gestational age was estimated using crown-rump length (CRL) and foot length. Fetal body weight was recorded using a digital weighing machine. The fetal liver was weighed separately after careful removal from the specimen. Specimens were preserved in 10% buffered formalin before dissection.

Results: All assessed hepatic dimensions showed a statistically significant positive correlation with gestational age. The strongest associations were observed for maximum liver breadth ($r = 0.959$, $r^2 = 0.920$, $p < 0.001$), right lobe length ($r = 0.955$, $r^2 = 0.913$, $p < 0.001$), and maximum liver length ($r = 0.951$, $r^2 = 0.904$, $p < 0.001$). Maximum and lobe-specific breadths, as well as caudate and quadrate lobe dimensions, also showed significant positive correlations with advancing gestational age (Table 2).

Conclusion: Fetal liver dimensions increase progressively with gestational age, with longitudinal measurements demonstrating particularly strong associations. Direct morphometric data may provide useful anatomical reference information for interpretation of prenatal ultrasonographic and MRI measurements. Larger studies with balanced gestational-age groups are required to establish robust reference ranges.

Keywords: fetal liver; fetal morphometry; gestational age; hepatic lobes; fetal development; autopsy; morphometric study

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Introduction

The liver is among the earliest major organs to develop during embryonic life and remains disproportionately large during the fetal period. Its importance during prenatal development extends beyond its anatomical size: the fetal liver serves as a major site of

hematopoiesis and participates in the synthesis and storage of proteins, carbohydrates and other substances required for fetal growth. Consequently, changes in hepatic size and morphology may reflect the overall developmental status of the fetus.

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Fetal hepatic growth has been investigated using both direct anatomical techniques and prenatal imaging. Direct fetal morphometric studies have demonstrated progressive increases in liver dimensions with advancing gestational age and have highlighted the usefulness of hepatic measurements for assessment of fetal development.^{1,2} MRI-based work by Hamabe et al. has also characterized fetal liver morphology and morphometry across 16–26 weeks of gestation, providing complementary imaging-based information on hepatic development.³

Direct anatomical studies provide complementary information because the liver and its individual lobes can be examined without the limitations imposed by imaging planes or acoustic windows. Agnihotri et al. reported the usefulness of fetal liver morphometry for estimation of gestational age, supporting the value of direct hepatic measurements during fetal development.¹ Yadav et al. similarly reported significant correlations between fetal liver morphometric measurements and gestational age in a series of fetal specimens.⁴ Subsequent anatomical and three-dimensional studies have described age-related changes in liver length, transverse and sagittal diameters, surface dimensions and lobe-specific measurements.^{2,5–7} Jaiswal et al. similarly evaluated fetal liver morphometry at different crown-rump lengths, supporting the use of fetal liver measurements as developmental parameters.⁸

Three-dimensional and volumetric anatomical studies have further contributed to the understanding of fetal hepatic growth by describing changes in liver dimensions and volume across gestation.^{5,9}

Despite the availability of several studies, detailed morphometric data covering the overall liver as well as the right, left, caudate and quadrate lobes remain relatively limited, particularly in Indian fetal specimens. The present study was therefore undertaken to characterize fetal liver dimensions and to determine their correlation with gestational age.

Materials and Methods

Study design and specimens

A descriptive observational study was conducted in the Department of Anatomy, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India. The study included 30 human fetal specimens of 13 weeks gestational age and above from the departmental museum collection. Both spontaneously aborted and medically terminated fetuses, irrespective of sex, were included in the study.

Inclusion and exclusion criteria

Fetuses without gross congenital anomalies were included. Specimens with known congenital malformations or those unsuitable for morphometric assessment because of damage were excluded.

Estimation of gestational age and preservation

Gestational age was estimated using crown-rump length (CRL) and foot length (Figures 1 and 2). Fetal body weight was recorded using a digital weighing

machine (Figure 3). Specimens were preserved in 10% buffered formalin before dissection.



Figure 1. Measurement of crown-rump length



Figure 2. Measurement of foot length



Figure 3. Measurement of fetal weight

Dissection and morphometric measurements

The liver was dissected according to the standard approach described in Cunningham's Manual of Practical Anatomy. Following opening of the thoracoabdominal cavity, major vascular and biliary attachments were divided carefully and the liver was removed intact to preserve its external morphology.

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Figure 4. Weight of the fetal liver

The following morphometric measurements were obtained using a digital Vernier caliper and recorded in millimeters: (1) maximum anteroposterior (AP) liver length, (2) maximum transverse liver breadth, (3) right lobe AP length and transverse breadth, (4) left lobe AP length and transverse breadth, (5) caudate lobe AP length and transverse breadth, and (6) quadrate lobe AP length and transverse breadth. Liver weight was recorded separately in grams (Figure 4). The measurement techniques for maximum liver dimensions and the right and left lobes are illustrated in Figures 5–7, while measurements of the caudate and quadrate lobes are shown in Figures 8 and 9.

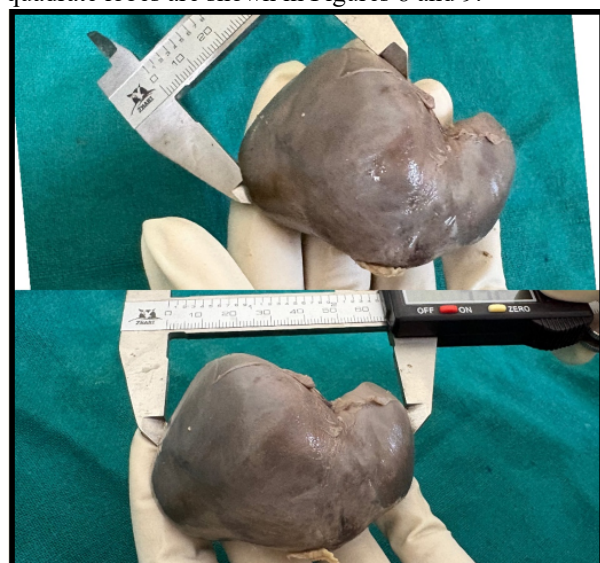


Figure 5. Maximum AP length and transverse width of liver

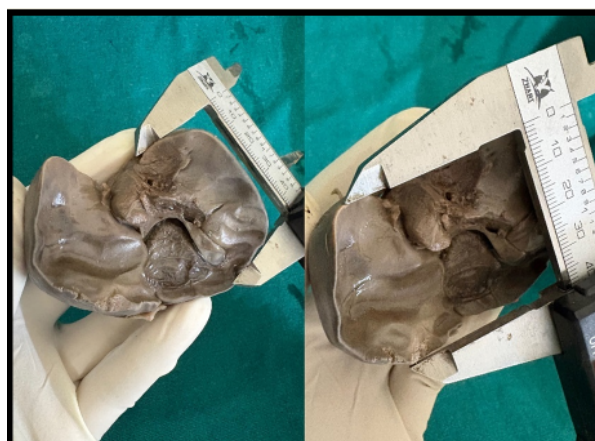


Figure 6. AP length of right and left lobe

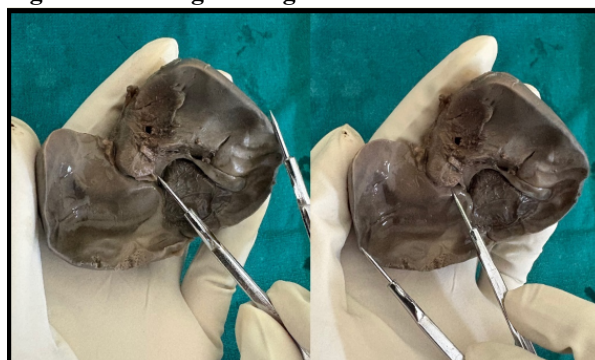


Figure 7. Transverse width of right and left lobe

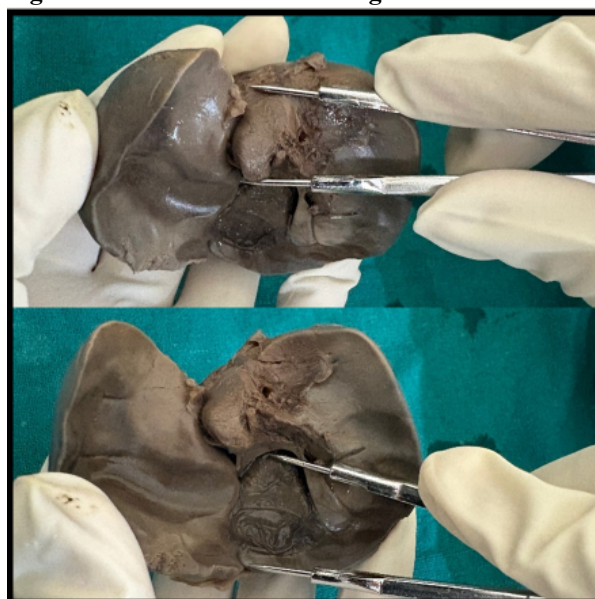


Figure 8. AP length of caudate and quadrate lobe

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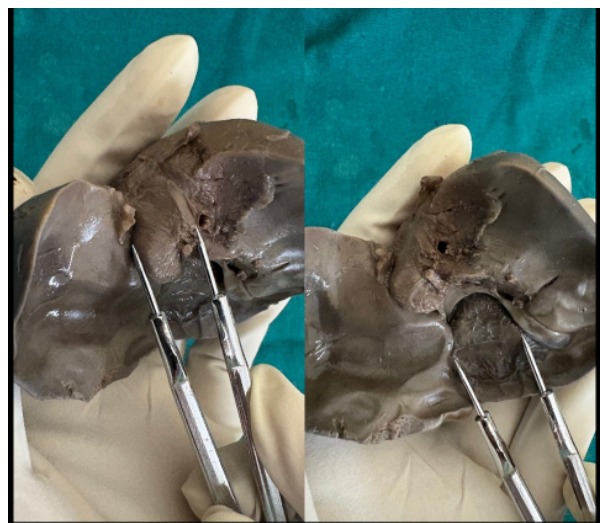


Figure 9. Transverse width of caudate and quadrate lobe

Statistical analysis

Descriptive data were expressed as mean $\pm$ standard deviation (SD). For grouped descriptive analysis, specimens were categorized according to gestational age as below 16 weeks, 17–20 weeks, 21–24 weeks, 25–28 weeks and >28 weeks (Table 1). The relationship between gestational age and individual liver morphometric parameters was assessed using Karl Pearson's correlation coefficient (r). The coefficient of determination (r^2) was also considered. A p-value <0.05 was considered statistically significant.

Results

The study included 30 fetal specimens with gestational ages ranging from approximately 13 to 34 weeks, with a mean gestational age of 23.23 ± 5.98 weeks. Descriptive analysis demonstrated a progressive increase in liver dimensions across the gestational-age groups. Maximum liver length increased from 22.06 ± 8.79 mm in the below-16-week group to 51.50 ± 2.49 mm in fetuses above 28 weeks, while maximum liver breadth increased from 28.80 ± 10.15 mm to 67.50 ± 3.41 mm across the same groups (Table 1). All evaluated hepatic parameters showed significant positive correlations with gestational age (Table 2).

Table 1. Descriptive statistics of the measured morphometric parameters (Mean and SD) according to gestational age.

Parameters	Below 16 wks.		17 to 20 wks.		21 to 24 wks.		25 to 28 wks.		>28 wks.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Maximum liver length (mm)	22.06	8.79	28.01	10.15	35.07	6.99	49.08	2.49	51.50	2.49
Maximum liver breadth (mm)	28.80	10.15	35.07	6.99	49.08	2.49	51.50	2.49	67.50	3.41

Maximum liver length (mm)	22.06	8.79	28.01	10.15	35.07	6.99	49.08	2.49	51.50	2.49
Maximum liver breadth (mm)	28.80	10.15	35.07	6.99	49.08	2.49	51.50	2.49	67.50	3.41
Right lobe length (mm)	18.3	3.42	28.5	2.72	37.19	7.63	45.35	2.5	51.5	2.49
Right lobe breadth (mm)	15.29	6.36	21.07	2.03	28.57	4.73	33.25	1.71	39.77	1.77
Left lobe length (mm)	22.4	10.26	26.79	2.69	35.18	3.96	42.35	2.5	49.31	2.87
Left lobe breadth (mm)	10.82	3.19	15.86	2.29	23.46	4.64	26.38	1.49	28.94	1.66

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(mm)										
Caudate lobe length (mm)	7.07	2.84	10.33	1.63	12.74	5.5	17.75	1.04	16.8	2.12
Caudate lobe breadth (mm)	3.23	0.96	1.6	1.3	7.45	4.74	11.25	0.65	10.5	1.28
Quadrate lobe length (mm)	4.48	1.24	8	2.1	13.06	6.08	18.12	1.93	24.12	2.03
Quadrate lobe breadth (mm)	4.64	4.3	4.92	1.32	7.51	5.28	10.75	1.04	13.6	0.9

The strongest correlation was observed for maximum liver breadth ($r = 0.959$, $r^2 = 0.920$, $p < 0.001$), followed by right lobe length ($r = 0.955$, $r^2 = 0.913$, $p < 0.001$) and maximum liver length ($r = 0.951$, $r^2 = 0.904$, $p < 0.001$). Right lobe breadth ($r = 0.942$) and left lobe length ($r = 0.930$) also showed very strong positive correlations. Quadrate lobe length demonstrated a strong association ($r = 0.906$), whereas caudate lobe length and breadth showed comparatively moderate

correlations ($r = 0.656$ and 0.702 , respectively) (Table 2).

Table 2. Descriptive statistics and Pearson's correlation coefficients (r) and p -values showing statistically significant correlation of gestational age with the measured parameters.

Parameter	Mean $\pm$ SD (Total sample)	r value	r ² value	p-value
Maximum length (mm)	38.06 $\pm$ 11.37	0.951	0.904	$p < 0.001$
Maximum breadth (mm)	49.58 $\pm$ 14.86	0.959	0.92	$p < 0.001$
Right lobe length (mm)	37.68 $\pm$ 11.95	0.955	0.913	$p < 0.001$
Right lobe breadth (mm)	28.53 $\pm$ 8.85	0.942	0.888	$p < 0.001$
Left lobe length (mm)	36.18 $\pm$ 10.72	0.93	0.865	$p < 0.001$
Left lobe breadth (mm)	21.94 $\pm$ 6.93	0.904	0.817	$p < 0.001$
Caudate lobe length (mm)	12.70 $\pm$ 5.11	0.656	0.431	$p < 0.001$
Caudate lobe breadth (mm)	7.60 $\pm$ 3.70	0.702	0.493	$p < 0.001$
Quadrate lobe length (mm)	14.27 $\pm$ 7.99	0.906	0.82	$p < 0.001$
Quadrate lobe breadth (mm)	8.28 $\pm$ 4.54	0.822	0.676	$p < 0.001$

Discussion

The principal observation of this study was the significant positive relationship between gestational age and every hepatic morphometric parameter assessed (Table 2). The descriptive data also showed progressive enlargement of the liver and its individual lobes across successive gestational-age groups (Table

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1), supporting coordinated growth of the fetal liver rather than enlargement confined to a single dimension or lobe. The strongest correlation in the present series was for maximum liver breadth, followed by right lobe length and maximum liver length.

The present findings are consistent with previous anatomical work on fetal liver morphometry. Agnihotri et al. evaluated fetal liver morphometry for estimation of gestational age, providing evidence that hepatic dimensions can be useful developmental indicators.¹ Similar findings were reported by Yadav et al., who investigated the correlation between fetal liver morphometric measurements and gestational age and demonstrated significant associations between hepatic dimensions and gestational age.⁴

The present findings also agree with previous anatomical studies of fetal liver growth. Albay et al. demonstrated significant correlations between liver size, weight, volume, individual lobe dimensions and gestational age in 121 fetal specimens, while Modi et al. reported significant relationships between fetal liver morphometric parameters and gestational age in specimens studied by conventional autopsy.^{2,10} Although focused on liver surface features rather than fetal morphometry, Joshi et al. emphasized that variations in hepatic surface morphology may have clinical implications, underscoring the importance of careful anatomical assessment of the liver.¹¹

The close association observed for the right lobe length in the present study is of particular interest. Right lobe length showed a very strong correlation with gestational age ($r = 0.955$), while left lobe length also demonstrated a strong correlation ($r = 0.930$) (Table 2). These findings suggest that longitudinal measurements of the major hepatic lobes may be useful indicators of developmental progression and are compatible with previous anatomical studies demonstrating age-related increases in fetal hepatic dimensions.^{1,2,5,10}

The breadth measurements also showed strong positive relationships with gestational age, although their relative strength varied among parameters. Maximum liver breadth showed the highest correlation in the present study ($r = 0.959$), followed by right lobe breadth ($r = 0.942$) and left lobe breadth ($r = 0.904$) (Table 2). Differences in correlation strength may reflect biological variability in transverse dimensions as well as methodological factors. Direct measurement of fetal specimens may also be influenced by preservation, tissue consistency and the precise selection of anatomical landmarks.

The caudate and quadrate lobes also demonstrated significant positive correlations with gestational age (Table 2). Quadrate lobe length showed a strong association ($r = 0.906$), whereas quadrate lobe breadth showed a strong-to-moderate association ($r = 0.822$). Caudate lobe length and breadth demonstrated comparatively moderate correlations ($r = 0.656$ and 0.702 , respectively). These findings indicate that fetal

hepatic growth involves coordinated enlargement of multiple anatomical components, although the strength of association differs among individual lobes.

Three-dimensional anatomical work by Szpinda et al. demonstrated systematic changes in fetal liver length, transverse diameter and sagittal diameter across gestation, while their volumetric study further characterized age-related changes in fetal liver volume.^{5,9} These findings support the concept that liver dimensions can be used as quantitative indicators of fetal maturation. The current study adds to this literature by simultaneously examining maximum liver dimensions and the dimensions of the four anatomically recognized lobes.

Volumetric anatomical work by Szpinda et al. also demonstrated systematic growth of the fetal liver across gestation, supporting the value of quantitative hepatic measurements as indicators of fetal development.⁹

From a clinical perspective, fetal liver size has potential relevance in conditions associated with altered fetal growth. Agnihotri et al. and Yadav et al. demonstrated that fetal hepatic morphometric parameters are significantly related to gestational age, supporting their potential value as developmental indicators.^{1,4} More recent ultrasound-based work has similarly demonstrated a positive relationship between fetal liver length and gestational age and fetal weight, supporting its potential use in antenatal assessment.¹²

The methodological differences among published studies should, however, be acknowledged. Anatomical studies permit direct visualization and measurement of the organ, whereas ultrasound provides measurements in living fetuses and is influenced by imaging plane and sonographic landmarks. Direct anatomical data should therefore be regarded primarily as reference observations that may complement, rather than directly substitute for, imaging-based nomograms.

The study contributes useful morphometric information from an Indian fetal specimen collection, but the relatively small sample size and uneven representation across gestational ages limit the establishment of definitive reference ranges. Future investigations incorporating larger numbers of specimens, standardized landmarks and regression-based gestational-age-specific equations may provide stronger reference standards and improve comparability with antenatal imaging studies.

Limitations

The sample size was relatively small ($n = 30$), and the distribution of specimens across gestational-age groups was unequal.

Conclusion

The present study demonstrates a significant positive correlation between gestational age and the morphometric dimensions of the fetal liver and its individual lobes (Table 2). Descriptive measurements showed progressive enlargement across the gestational-

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age groups (Table 1). Maximum liver breadth, right lobe length and maximum liver length showed the strongest relationships with gestational age. The caudate and quadrate lobes also demonstrated significant age-related growth. These findings support the concept of progressive and coordinated hepatic enlargement during fetal development and provide anatomical data that may complement prenatal imaging-based assessment.

Larger studies with wider and more evenly distributed gestational-age ranges are recommended to establish robust normative equations and reference intervals for overall liver and lobe-specific dimensions.

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