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MORPHOLOGICAL VARIATIONS IN FETAL AND CADAVERIC LIVER: AN OBSERVATIONAL STUDY

Ms. Akanksha Deshwal[1]*, Dr. Manish S Ahuja[2], Dr. Susmita Saha[3], Dr. Prachi Saffar Aneja[4]

[1]PhD Scholar, Department of Anatomy, FMHS, SGT University, Gurugram
[2]Professor, Department of Anatomy, FMHS, SGT University, Gurugram
[3]Professor, Department of Anatomy, FMHS, SGT University, Gurugram
[4]HOD and Professor, Department of Anatomy, FMHS, SGT University, Gurugram

ABSTRACT
Introduction: The liver is the largest abdominal organ and undergoes complex development from the fourth week of gestation.
Aim & Objectives: This study aimed to observe and compare morphological variations, such as accessory fissures, accessory lobes, and lingular processes, between fetal and cadaveric livers.
Materials and Methods: An observational study was conducted on 30 preserved human abortus (≥12 weeks gestation) and 30 cadaveric livers. Fetuses were grouped by age using crown-rump and foot length measurements.
Results: Accessory fissures were most prevalent in early fetal groups (up to 66.6%) compared to cadaveric livers (40%). Conversely, **accessory lobes** and **lingular processes** were found to be more frequent in cadaveric specimens.
Conclusion: Fetal livers exhibit higher morphological variations overall, some of which regress with age, while others persist into adulthood, impacting clinical and surgical practices.

INTRODUCTION
The liver is the largest gland and the largest internal organ of the human body, weighing approximately 1.5 kg in an average adult. It occupies most of the right hypochondrium and epigastric region and extends into the left hypochondrium.(1) Owing to its diverse metabolic, synthetic, detoxification, and excretory functions, the liver plays a crucial role in maintaining physiological homeostasis and is indispensable for survival.(2)
Anatomically, the liver is divided into right and left lobes by the attachment of the falciform ligament on its diaphragmatic surface. On the visceral surface, two additional lobes—the caudate and quadrate lobes—are identified. (3) Functionally, the liver is subdivided into eight segments based on vascular and biliary distribution. The visceral surface also contains several important anatomical landmarks, including the fissure for ligamentum teres, fissure for ligamentum venosum, porta hepatis, fossa for the gallbladder, and groove for the inferior vena cava.(1)
The liver develops during the fourth week of intrauterine life from the hepatic diverticulum, an endodermal outgrowth of the foregut. Rapid growth and differentiation during fetal development result in the formation of the definitive hepatic architecture. Initially, the right and left lobes are nearly equal in size; however, the right lobe subsequently enlarges and becomes dominant. Since liver development involves a complex sequence of embryological events, variations may arise during organogenesis, leading to differences in morphology that persist into postnatal life and adulthood.(4)
Morphological variations of the liver have long attracted the attention of anatomists, radiologists, and surgeons. These variations may be congenital or acquired. Congenital variations include agenesis or hypoplasia of lobes, accessory lobes, abnormal fissures, absence of normal fissures, and unusual lobar configurations.(5) Acquired variations may result from age-related changes, disease processes, or adaptive responses to surrounding structures. Variations in the shape, size, fissures, and lobar patterns of the liver are commonly encountered during cadaveric dissections and imaging studies.(6)
The study of fetal liver morphology provides valuable insights into normal developmental anatomy and the origin of anatomical variations. Similarly, examination of cadaveric livers helps establish the prevalence and patterns of these variations in adults.
Knowledge of such variations is important for accurate interpretation of radiological images, prenatal ultrasonography, liver transplantation, laparoscopic procedures, and hepatobiliary surgeries. Unrecognized anatomical variations may lead to diagnostic errors or surgical complications.
Despite numerous studies on adult liver anatomy, comparative observations on morphological variations in both fetal and cadaveric livers remain limited. Understanding these variations can contribute to developmental anatomy, improve anatomical knowledge, and provide clinically relevant information for surgeons, radiologists, and anatomists.(7)
Therefore, the present observational study was undertaken to examine and document the morphological variations of fetal and cadaveric livers, with special emphasis on variations in lobes, fissures, and external anatomical features.

MATERIALS AND METHODS
An observational study was conducted in the Department of Anatomy, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India. The study was carried out using preserved human abortus of varying gestational ages and cadaveric liver specimens available in the departmental museum and dissection hall.

Since the study exclusively involved preserved fetal specimens and cadaveric livers available in the department, approval was obtained from the Institutional Ethics Committee prior to commencement of the study.

Study Sample

The study comprised a total of 60 specimens, including 30 human abortus of gestational age 12 weeks onwards and 30 cadaveric human livers. The fetal specimens included both spontaneously aborted and medically terminated fetuses irrespective of sex.

Source of Specimens

Human abortus of 12 weeks gestation onwards and cadaveric liver specimens were obtained from the Museum and Department of Anatomy, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Human abortus of different gestational ages (12 weeks onwards) without obvious congenital anomalies.
- Well-preserved cadaveric livers with intact external morphology.

Exclusion Criteria

- Fetuses with known congenital anomalies or gross developmental abnormalities.
- Cadaveric livers showing pathological lesions, traumatic damage, surgical alterations, or distortion of normal anatomical features.

Determination of Gestational Age

The gestational age of the fetuses was estimated using standard fetal parameters:

- **Crown-rump length (CRL):** Measured as the maximum distance from the vertex of the head to the buttocks in the most straightened position using a thread and measuring scale.
- **Foot length:** Measured from the posterior aspect of the heel to the tip of the longest toe using Vernier callipers.

Based on gestational age, the fetuses were categorised into three groups:

- **Group I:** Less than 18 weeks gestation
- **Group II:** 18–24 weeks gestation
- **Group III:** More than 24 weeks gestation

The body weight of each fetus was also recorded using a digital weighing machine.

METHODOLOGY

After documentation of gestational age and external parameters, the fetal specimens were preserved in 10% formalin. A midline incision extending from the xiphoid process to the pubic symphysis was made. A transverse incision was then given along the costal margins, and the thoracoabdominal wall was reflected to expose the abdominal cavity.

The liver was identified and carefully dissected by retracting the surrounding viscera. The inferior vena cava, hepatic veins, and portal structures were identified and divided to facilitate removal of the liver. The organ was removed intact while preserving its external anatomical features.

Cadaveric livers were similarly examined following standard dissection procedures as described in Cunningham's Manual of Practical Anatomy, 15th Edition.

Each fetal and cadaveric liver was observed for gross morphological features including the number and configuration of lobes, presence of accessory lobes, fissures, lingular process, and any other unusual anatomical characteristics(Table 1). The observed variations were photographed and documented systematically.

S.NO	MORPHOLOGICAL FEATURES
1	Accessory Fissure
2	Accessory lobe
3	Lingular process of left lobe

Table 1: Morphological Parameters seen in fetal Vs Cadaveric Livers

The findings were recorded, classified, and compared between fetal and cadaveric specimens to identify common and uncommon morphological variations of the liver.

RESULTS

The present study evaluated and compared the gross morphological variations of the liver in 30 fetal specimens of varying gestational ages and 30 cadaveric liver specimens. The observations were focused on the presence of accessory fissures, accessory lobes, and the lingular process, which are among the most commonly reported anatomical variations of the liver.

Accessory fissures were the most frequently encountered morphological variation in the study. Their incidence was considerably higher in fetal specimens than in cadaveric livers. In Group I fetuses (less than 18 weeks gestation), accessory fissures were observed in 66.6% of specimens(Fig 1), indicating that they are relatively common during the early stages of fetal development. In Group II fetuses (18–24 weeks gestation), the incidence remained high at 60%, suggesting persistence of these fissures during mid-gestation(Fig 2).

However, a marked decline was observed in Group III fetuses (more than 24 weeks gestation), where accessory fissures were present in only 13.3% of specimens(Fig 3) (Table 2) . Among cadaveric livers, accessory fissures were identified in 40% of the specimens(Table 3) (Fig 4). The progressive reduction in the incidence of accessory fissures with advancing gestational age may reflect developmental remodeling and fusion of hepatic surfaces during fetal growth.

FETAL LIVER			
PARAMETERS	NO.	GROUPS	%
ACCESSORY FISSURE	30	I	66.6
		II	60
		III	13.3

Table 2: Incidence of Accessory Fissures in the Fetal Liver

Fig 1: Presence of accessory fissure in Group I fetal

Fig 2: Presence of accessory fissure in Group II fetal

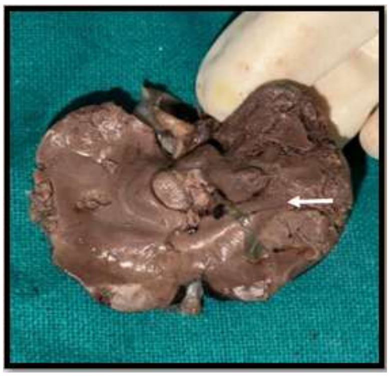

Fig 3: Presence of accessory fissure in Group III

CADAVERIC LIVER			
PARAMETERS	NO.	AGE	%
ACCESSORY FISSURE	**30**	**50-80**	**40**

Table 3: Incidence of Accessory Fissures in the Cadaveric Liver

Fig 4: Presence of accessory fissure in Cadaveric liver

Accessory lobes were observed less frequently than accessory fissures. In the fetal group, accessory lobes were identified in 6.6% of specimens in both Group I and Group II(Fig 5 & 6), while no accessory lobes were observed in Group III fetuses. (Table 4)

In contrast, accessory lobes were present in 20% of cadaveric liver specimens (Table 5) (Fig 7). The relatively higher prevalence of accessory lobes in adults may indicate that certain developmental variations persist into postnatal life and become more evident in mature livers. These lobes varied in size and location but were generally found along the margins of the liver.

FETAL LIVER			
PARAMETERS	NO.	GROUPS	%
ACCESSORY LOBE	30	I	6.6
		II	6.6
		III	-

Table 4: Incidence of Accessory Lobe in the Fetal Liver

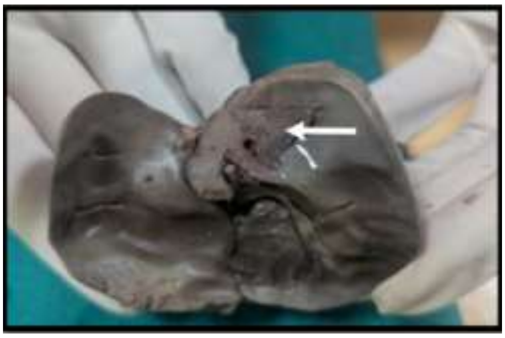

Fig 5: Presence of accessory lobe in Group I

Fig 6: Presence of accessory lobe in Group II

CADAVERIC LIVER			
PARAMETERS	NO.	AGE	%

ACCESSORY LOBE	30	50-80	20

Table 5: Incidence of Accessory Lobe in the Cadaveric Liver

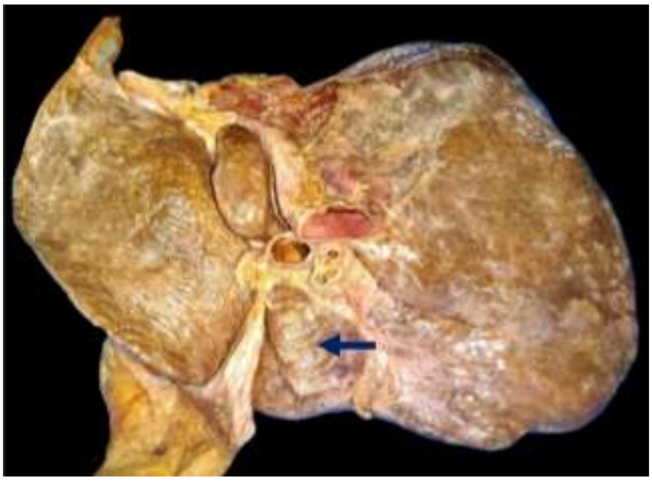

Fig 7: Presence of accessory lobe in cadaveric liver

The **lingular process** was the least common morphological variation encountered in the present study. It was observed in 6.6% of specimens in both Group I and Group II fetuses (Fig 8&9)and was absent in Group III fetuses(Table 6). Among cadaveric livers, the lingular process was identified in 13.3% of specimens (Table 7) (Fig10). Although uncommon, its presence highlights the diversity of hepatic morphology and the need for awareness of such variations during radiological interpretation and surgical procedures.

Overall, the findings demonstrate that accessory fissures are more prevalent during fetal life, whereas accessory lobes and lingular processes are relatively more common in adult cadaveric livers. These observations contribute to the understanding of developmental and anatomical variations of the liver and provide useful information for anatomists, radiologists, and hepatobiliary surgeons.

FETAL LIVER			
PARAMETERS	NO.	GROUPS	%
LINGULAR PROCESS	30	I	6.6
		II	6.6
		III	-

Table 6: Incidence of lingular process in the Fetal Liver

Fig 8: Presence of lingular process in Group I

Fig 9: Presence of lingular process in Group II

CADAVERIC LIVER			
PARAMETERS	NO.	AGE	%
LINGULAR PROCESS	**30**	**50-80**	**10**

Table 7: Incidence of lingular process in the Cadaveric Liver

Fig 10: Presence of lingular process in cadaveric liver

DISCUSSION

The present study demonstrated that fetal livers exhibited a higher frequency of morphological variations than cadaveric adult livers. Accessory fissures were particularly common during early fetal life, with their incidence progressively decreasing with advancing gestational age. This developmental trend suggests that several fetal morphological variations undergo remodelling or regression during intrauterine development, whereas a proportion persist into adulthood as normal anatomical variants.

Previous studies by Agnihotri D et al. [8] and Bhadoria P et al.[7] have primarily focused on fetal liver morphometry and histogenesis, while Joshi MM et al. described morphological variations in adult cadaveric livers, including accessory fissures, pons hepatis, and the lingular process.[5] However, comparative studies evaluating the persistence or regression of these anatomical variations from fetal life to adulthood remain scarce. The present study addresses this gap by comparing morphological variations across different fetal gestational age groups and adult cadaveric specimens, thereby providing insight into the developmental evolution of these variations.

The human liver exhibits considerable variation in its morphometric dimensions, external morphology, lobar configuration, and fissural anatomy. Knowledge of these variations is of considerable clinical importance for anatomists, surgeons, radiologists, and hepatobiliary specialists, as unrecognized anatomical variants may complicate radiological interpretation, liver transplantation, hepatic resections, and other surgical procedures. [9]

Morphological variations of the liver may be congenital or acquired. Congenital anomalies include agenesis or hypoplasia of hepatic lobes, accessory lobes, lobar atrophy, and abnormal fissural patterns. Numerous investigators have documented these variations, emphasizing their developmental and clinical significance.

Variations involving the right lobe are relatively uncommon. The most frequently reported abnormalities include accessory fissures and accessory lobes, particularly Riedel's lobe. Peela D et al. reported a communication between the right lobe and quadrate lobe in 15.52% of specimens.[10] However, no such communication was observed in either the fetal or cadaveric specimens examined in the present study, suggesting that this variation may be relatively uncommon in the studied population.

Among the left lobe variations, the lingular process represents one of the most frequently encountered findings. In the present study, the lingular process was identified in 13.3% of cadaveric livers, which is comparable to the findings of Anasuya G et al. (14%) [11] and Chaudhari H et al. (12.5%)[12]. Lower incidences have been reported by Abhilasha et al. (4%) (13)and, Aliya et al. (2.7%)[14] whereas Mamatha et al. reported the highest incidence (21.3%)[15]. In contrast, among fetal specimens, the lingular process was observed in 6.6% of Group I and Group II specimens but was absent in Group III. This pattern may indicate regression or remodeling of this variation during later fetal development, although the higher prevalence in adult livers also suggests that some cases may become more prominent with postnatal growth.

Accessory lobes are believed to result from excessive proliferation of hepatic tissue during embryogenesis and are among the most frequently reported congenital hepatic variations. In the present study, accessory lobes were observed in 20% of cadaveric livers, closely approximating the findings of Saritha S et al. (16%)[2], while higher incidences than those reported by Aliya et al. (10.8%)[14] and Chaudhari H et al. (3.7%)[12]. Among fetal specimens, accessory lobes were present in 6.6% of Group I and Group II livers but were absent in Group III. Although the relatively low fetal incidence compared with adults may partly reflect sample size, these findings indicate that accessory lobes can persist into adult life rather than representing transient developmental features.

Accessory fissures constituted the most common variation observed in fetal specimens. They were identified in 66.6% of Group I, 60% of Group II, and only 13.3% of Group III fetal livers, demonstrating a marked decline with increasing

gestational age. In adult cadaveric livers, accessory fissures were present in 40% of specimens, a frequency comparable to those reported by Mansur et al. (32.86%)[6]nd Saritha S et al. (30%)[2] and very low incidence has reported by Prabahita et al. (3.33%)[16]. These findings support the hypothesis that accessory fissures are common during early hepatic development and that many regress with maturation, while a substantial proportion persist into adulthood.
Several investigators have also described the distribution of accessory fissures according to hepatic lobes. Anbumani L et al. reported accessory fissures involving all lobes, with the highest frequency in the right lobe (40%), followed by the caudate lobe (10%) and left lobe (3%)[17]. Mamatha et al. identified accessory fissures in the right lobe in 10% of cases[15], whereas Sangam et al. and Saritha et al.reported considerably lower frequencies (2.5% and 2%, respectively) [18,2].whereas in the present study accessory fissure were found in 20% of the cadaveric livers and 6.6% in the fetal livers. These observations, together with the findings of the present study, underscore the considerable variability in fissural anatomy of the liver across different populations and developmental stages.
Overall, the present study suggests that fetal liver morphology is more variable than adult liver morphology. The progressive decline in accessory fissures and certain other variations with advancing gestation supports the concept of ongoing hepatic remodeling during fetal development. Conversely, the persistence of variations such as accessory lobes and the lingular process into adulthood indicates that some embryological features remain as permanent anatomical variants. Recognition of these developmental patterns is important for improving anatomical understanding and may help prevent misinterpretation of normal variants during imaging, surgical planning, and hepatobiliary interventions.

CONCLUSION

The present study demonstrates that the fetal liver exhibits greater morphological variability than the adult cadaveric liver, indicating that hepatic morphology undergoes significant remodelling during fetal development. The higher prevalence of accessory fissures in early gestation, followed by their progressive decline with advancing gestational age, suggests that many developmental variations regress before birth, whereas certain features, such as accessory lobes and the lingular process, may persist into adulthood as normal anatomical variants.
These morphological variations are of considerable clinical importance rather than merely being anatomical curiosities. A thorough understanding of hepatic anatomical variants is essential for anatomists, radiologists, and hepatobiliary surgeons to ensure accurate interpretation of imaging studies, avoid misdiagnosis of normal variants as pathological lesions, and facilitate safe surgical planning and liver transplantation. The developmental perspective provided by this study contributes to a better understanding of the embryological basis of hepatic morphology and emphasizes the importance of recognizing normal anatomical variations in both fetal and adult livers.

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