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A Morphological Study of Variations in the Human Cadaveric Liver with Reference to Their Surgical and Radiological Significance

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ABSTRACT

Background: The liver exhibits considerable morphological and morphometric variability, which may influence radiological interpretation and surgical management. Detailed knowledge of these variations is essential to minimize diagnostic errors and operative complications, particularly in the context of advanced hepatobiliary procedures. **Objectives:** The present study aimed to document the morphometric parameters and morphological variations of the human cadaveric liver and to evaluate their surgical and radiological significance in a Central Indian population. **Materials and Methods:** A descriptive cadaveric study was conducted on 100 adult human livers obtained from embalmed cadavers in the Department of Anatomy, Index Medical College, Indore. Each specimen was subjected to detailed morphometric measurements of the right and left hepatic lobes and systematic examination of external morphological features. Variations involving lobes, fissures, and surface anatomy were recorded. Liver morphology was further categorized according to Netter's classification. **Results:** The right hepatic lobe consistently demonstrated larger transverse and vertical dimensions than the left. Normal lobar morphology was observed in 72% of specimens, while 28% exhibited anatomical variations. Accessory fissures of the right lobe were the most common finding, followed by fusion of the quadrate lobe with the left lobe, lingular processes, hypoplasia, and accessory lobes. According to Netter's classification, only Types I, V, and VI were identified, with diaphragmatic grooves (Type VI) being the most frequent variant. Types II, III, and IV were not observed. **Conclusion:** The study demonstrates that while classical liver anatomy predominates, a significant proportion of cadaveric livers exhibit morphological variations with important clinical implications. These variations may complicate radiological interpretation and increase surgical complexity, particularly during minimally invasive hepatobiliary procedures. Population-specific anatomical data such as those obtained in this study are valuable for improving diagnostic accuracy, refining surgical planning, and enhancing patient safety in hepatobiliary practice.

Key words: morphological variation, liver, cadaveric study, Caudate lobe, Quadrate lobe

Introduction

The liver is the largest visceral organ of the abdominal cavity and is characteristically wedge-shaped in appearance. It occupies the right hypochondrium and epigastrium and extends variably into the left hypochondrium. Anatomically, the liver is divided into a larger right lobe and a smaller left lobe by an imaginary line joining the attachment of the falciform ligament anteriorly with the fissures for the ligamentum teres and ligamentum venosum on its inferior surface. In addition to these primary lobes, two supplementary lobes are described: the quadrate lobe located anteriorly and the caudate lobe situated posteriorly. The inferior margin of the caudate lobe frequently exhibits two projections, namely the papillary process and the caudate process. Variations in the morphology of the human liver may be congenital or acquired in origin [1,2]. From a functional perspective, the quadrate lobe is considered part of the left lobe, as it derives its arterial and portal venous blood supply from the left hepatic artery and the left branch of the portal vein. The caudate lobe demonstrates a complex subdivision, consisting of Spiegel's lobe (which includes the caudate lobe proper and the papillary process), the caudate process, and the paracaval portion. Notably, the caudate lobe receives dual blood supply from both the right and left hepatic arteries as well as from corresponding branches of the portal vein [3].

The presence of papillary processes, caudate processes, and accessory processes on other hepatic lobes may lead to diagnostic confusion and potential misinterpretation during radiological evaluation of liver pathology. Accessory lobes of the liver arise due to localized overgrowth of hepatic tissue and may be erroneously identified as lymph nodes or pathological masses [4]. In addition to the primary fissures, less commonly occurring fissures may be observed on various surfaces and lobes of the liver. These are referred to as accessory hepatic fissures and are recognized as potential sources of diagnostic error in imaging studies [5].

Although major hepatic fissures serve as important anatomical landmarks for lobar identification in radiological imaging, comprehensive knowledge of accessory fissures and accessory lobes is essential for both radiologists and surgeons to ensure accurate diagnosis and optimal surgical planning [6]. With the increasing adoption of advanced minimally invasive procedures such as laparoscopic hepatectomy and laparoscopic ablation of hepatic tumours, detailed anatomical studies of liver morphology and its variations have become increasingly significant. Such studies provide valuable insights that enhance the safety and efficacy of modern surgical and radio diagnostic practices [7].

Materials & methods

This study was conducted on 100 human cadaveric livers at the Department of Anatomy, Index Medical College, Hospital & Research Centre, Indore, M.P.

Liver specimens were obtained from adult embalmed human cadavers following routine anatomical dissection performed by undergraduate and postgraduate students in the Department of Anatomy. Each specimen was subjected to meticulous morphological and morphometric examination. The lobes, surfaces, and borders of every liver were systematically inspected for the presence of anatomical variations, including accessory fissures, accessory lobes, accessory processes, deep impressions, pons hepatis, appendicular projections, elongation, atrophy, and any other notable morphological deviations.

Results

100 human cadaveric livers were studied. Among them, a morphometric analysis of the right and left hepatic lobes was performed on cadaveric specimens, demonstrating consistent dimensional patterns with moderate variability. The right lobe showed a mean transverse diameter of 13.9 ± 1.2 cm (range: 11.5–16.3 cm) and a mean vertical diameter of 8.7 ± 0.42

cm (range: 7.86–9.54 cm). The left lobe had a mean transverse diameter of 12.5 ± 0.9 cm (range: 10.7–14.3 cm) and a mean vertical diameter of 7.9 ± 0.71 cm (range: 6.48–9.32 cm). Overall, the right lobe was consistently larger than the left in both dimensions, providing baseline morphometric data relevant to hepatobiliary surgery, radiological assessment, and anatomical reference for the Central Indian population. (Table 1)

Measurements	Mean±SD (cm)	Range	Maximum Frequency
Transverse diameter of the right lobe	13.9±1.2	11.5-16.3	13-14
Vertical diameter of the right lobe	8.7±0.42	7.86-9.54	8-9.1
Transverse diameter of the left lobe	12.5±0.9	10.7-14.3	12-12.6
Vertical diameter of the left lobe	7.9±0.71	6.48-9.32	7.9-8.5

The morphological features of the right and left hepatic lobes were evaluated in all cadaveric specimens. Normal morphology was observed in 72% of specimens for both lobes. Variations of the right lobe were identified in 28% of cases, most commonly accessory fissures on the visceral surface (18%), followed by fissures on the diaphragmatic surface (8%) and near-equal size of the right and left lobes (2%). Similarly, the left lobe showed variations in 28% of specimens, with fusion of the quadrate lobe being the most frequent finding (13%), followed by the presence of a lingular process (6%), hypoplasia (4%), accessory fissures (3%), and accessory lobes (2%). Although normal lobar anatomy predominated, the observed variations particularly accessory fissures and altered lobar configurations—are clinically relevant, as they may affect radiological interpretation and complicate hepatobiliary surgical procedures. (Table 2)

	Morphological features	No. of specimens	Percentage
Variation of the right lobe	Normal	72	72%
	Accessory fissures on the diaphragmatic surface	8	8%
	Accessory fissure on the visceral surface	18	18%
	Equal size of the right and left lobes	2	2%
Variation on the left lobe	Normal	72	72%
	The quadrate lobe fused with the left lobe	13	13%
	Lingular process	6	6%
	Accessory fissures on the visceral surface	3	3%
	Hypoplastic left lobe	4	4%
	Accessory lobe on the visceral surface	2	2%

Liver specimens were classified according to Netter’s morphological criteria. Only a limited range of Netter’s variants was identified in the present study. Type I morphology, characterized by a small left lobe with deep costal impressions, was observed in 3% of specimens. Type V morphology, showing marked surface impressions and corset-like constrictions, was present in 6% of cases. Type VI morphology, defined by diaphragmatic grooves, was the most frequently encountered variant (7%). No specimens exhibited Types

II, III, or IV morphology. Although most livers did not conform to specific Netter variants, the observed patterns—particularly diaphragmatic grooves and deep surface impressions—are clinically significant because they can be misinterpreted during radiological assessment and surgical procedures. (Table 3)

Netter’s type	No. of specimens	Percentage
Type 1 (Very small left lobe, deep coastal impressions)	3	3%
Type 2 (complete atrophy of the left lobe)	0	0
Type 3 (Transverse saddle-like liver, relatively large left lobe)	0	0
Type 4 (Tongue-like process of the right lobe)	0	0
Type 5 (Very deep impressions and corset constrictions)	6	6%
Type 6 (Diaphragmatic grooves)	7	7%

Study	Year	Accessory fissures of the right lobe [%]	Fusion of the Quadrate lobe with left lobe [%]	Accessory fissures of the left lobe [%]	Lingular process [%]	Accessory lobe Visceral surface [%]	Hypoplastic left lobe [%]
Sangeetha M et al.[75]	2014	0	-	1.81	-	9.09	-
Wahane A et al.[76]	2013	-	-	-	4	16	4
Saritha S et al.[77]	2015	16	-	2	-	-	-
Saxena A et al.[78]	2016	-	20		25	-	-
Tallapanenisreekanth [79]	2016	26.66	-	4.44	-	-	-
Chaudhari HJ et al.[80]	2017	-	-	-	-	3.7	-
Khajuria SR et al.[81]	2018	-	-	-	6	12	-
Anbumani L et al.[82]	2020	40	-	3.3	6.6	10	-

Anasuya DG et al. [82]	2020	-	-	-	14	24	6
Seeja PJ et al. [84]	2022	28	14	4	6	6	4
Present study	2025	26	13	3	6	2	4

Table 5: Comparative Distribution of Liver Morphological Variants Based on Netter's Classification Across Different Studies

Study	Year	Netter's classification (in %)					
		Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Sangeetha M et al. [75]	2014	7	4	7	9	6	7
Saritha S et al. [77]	2015	2	-	4	2	6	4
Saxena A et al. [78]	2016	10	-	-	-	10	10
Chaudhari HJ et al. [80]	2017	17.5	-	-	1.25	1.25	7.5
Anbumani L et al. [82]	2020	-	3.3	-	6.6	-	-
Anasuya DG et al. [83]	2020	36	8	12	14	10	28
Seeja PJ [84]	2022	2	-	-	-	6	8
Present study	2025	3	-	-	-	6	7

Discussion

The present cadaveric study demonstrates consistent morphometric dominance of the right hepatic lobe over the left, with greater transverse and vertical dimensions. These findings agree with earlier cadaveric studies across different populations, which have consistently reported larger right lobe dimensions relative to the left by Sangeetha M et al, Saritha S et al., and Anbumani L [8,9,10]. Minor interstudy variations in absolute measurements may be attributed to differences in population characteristics, sample size, and measurement techniques. The morphometric data obtained provide population-specific reference values of relevance to radiological assessment and hepatobiliary surgery.

Although normal lobar morphology predominated, morphological variations were observed in a considerable proportion of specimens. Accessory fissures, particularly on the visceral surface of the right lobe, constituted the most frequent variation, a finding comparable to reports by Tallapanenisreekanth [11] and Anbumani L et al. [10]. Such fissures are clinically important, as they may mimic pathological lesions on imaging studies, leading to diagnostic errors [12]. Variations of the left lobe, including fusion with the quadrate lobe, lingular processes, and hypoplasia, were also observed and are consistent with previous reports [13,14,15,16]. These variations may alter normal surface anatomy and complicate surgical orientation during hepatic resections and laparoscopic procedures.

Application of Netter's classification revealed only Types I, V, and VI in the present study, with diaphragmatic grooves (Type VI) being the most frequent variant. Similar predominance of selected Netter's types and absence of others has been reported in several studies, highlighting marked population-based variability [8,9,12,16]. The absence of Types II–IV in the present series underscores the limitation of universal application of this classification system without regional anatomical correlation.

Overall, comparison with previous studies demonstrates substantial heterogeneity in the frequency and distribution of hepatic morphological variations. This variability emphasizes the importance of region-specific anatomical studies to support accurate radiological

interpretation and safe surgical practice. Detailed knowledge of hepatic morphometry and morphology is essential to minimize diagnostic pitfalls and reduce intraoperative complications, particularly in the era of minimally invasive hepatobiliary surgery.

Conclusion

The present cadaveric investigation demonstrates a consistent predominance of the right hepatic lobe over the left in terms of morphometric dimensions, thereby establishing reliable baseline measurements for the Central Indian population. While classical lobar anatomy was observed in the majority of specimens, a substantial proportion exhibited morphological variations, most notably accessory fissures and modified lobar configurations involving both the right and left hepatic lobes.

Evaluation based on Netter's morphological classification revealed the presence of only selected variants, with diaphragmatic grooves (Type VI) and pronounced surface impressions (Type V) being the most frequently encountered. The absence of other Netter's types in this series highlights the population-dependent nature of hepatic morphology and underscores the limitations of applying standardized classification systems universally without regional anatomical correlation.

These morphological variations possess significant clinical relevance, as they may contribute to diagnostic ambiguity during radiological assessment and increase technical complexity during hepatobiliary surgical procedures, particularly minimally invasive interventions. Accordingly, comprehensive awareness of hepatic morphometry and morphological diversity is essential for radiologists and surgeons to optimize diagnostic precision, refine surgical planning, and reduce the likelihood of intraoperative complications. Population-specific cadaveric studies such as the present work provide valuable anatomical insights that support safer and more effective hepatobiliary practice.

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