Section: Anatomy

Original Research Article

MORPHOMETRIC ANALYSIS OF QUADRATE LOBE OF CADAVERIC LIVER: A CROSS SECTIONAL STUDY

Harini Shree Subburaj[1], Padmashree BR[2], Vasudha Kulkarni[3]

[1]*Medical Student, Department of Anatomy, Akash Institute of Medical Sciences and Research Center, Bangalore, India.*
[2]*Associate Professor, Department of Anatomy, Akash Institute of Medical Sciences and Research Center, Bangalore, India.*
[3]*Professor and HOD, Department of Anatomy, Akash Institute of Medical Sciences and Research Center, Bangalore, India.*

Received *: 10/01/2025*
Received in revised form *: 02/03/2025*
Accepted *: 17/03/2025*

Corresponding Author:
Dr. Padmashree BR,
Associate Professor, Department of Anatomy, Akash Institute of Medical Sciences and Research Center, Bangalore, India.
Email: padmashreebr5@gmail.com

DOI: 10.70034/ijmedph.2025.1.357

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (1); 1914-1918

ABSTRACT

Background: The liver is the largest glandular organ in the right hypochondriac region of the abdomen. The quadrate lobe (QL) is unique amongst its five distinct anatomical lobes as it forms a single vascular segment - segment IV. The morphometric study of the QL has many clinical implications, ranging from surgical planning, and accurate diagnostic imaging to identifying certain pathological conditions like liver cirrhosis, wherein the QL undergoes atrophy. Its absence or hypoplasia may suggest abnormalities of branches of the portal vein, hepatic artery, and bile duct specific to the lobe. This study aims to determine the variations in the dimensions and features of the QL of cadaveric livers.

Materials and Methods: Morphometric data (transverse diameter, maximum length) of 24 cadaveric livers were recorded using a Vernier caliper and meter scale. Any abnormal surface features of QL were also recorded.

Results: The most common shape of the QL was irregular (33.3%), followed by quadrangular (16.7%) and rectangular (16.7%). The mean transverse diameter was 3.8cm and the mean length of QL was 5.8cm. Pons hepatis was recorded in 16.7% of cases, transverse fissures in 12.5%, oblique fissures in 37.5%, and tongue-like processes in 16.7%.

Conclusions: The knowledge of morphometric variations of QL becomes important for planning surgical procedures like resection and liver transplant, cholecystectomy, and laparoscopic procedures, to minimize iatrogenic injuries. It is also essential for accurate interpretation of imaging studies.

Key-words: Quadrate lobe, Liver, Morphometry, Variation, Coinuaud segment.

INTRODUCTION

The liver originates from the endodermal diverticulum in the foregut during the third week of embryonic development. Interactions between hepatic bud cells and the vitelline and umbilical veins lead to the formation of hepatic sinusoids, while hepatic cords form the liver parenchyma.[1] By the third month of gestation, the liver occupies a significant portion of the abdominal cavity, with the left and right lobes nearly equal in size. As hematopoietic activity shifts to the spleen and bone marrow, the left lobe undergoes relative reduction in size compared to the right. Variations in liver morphology, including those of the quadrate lobe, can arise due to interruptions or deviations during these developmental stages.[2]

Anatomically, it is divided into four primary lobes: right, left, caudate, and quadrate. The quadrate lobe, often less emphasized in anatomical studies, is situated on the liver's inferior surface. It is bounded anteriorly by the liver's free margin, posteriorly by the porta hepatis (transverse fissure), on the left by the fissure for the ligamentum teres, and on the right by the gallbladder fossa.[3] According to Couinaud's classification, which segments the liver based on vascular supply and biliary drainage, the quadrate lobe corresponds to segment IV. This classification divides the liver into eight functionally independent segments, each with its own vascular inflow, outflow, and biliary drainage.[4]

The quadrate lobe, or the square lobe is situated on the inferior surface of the liver, bounded anteriorly by the free surface of the liver, posteriorly by the transverse fissure, on the left by the fissure for ligamentum teres and on the right by the gallbladder fossa.[5] The quadrate lobe forms segment IV of the liver, according to Couinaud's terminologies, which divides the liver into eight segments based on the presence of a separate branch of the artery, bile duct, and tributary of the hepatic vein and the portal vein to that part of the liver.[6] The widespread morphological variations of the liver occur primarily due to the interruption in normal development of the organ at a precise embryonic stage.[7] These malformations mostly remain asymptomatic and are revealed accidentally during autopsies or imaging studies conducted for other visceral organ disorders.[8] While the segmental anatomy of the liver has been thoroughly examined, there is a lack of research focusing on its surface variations. In today's age of advanced imaging and minimally invasive techniques, both radiologists and surgical teams need to possess a comprehensive understanding of the liver's normal anatomy and its common variation.[9]

Hence the present descriptive study provides value addition for expanding the medical literature on the morphometry of the quadrate lobe, which is shrouded in mystery and is yet to be explored in detail.

MATERIALS AND METHODS

A cross-sectional observational study was conducted from May 2023 to August 2023 on 24 adult human cadaveric livers obtained during routine anatomical dissections in the anatomy departments of anatomy Akash Institute of Medical Sciences and Research Center, Bangalore. The study aimed to analyze morphometric variations of the quadrate lobe and other surface features of the liver.

During routine abdominal dissections, an incision was made along the midline from the xiphoid process to the pubic symphysis and extended laterally on both sides at the levels of the xiphoid process, umbilicus, and pubic symphysis to reflect the skin into four flaps. Following this, the superficial fascia, abdominal muscles, and parietal peritoneum were carefully incised to expose the liver. The liver was then mobilized by pulling it downward, and the anterior layers of the coronary and left triangular ligaments were divided. The inferior vena cava (IVC) was identified between the liver and diaphragm and separated. In cases where the IVC was deeply embedded within the liver, a segment of the IVC was excised along with the liver specimen. The porta hepatis structures were exposed and carefully cut close to their entry point. The liver was then completely separated by detaching all its peritoneal ligaments and folds before removal, following the standard dissection technique described in Cunningham's Manual of Practical Anatomy.

After extraction, the liver specimens were preserved in 10% formalin. Each liver was carefully examined for its normal external features, including borders, surfaces, and lobes. Specimens displaying any disease, surgical alterations, or damage were excluded from the study to ensure anatomical integrity.

Each liver was meticulously examined and special attention was given to the quadrate lobe, assessing its shape, dimensions, and surface features. Parameters such as the transverse diameter and maximum length of the quadrate lobe were recorded using a Vernier caliper and meter scale. To ensure accuracy, each measurement was taken three times, and the mean value was calculated.

Additionally, the presence of pons hepatis, a band of hepatic tissue bridging either the IVC groove or the groove for the ligamentum teres, was documented. The pons hepatis bridging the IVC was categorized as completely covering or partially bridging the IVC. When it was present over the ligamentum teres, it was classified as either open or closed based on its length extending from the transverse fissure to the anterior margin. The dimensions of pons hepatis were also recorded using a Vernier caliper.

Each liver specimen was numbered, photographed, and systematically documented, focusing on gross morphology and specific features of the quadrate lobe, including fissures, pons hepatis, and tongue-like processes.

Statistical analysis was performed using SPSS version 23.0 software. Quantitative data, including the transverse diameter and maximum length of the quadrate lobe, as well as the dimensions of pons hepatis were presented as mean and standard deviation. Qualitative data, such as the presence or absence of pons, variations in fissures and tongue-like processes, were expressed as frequencies and percentages. Pearsons correlation coefficient was used for establishing correlation between parameters. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The most common variation in the shape of the quadrate lobe was irregular (33.3%) followed by quadrangular (16.7%) and rectangular (16.7%) (Figure 1A to 1C). The other shapes observed were triangular (12.5%), narrow (12.5%), elongated (4.2%), and trilobed (4.2%). [Table 1, Figure 1]

Table 1: Variations in Shape of Quadrate lobe in studied specimens.

Shape of Quadrate Lobe	Number	Percentage (%)
Irregular	8	33.33%
Quadrangular	4	16.67%

Rectangular	4	16.67%
Triangular	3	12.50%
Narrow	3	12.50%
Elongated	1	4.17%
Trilobed	1	4.17%

Additional features found on the quadrate lobe include oblique fissures (37.5%), transverse fissures (12.5%), tongue-like processes (16.7%), and pons hepatitis (16.7%). (Table 2, Figure 1).

Table 2: ?

Additional Feature	Number	Percentage (%)
Oblique fissures	9	37.50%
Transverse fissures	3	12.50%
Tongue-like processes	4	16.67%
Pons hepatitis	4	16.67%

The analysis of the measured parameters showed that the transverse diameter ranged from a minimum of 1.9 cm to a maximum of 6.1 cm, with a mean value of 3.8 cm. The length varied between 4.5 cm and 7.7 cm, with an average of 5.8 cm. Pearson's correlation coefficient was 0.48, suggesting a moderate positive correlation between transverse diameter and length. However, the p-value was 0.176, indicating that this correlation was not statistically significant. [Table 2]

Table 2: Maximum and Minimum Values Recorded and Pearson's Correlation Coefficient

Parameter	Maximum	Minimum	Mean
Transverse Diameter	6.1 cm	1.9 cm	3.8 cm
Length	7.7 cm	4.5 cm	5.8 cm
Pearson's Correlation Coefficient = 0.48 , p= 0.176 (Not significant)			

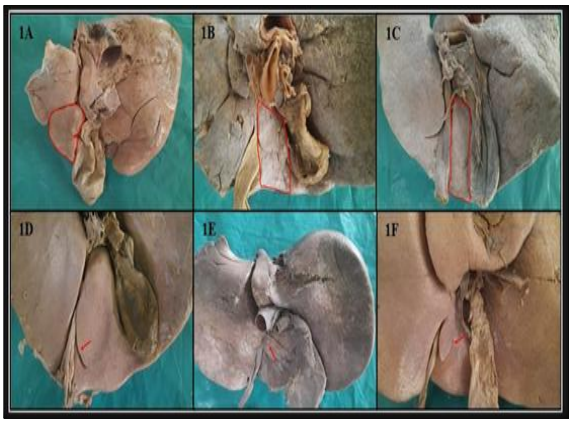

Figure 1: Varying shapes of quadrate lobe: (1A) Irregular shape (1B) Quadrangular shape (1C) Rectangular-shaped. Presence of additional features on quadrate lobe (1D) Oblique fissure (1E) Pons Hepatis connecting the quadrate lobe to the left lobe (1F) Tongue-like process.

DISCUSSIONS

The liver is a large glandular organ, primarily performing the function of bile secretion and modifying certain blood constituents that pass through it. It consists of five anatomically distinct lobes: the right lobe, left lobe, caudate lobe, quadrate lobe, and the Spigelian lobe.[10]

Variations in the morphometry of the quadrate lobe are rare, and often asymptomatic. They are usually accidental finds in autopsies or imaging studies. Congenital variations of the liver often involve changes in the vascular system and biliary tree of the hepatobiliary system. The common variations that occur as a result, are deformation of the lobes, atrophy or reduced size of the lobes, agenesis, and hypoplasia.[11] Some of the most common hepatic variations observable during clinical examination include accessory hepatic fissures/sulci, accessory lobes, and the pons hepatis. Acquired diaphragmatic and ligamentous abnormalities may be induced by the neighbouring structures during the lifetime, while accessory fissures discovered in the adult are due to the persistence of such fissures past the post-natal reformation of the liver. Acquired liver defects also impact external morphology, but their clinical effects are usually dormant unless triggered by factors like torsion, trauma, or tumors.[12]

As the diagnosis and treatment of liver pathologies, such as laparoscopic procedures including hepatectomy and ablation, largely rely on radiological imaging, a comprehensive understanding of the liver's anatomical variations is crucial for surgeons and radiologists. The shape of the quadrate lobe seems to vary over a wide range, which is a significant clinical criterion that may lead to erroneous diagnosis and unfavourable surgical outcomes. A narrow quadrate lobe, or one of size smaller than usual may create confusion during imaging studies where the lobe may be mistaken for the fissure for ligamentum teres which is closer to the left border of the gallbladder fossa.[13]

The liver, gallbladder, and bile duct system originate from the hepatic diverticulum, a ventral outgrowth from the distal part of the foregut, during the fourth week of embryonic development. Adequate levels of fibroblast growth factors (FGFs), secreted by the developing heart, trigger the formation of the hepatic diverticulum. The proliferation and differentiation of hepatic progenitor cells into

hepatocytes is facilitated by the Wnt/beta-catenin signalling pathway.[14]

From the fifth to the tenth week of gestation, the liver grows rapidly, coming to occupy a significant portion of the upper abdominal cavity. The volume of oxygenated blood entering the liver from the umbilical vein influences the liver's growth and segmentation into functional units.[15] Under non-pathological conditions, the liver develops homogenous parenchyma and is partitioned into its functionally and anatomically distinct lobes by peritoneal and ligamentous connections. This knowledge helps prevent incorrect interpretations in diagnosis and ensures accurate treatment planning and execution.[16]

In the present study, the most common shape of the quadrate lobe was irregular (33.3%), followed by quadrangular (16.7%) and rectangular (16.7%), which is in contrast to previous studies, such as the study by Sambhav et al which reported the variations in the shape of the quadrate lobe as quadrangular in 25%, triangular in 17.5%, rectangular in 15%, irregular in 12.5%, narrow in 7.5%, elongated in 5%, bilobed in 5% and absent in 2.5% of the cases studied.[17]

In another study by Reddy N et al the shape of the quadrate lobe was recorded as quadrangular in 85% of cases and rectangular in 10% of cases. Other shapes that were also noted include triangular, pear-shaped, and bell-shaped.[18]

Joshi SD et al (2009) noted that 66% of cases showed rectangular quadrate lobes while 6% were characterized as narrow. However, there was no differentiation between the quadrangular and rectangular shapes of the lobes in this study.[19]

The literature on the dimensions of the quadrate lobe, namely, the transverse diameter and maximum length, seems to be quite scant. However, Sambhav K et al recorded the maximum length of the quadrate lobe to range from 2.8 to 10.3cm, and the transverse diameter to vary between 1.5 to 5.3cm.[17] The average maximum length recorded by Reddy N et al was 5.5cm, and the average transverse diameter was 2.8cm. These values correspond with those found in the present study, namely the mean maximum length being 5.8cm and the mean transverse diameter being 3.8cm.[18]

Pons hepatis was first described in 1743 as a hepatic bridge or "pont hepatique" - a segment of hepatic tissue that bridges over the fissure for ligamentum teres to connect the quadrate lobe and the left lobe. The presence of pons hepatitis makes it difficult to visualize the fissure for ligamentum teres normally, potentially leading to misinterpretation of the dimensions of the left and right lobe in imaging studies.[20]

The presence of pons hepatis was recorded by several authors and the occurrence of this feature was found to be within the same frequency in the present study also. The percentage incidence of Pons Hepatis recorded in the present study closely correlated to that recorded in the 2017 study by Joshi MM et al.[21] It has been clinically observed that metastatic hepatomas originate from the pons hepatis and that this bridging structure serves as a site for harboring peritoneal disseminated tumor cells. The pons hepatis also is significant as a landmark for cryo-reductive surgeries of the liver. Various studies have reported the prevalence of pons hepatis to range from 4-22%. [Table 3]

Table 3: Occurrence of Pons Hepatis as reported by various authors

Serial Number	Author	Occurrence of Pons Hepatis
1	Sangeetha A et al[8]	6%
2	Sambhav K et al[17]	5%
3	Reddy N et al[18]	32.5%
4	Joshi SD et al[19]	30%
5	Joshi MM et al[21]	13%
6	Patil S et al[22]	10%
7	Singh HR et al[23]	22.86%
8	Mehare T et al[24]	9.09%
9	Saritha S et al[25]	4%
[10]	Kumar BS et al[26]	10%
11	Present Study	16.7%

CONCLUSION

The presence of accessory fissures on the surface of the quadrate lobe holds great clinical significance. Fissures on the diaphragmatic surface were previously thought to be caused by the diaphragm's muscular invaginating into the liver on the costal surface. However, recent radiological research has demonstrated that they are surface portal fissures. These fissures may result from various conditions like gastric volvulus, diaphragmatic hernia, portal hypertension, etc. They are markers of hepatic "weak zones," that is, areas with low vascularization, which can aid during resection procedures. Accessory fissures pose as sources of errors in diagnostic imaging, where fluid accumulation in the fissures may be misinterpreted as a liver cyst, intrahepatic hematoma, or liver abscess. In the present study, it was found that oblique fissures appeared in 37.5% of cases while transverse fissures were found in 12.5% of the specimens observed. Joshi MM et al in 2017 recorded the presence of accessory fissures in a total of 34% of quadrate lobes, without differentiating as oblique or transverse fissures.[21] Patil S et al noted the presence of accessory fissures on the right lobe,

quadrate lobe, and caudate lobe. A complete transverse fissure was observed in 4% of cases, dividing the quadrate lobe into a superior and inferior lobe.[22] The incidence of fissures on the surface of the quadrate was found to be 56.25% in the study by Reddy N et al,[17] and Singh HR et al,[23] recorded the presence of fissures on the quadrate lobe in 32.9% of cases. The total occurrence of fissures on the quadrate lobe in the present study (45.8%) is consistent with the findings in other studies.

Tongue-like processes, another source of misinterpretation of the imaging studies, were observed and recorded by a few authors. In 20 (25%) livers, a well-demarcated tongue-like projection was observed on the quadrate lobe, delineated by a curved fissure by Reddy N et al,[18] A prominent papillary process was observed in 5 (5%) of the livers by Joshi MM et al,[21] while Joshi SD et al,[19] reported a higher incidence, with prominent papillary processes seen in 33% of the livers in their study. A tongue-like projection was observed in 5 (7.14%) specimens, in a 2018 study by Singh HR et al.[23] In the present study, tongue-like processes were observed in 16.7% of cases.

Conflict of Interest: None

Acknowledgement: We extend our heartfelt gratitude to the management, the esteemed principal, and the faculty of the anatomy department for their support and guidance throughout the research process.

REFERENCES

1. Gordillo M, Evans T, Gouon-Evans V. Orchestrating liver development. Development. 2015 Jun 15;142(12):2094-108. doi: 10.1242/dev.114215. PMID: 26081571; PMCID: PMC4483763.
2. Srimani P, Saha A. Liver morphology: anatomical study about the outer aspects. Surg Radiol Anat. 2020 Dec;42(12):1425-1434. doi: 10.1007/s00276-020-02485-9. Epub 2020 May 3. PMID: 32363408.
3. Sibulesky L. Normal liver anatomy. Clin Liver Dis (Hoboken). 2013 Mar 29;2(Suppl 1):S1-S3. doi: 10.1002/cld.124. PMID: 30992874; PMCID: PMC6448666.
4. Ichida H, Imamura H, Yoshioka R, Mizuno T, Mise Y, Kuwatsuru R, Kawasaki S, Saiura A. Re-evaluation of the Couinaud classification for segmental anatomy of the right liver, with particular attention to the relevance of cranio-caudal boundaries. Surgery. 2021 Feb;169(2):333-340. doi: 10.1016/j.surg.2020.08.029. Epub 2020 Oct 16. PMID: 33077202.
5. Gray H. Anatomy, descriptive and surgical. 5th ed. Philadelphia: Henry. C. Lea; 1870. P. 744.
6. Rutkauskas S, Gedrimas V, Punzius J, Barauskas G, Basevicius A. Clinical and anatomical basis for the classification of the structural parts of liver. Medicina (Kaunas) 2006; 42(2): 98 – 106.
7. Deshwal A, Mahajan A, Razdan SK, Indora NK. Significance and Clinical Implications of Morphometric and Morphological Variability in Cadaveric Liver. Cureus. 2024 Apr 29;16(4):e59275. doi: 10.7759/cureus.59275. PMID: 38813305; PMCID: PMC11135240.
8. Sangeetha A, Kumar SN. Morphological variations of the liver and its applied significance: A cadaveric study. J Datta Meghe Inst Med Sci Univ 2021; 16: 303 – 7.
9. Nayak BS. A study on the anomalies of liver in the south Indian cadavers. Int. J. Morphol 2013; 31(2): 658 – 661.
10. Kostov S, Selçuk I, Watrowski R, Dineva S, Kornovski Y, Slavchev S, Ivanova Y, Dzhenkov D, Yordanov A. Surgical Anatomy of the Liver-Significance in Ovarian Cancer Surgery. Diagnostics (Basel). 2023 Jul 14;13(14):2371. doi: 10.3390/diagnostics13142371. PMID: 37510115; PMCID: PMC10378601.
11. Seeja PJ, Venugopal GE, Sivakumari S, Sangeetha HG. Morphological study of the human liver and its variations in the south Indian population. Int. J Acad Med Pharm 2023; 5(2): 687-691.
12. Choi BY, Nguyen MH. The diagnosis and management of benign hepatic tumors. J Clin Gastroenterol. 2005 May-Jun;39(5):401-12. doi: 10.1097/01.mcg.0000159226. 63037.a2. PMID: 15815209. Rajkomar K, Bowman M, Rodgers M, Koea JB. Quadrate lobe: a reliable landmark for bile duct anatomy during laparoscopic cholecystectomy. ANZ J Surg. 2016 Jul;86(7-8):560-2. doi: 10.1111/ans.13509. Epub 2016 Apr 8. PMID: 27061019.
13. Russell JO, Monga SP. Wnt/β-Catenin Signaling in Liver Development, Homeostasis, and Pathobiology. Annu Rev Pathol. 2018 Jan 24; 13:351-378. doi: 10.1146/annurev-pathol-020117-044010. Epub 2017 Nov 10. PMID: 29125798; PMCID: PMC5927358.
14. Vernon H, Wehrle CJ, Alia VSK, Kasi A. Anatomy, Abdomen and Pelvis: Liver. 2022 Nov 26. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 29763190.
15. Auh YH, Rubenstein WA, Zirinsky K, Kneeland JB, Pardes JC, Engel IA, Whalen JP, Kazam E. Accessory fissures of the liver: CT and sonographic appearance. AJR Am J Roentgenol. 1984 Sep;143(3):565-72. doi: 10.2214/ajr.143.3.565. PMID: 6331736.
16. Ober EA, Lemaigre FP. Development of the liver: Insights into organ and tissue morphogenesis. J Hepatol. 2018 May;68(5):1049-1062. doi: 10.1016/j.jhep.2018.01.005. Epub 2018 Jan 13. PMID: 29339113.
17. Sambhav K, Krishna H, Dixit SG, Ghatak S. Morphological Study of Variations of the Human Cadaveric Liver and Its Clinical Implications. Cureus. 2023 Feb 26;15(2):e35507. doi: 10.7759/cureus.35507. PMID: 37007425; PMCID: PMC10050914.
18. Reddy N, Joshi SS, Mittal PS, Joshi SD. Morphology of caudate and quadrate lobes of liver. J. Evolution Med. Dent. Sci 2017; 6(11): 897 – 901.
19. Joshi SD, Joshi SS, Athavale S A. Some interesting observations on the surface features of the liver and their clinical implications. Singapore Med J. 2009; 50(7): 715 – 719.
20. Kalamutharasi R, Dhanalakshmi V, Saranya G. Pons Hepatis: An Anatomic Curiosity. Res J Pharm Biol Chem Sci. 2024;15(1):307-310. doi:10.33887/rjpbcs/2024.15.1.40.
21. Joshi MM, Chavan SK. Morphological study of adult human cadaveric liver. Int J Anat Res 2017; 5(3.2): 4284 - 4289.
22. Patil S, Sethi M, Kakar S. Morphological study of human liver and its surgical importance. Int J Anat Res 2014; 2(2): 310 - 14.
23. Singh HR, Rabi S. Study of morphological variations of liver in human. Translational Research in Anatomy 2019; 14: 1 - 5.
24. Mehare T, Bekele A, Getachew A, Yigremali. Assessment of morphological variations and its specific location on the surface of adult human liver in Ethiopian cadavers University of Gondor, Bahir Dar University, Addis Ababa University, St. Paulos Medical School and Hawassa University, Ethiopia. Int J Med Res Health Sci 2017; 6(10): 121-129.
25. Saritha S, Ramani, Nagajyothi, Yesender. Cadaveric study of morphological variations in the human liver and its clinical importance. Valley International Journals 2015; 2(6): 1020 – 1031.
26. Kumar BS, Anand A. Architectural variations on the external surfaces of liver. International Journal of Current Research and Review 2012; 4(14): 1 – 9.