

Morphological Variations and Morphometric Analysis of the Caudate Lobe of Liver: A Cadaveric Cross-sectional Study from Karnataka, India

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ABSTRACT

Introduction: Liver being the largest gland of the body divided into four major anatomical lobes on the basis of peritoneal and ligamentous attachments. Liver is divided into eight functional segments according to Couinaud's classification based on branching of the portal vein and bile duct. Caudate/Spigelian lobe being the first segment and is anatomically distinct. It is the only part of the liver covered with peritoneum of lesser sac.

Aim: To assess the morphological variations and morphometric analysis of caudate lobe. Transverse Diameter (TD) of right lobe of liver taken to calculate Caudate to Right Lobe ratio (CRL ratio) to diagnose prevalence of cirrhosis of liver.

Materials and Methods: A cadaveric cross-sectional study was conducted on 30 formalin-fixed adult human liver specimens collected from the Department of Anatomy, Adichunchanagiri Institute of Medical Sciences BG Nagara, affiliated to ACU, district Mandya in state, Karnataka, India from 1st July 2025 to 31st December 2025. Liver specimens with intact caudate and right lobes were selected for the study. The following observations were noted: caudate lobe shape, surface variations such as

fissures, and variations in caudate and papillary processes. Morphometry such as transverse and Anteroposterior Diameters (APD) of the caudate lobe and TD of the right lobe was taken using vernier calipers. Midpoint of hepatic segment of Inferior Vena Cava (IVC) was taken as reference point to measure TD of caudate and right lobe of liver.

Results: The caudate lobe shapes observed was rectangular (47%), pear shaped (30%), pyriform (17%) and oval/irregular (7%). The mean length, transverse and anteroposterior diameter of caudate lobe was found to be 6.78 ± 1.15 cm, 3.61 ± 0.89 cm and 2.7 ± 0.67 cm, respectively. The mean width of the right lobe was 8.31 ± 1.09 cm. In 12 of the specimens, a vertical fissure was seen in the caudate lobe, extending from the lower margin, and two of them showed an oblique fissure. An enlarged papillary process was seen in five liver specimens. CRL ratio ≥ 0.65 (Harbin's Index) was seen in two cases, indicating cirrhosis of the liver.

Conclusion: Variations in the shape of caudate lobe and accessory fissures would be helpful for surgeons and radiologist for management of cases.

Keywords: Accessory fissure, Caudate to right lobe ratio, Cirrhosis of liver, Harbin's index

INTRODUCTION

Liver is the largest of the abdominal viscera occupying substantial portion of the upper abdominal cavity. It occupies most of the right hypochondrium and epigastrium and frequently enters into left hypochondrium [1]. As the body grows from infancy to adulthood the liver rapidly increases in size. This period of growth reaches around 18 years and is followed by gradual decrease in weight from middle age [1]. Morphology of liver resembles wedge shaped organ with a pointed end towards the left hypochondrium. It is convex in appearance in all the surfaces except inferiorly. Inferior surface is concave as it is moulded to the shape of adjacent viscera [2].

Liver is divided anatomically into four major lobes, right, left, caudate and quadrate based on the peritoneal and ligamentous attachments [1]. According to Couinaud's classification liver is divided into eight segments based on vascular organisation and the segments are numbered I-VIII clockwise from the groove for IVC. Segment-I was considered as the caudate lobe [3]. Caudate lobe also mentioned as Spiegel's lobe is well demarcated and is located on the posterior surface of liver. Caudate lobe is bounded by fissure for ligamentum venosum on left-side, groove for IVC on right-side, antero-inferiorly by porta hepatis and superiorly by superior surface of right end of ligamentum venosum [4].

It is separated into three sections - the caudate lobe proper, papillary process and paracaval part. The medial small projection is called

papillary process and a lateral projection called the caudate process [4]. Caudate lobe proper and papillary process together constitute Spiegel's lobe. The connections with right lobe are caudate process and paracaval portion. Caudate process is between groove for IVC and porta hepatis and paracaval portion is the part anterior to groove for IVC [5].

Dodds et al., hypothesised that during second trimester the ductus venosus rotates rightward as the liver enlarges, so that a small portion of the liver become inserted behind the mesentery for the ductus venosus, and this part represents caudate lobe of liver [1].

Caudate lobe has separate blood supply and biliary drainage [1]. Arterial supply to the caudate lobe is by multiple caudate arteries which arise from both right and left hepatic arteries (and middle when present). These arteries are frequently connected to each other and have an overlapping vascular territory. Venous outflow is through multiple minor hepatic veins which open directly into the IVC. Due to this anatomical and functional independence, caudate lobe stands out suggesting a mechanism in which it is differentially affected when compared with the rest of the liver [3]. In cases of vascular based pathologies such as Budd-Chiari syndrome hepatic venous outflow is blocked except the caudate lobe resulting in compensatory hypertrophy of this lobe [3]. Similarly, as in case of hepatic parenchymal atrophy (cirrhosis) it undergoes compensatory hypertrophy while the other lobes undergo shrinkage [3].

Due to this differential effect, it is beneficial to diagnose cirrhotic livers from the non-cirrhotic ones before deciding any further potentially invasive investigations. This is achieved by using hepatic indices such as Harbin's index which is taken as the ratio of TD of the caudate lobe to the TD of the right lobe (Rt lobe undergoes shrinkage). These indices which compare the volume of the caudate lobe with the remainder of the liver have a sensitivity of 84% and a specificity of 100%, and are a reliable indicator for liver cirrhosis [6].

Gross abnormalities of the liver are rare despite its complex development. Surface variations can be acquired or congenital. Such as agenesis, atrophy, accessory lobes and fissures or any undue size are all due to interrupted development at a precise embryonic stage [7]. Enlarged papillary process can simulate mass in the head of the pancreas or periportal lymph nodes [6]. Most of the fissures disappear during the reformation of liver during postnatal period and a very few persist, if they do so they can mimic focal lesions when metastatic tumours are lodged [7].

The aim of the present research was to study the morphological variations and morphometric measurements of caudate lobe and TD of right lobe of the liver specimens. Also, the ratio of TD of caudate lobe and TD of right lobe (CRL ratio) was determined to diagnose the cirrhosis of liver.

MATERIALS AND METHODS

A cadaveric cross-sectional study was conducted in the Department of Anatomy, Adichunchanagiri Institute of Medical Sciences BG Nagara/ ACU, district Mandya in state, Karnataka, India from 1st July 2025 to 31st December 25. Institutional Ethics Committee permission as well as permission from the competent authority of the same institution bearing registration number EC/NEW/INST/2023/KA/0382 dated 02/07/2025 was taken.

Sample size: A total of 30 liver specimens were obtained from Anatomy Department museum and liver specimens eviscerated during dissection.

Inclusion criteria: Liver specimens irrespective of the age and gender and liver specimens having normal anatomical features were included in the present study.

Exclusion criteria: Liver specimens which were damaged during dissection and any abdominal surgery or trauma, surgically resected liver specimens and specimens with distorted shape during preservation and storage were excluded from the present study.

Study Procedure

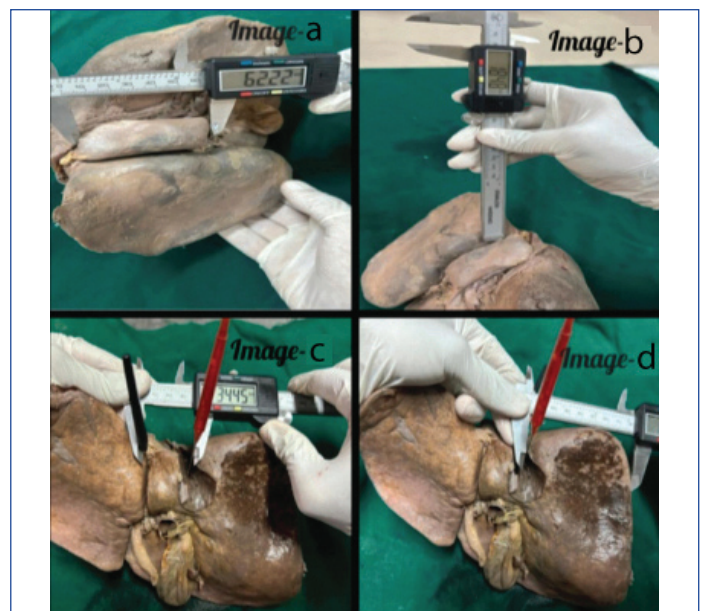
Each liver specimen was cleaned and placed in the anatomical position to facilitate visualisation of the visceral and diaphragmatic surfaces. Caudate lobe was studied for shape [5] variations in papillary, caudate processes and presence of fissures.

Morphometric measurements were taken using digital vernier callipers. Each parameter was taken three times and their mean was noted to minimise the subjective error.

The following parameters regarding the caudate lobe were noted: TD, Vertical Diameter (VD), APD. The midpoint of the IVC groove was used as the reference point for TD [6]. TD of the caudate lobe was taken from this reference point to the right lateral margin of the caudate lobe. VD of the caudate was taken from the lower margin to the upper margin at maximum height. APD of the caudate lobe was taken from the right margin to the floor of the groove for ligamentum venosum (depth) [Table/Fig-1]. TD of the right lobe was taken from the reference point to the right margin of the liver.

The ratio of TD of the caudate lobe to that of the right lobe (CT/RT), known as Harbin's Index of the liver, was determined, and any value crossing ≥ 0.65 was considered cirrhotic [6].

Surface variations when compared to the normal anatomy of the liver as stated in Gray's Anatomy were noted, photographed, and evaluated.



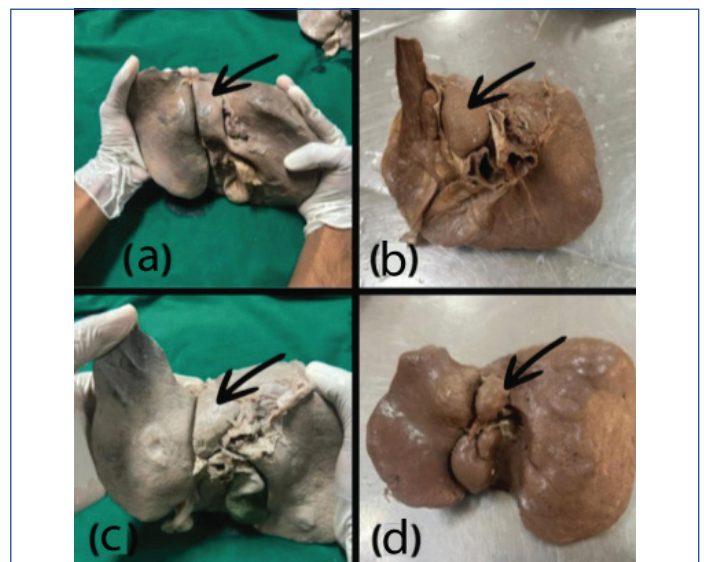
[Table/Fig-1]: Showing the methods to take measurements. a) Caudate lobe length (VD)- at the level of the greatest longitudinal extension; b) Anteroposterior diameter of caudate lobe (APD)- at the level of the greatest anterolateral extension; c) Transverse Diameter (TD) of caudate lobe from fissure for Ligamentum Venosum to the mid-point of hepatic part of Inferior Vena Cava (IVC); d) Measurement of the TD of right lobe (RT)-from the mid-point of hepatic part of the Inferior Vena Cava (IVC) to the most lateral margin of the right lobe

STATISTICAL ANALYSIS

Data were analysed using Statistical Packages of Social Sciences (SPSS) software version 26.0. Descriptive statistics such as percentage, mean, Standard Deviation (SD) were used.

RESULTS

The shape of caudate lobe was (A) Rectangular 14 (47%), (B) Pear 9 (30%), (C) Pyriform 5 (17%) and any (D) oval (irregular) shape of 7% with a frequency of 2 [Table/Fig-2].



[Table/Fig-2]: Showing the shape of caudate lobe: a) Rectangular- shaped; b) Pear- shaped c) Pyriform- shaped; d) Oval/irregular-shaped

The mean length, transverse and anteroposterior diameter of caudate lobe was found to be 6.78 ± 1.15 cm, 3.61 ± 0.89 cm and 2.7 ± 0.67 cm, respectively [Table/Fig-3]. Partial vertical fissure extending from the inferior border was seen in 12 specimens with a prevalence of 40% [Table/Fig-4]. Oblique fissure was seen arising from other borders in two of the specimens [Table/Fig-5]. Complete oblique fissure was seen extending to the inferior border forming a bilobed appearance in one of the study specimens [Table/Fig-6]. Below and medially, the small rounded papillary process was seen enlarged in five of the specimens [Table/Fig-7].

Parameters	Caudate lobe	Range	Right lobe
Transverse Diameter (TD CT)	3.61±0.89 cm	1.6-5.0	8.31 cm±1.09
Vertical Diameter (VD CL)	6.78±1.15 cm	4.4-8.5	-
Antero-posterior Diameter (APD CAP)	2.7±0.67 cm	1.6-4.0	-
CT/RT Right Lobe (CRL)	0.43±0.13	0.2-0.9	-

[Table/Fig-3]: The mean of all the parameters of caudate lobe, TD of right lobe and CRL.



[Table/Fig-4]: Showing partial vertical fissure.



[Table/Fig-5]: Oblique fissure extending from left border to slightly above inferior border.



[Table/Fig-6]: Complete fissure showing bilobed appearance.

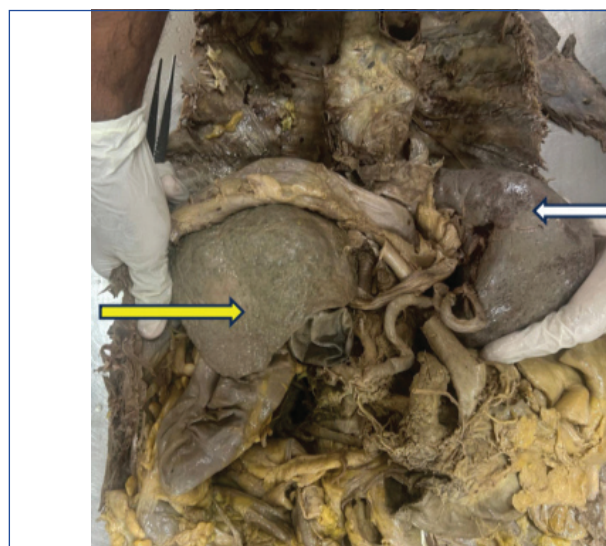
Abnormal Harbin's index showing Caudate lobe thickness (CT) / Right lobe Thickness (RT) ratio of about 0.9 with caudate lobe hypertrophy and right lobe atrophy was appreciated in two of the liver specimens, suggesting cirrhosis based on Harbin's index associated with micronodular formation; other proofs, such as splenomegaly in the same cadaver, pointed to the confirmation [Table/Fig-8,9]. However, the histopathology report was not available.



[Table/Fig-7]: Enlarged papillary process (blue arrow).



[Table/Fig-8]: Cirrhotic liver showing abnormal CRL ratio.



[Table/Fig-9]: White arrow showing splenomegaly with cirrhotic liver (yellow arrow).

DISCUSSION

Organogenesis of the liver begins during the 3rd week of intrauterine life and involves a complex embryological process, yet gross deformities are rare [2,4,6]. The caudate lobe has clinical importance due to its independent biliary drainage and blood supply; hence, it exhibits paradoxical behaviour compared with the rest of the liver lobes [6].

In the present study, there were variations in the shape of the caudate lobe of the liver, and the percentage of these variations was compared with relevant studies [Table/Fig-10,11] [1,4-8].

Author and Region ⇐ Shape of caudate lobe ↓	Sambhav K et al., [7]	Roy T and Basu R [5]	Prasad RJ et al., [4]	Contractor JB et al., [8]	Arora NK et al., [1]	Ibrahim IH [6]	Present study
	Rajasthan	India	Nepal	Gujarat	Bareilly	Egypt	Karnataka
Sample size	40	51	48	100	36	56	30
Rectangular	40.00%	37.25%	31.25%	67.00%	91.66%	73.21%	47%
Triangular	17.5%	9.8%	NA	NA	5.56%	21.43%	NA
Pear	NA	NA	NA	NA	NA	NA	30.00%
Pyriform	NA	33.33%	54.16%	21.00%	NA	NA	17%
Irregular	8%	19.60%	14.58%	12.00%	2.78%	5.36%	7%

[Table/Fig-10]: Comparison of shapes of caudate lobe with different studies [1,4-8].

Sl. no	Studies	TD	VD	APD
1	Sambhav K et al., [7]	2.48±1.00 cm	5.62±1.67 cm	NA
2	Roy T and Basu R [5]	2.45±0.54 cm	4.70±0.75 cm	1.90±0.51 cm
3	Prasad R J et al., [4]	30.05±4.93 mm	57.46 ±5.26 mm	NA
4	Contractor JB et al., [8]	28.69±7.73 mm	54.97±10.73 mm	NA
5	Present study	3.61±0.89 cm	6.78±1.15 cm	2.7±0.67cm

[Table/Fig-11]: Shows the comparison of the parameters of caudate lobe with other studies [4,5,7,8].

The percentage of other shapes varies significantly, which might point out to the reason that this difference must be due to bodily habitus of the different set of population considered for the study [9].

In the present study, the CRL ratio is comparable with other studies [Table/Fig-12] [1,4-6].

Authors	Studies	CT	RT	CRL
1	Sambhav K et al., [7]	2.48±1.0 cm	7.98±1.2 cm	0.15-0.67
2	Roy T and Basu R [5]	2.45±0.54 cm	8.1±0.93 cm	0.30
3	Prasad RJ et al., [4]	30.05±4.93 mm	90.87±12.52 mm	0.14
4	Arora NK et al., [1]	2.70 cm	11.43 cm	0.16
5	Ibrahim IH [6]	22.16-37.16 mm	73.51-115.12	0.22-0.38
6	Present study	3.61±0.89 cm	8.31±1.09 cm	0.43±0.13

[Table/Fig-12]: Shows the comparison of the parameters CT, RT and CRL ratio [1,4-6].

The midpoint of the hepatic part of the IVC is an ideal reference point as it remains the same in cases of either narrowing or widening of IVC [6].

The prevalence of an enlarged papillary process was 16.66% (less) in the present study, compared with the study of Ibrahim IH [6], which showed 42.86%. An enlarged papillary process can displace the stomach antrum and duodenum anteriorly and can simulate a retroperitoneal mass on the right-side of the body during a Computed Tomography (CT) scan [6]. The present study also had a higher percentage of accessory fissures (around 50%), which are a

potential source of misdiagnosis in either sonography or CT due to fluid collection in these fissures, or may be misdiagnosed as a cystic lesion, liver abscess, or intrahepatic haematoma [9].

Limitation(s)

The present cadaveric study was limited by its Institution-based sample, potential embalming-related measurement variations, lack of detailed demographic data, and absence of radiological or clinical correlation, which may limit the generalisability of the findings.

CONCLUSION(S)

Caudate lobe showed variable shape and size. Rectangular shape was most prevalent in present study. The present study highlighted variations in the caudate lobe in morphology and morphometry. These observations not only enrich anatomists' knowledge to facilitate anatomical teaching but also help morphologists identify new variants, embryologists identify new developmental defects, clinicians diagnose diseases, radiologists avoid misinterpretation, and surgeons plan surgery.

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