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# Morphology of the caudate lobe of the liver in a Caribbean population

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Abstract

There have been no prior reports of the morphology of the caudate lobe of the liver in a Caribbean population. We sought to document the variations in caudate surface anatomy in this population. Two independent investigators observed 56 consecutive cadaveric dissections over a period of five years. Each liver was explanted using a standardized technique. The caudate lobe was observed and standardized measurements were taken using electronic calipers. There were 56 cadavers dissected over the study period. Morphologic anomalies of the caudate lobe were present in 64% of unselected persons in this Caribbean population. These included the presence of a linguiform process (64.3%), absence of a caudate process (28.6%), presence of an inferior caudate notch (21.4%), the presence of a vertical caudate fissure (19.6%) and the presence of a papillary process (10.7%). The caudate fissure co-existed with a caudate notch in 91.6% of our population. Only 36% of persons in this Caribbean population had normal caudate lobe anatomy. These variations carry clinical significance and are of importance to any clinician treating liver diseases in persons of Caribbean extract. This population has the highest prevalence of a linguiform process (64.3%) to be reported in medical literature. It is unclear why the incidence was so high in this Caribbean population, but it is tempting to think that there might be an ethnic predisposition since the majority of cadavers in our study were of Afro-Caribbean ethnicity (91.1%).

Keywords

Hepatic, Surface, Lobe, Segment, Caribbean, Liver.

## Introduction

The caudate lobe of the liver was originally assigned the name "Lobus Exiguus" by Adrien van den Spieghel in 1622 (Van den Spieghel and Casseri, 1627). It was later renamed "Spieghel's Lobe" by Glisson et al. (1654) and as then "segment I" by Couinaud (1957).

In classic anatomic descriptions, the caudate lobe is a projection from the posterior hepatic surface that is elongated vertically (Sibulesky et al., 2013). It is bounded on the left by the fissure for the ligamentum venosum, anteriorly by the porta hepatis and on the right by the groove for the inferior vena cava (IVC) (Dodds et al., 1990;

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Sibulesky et al., 2013; Sagoo et al., 2018). Superiorly, the caudate lobe continues into the superior surface of the right upper end of the fissure for the ligamentum venosum (Dodds et al., 1990; Sibulesky et al., 2013; Sagoo et al., 2018). From the visceral surface of the liver, two parts of the normal caudate lobe are described: (1) Spieghel's lobe (Couinaud's segment I) to the left of the IVC and (2) the para-caval portion (so-called caudate process) that extends anterior to the IVC toward the right half of the liver. A thin bridge of parenchyma, known as the caudate isthmus, joins these parts. This classic anatomy is demonstrated in figures 1 and 2.

Many authors have previously described variations in the surface anatomy of the caudate lobe (Auh et al., 1984; Chang et al, 1989; Dodds et al., 1990; Sahni et al., 2000; Murakami and Hata, 2002; Sagoo and Agnihotri, 2009; Sibulesky et al., 2013; Chavan and Wabale, 2014; Sagoo et al., 2018), but to the best of our knowledge the variations have not been evaluated in a Caribbean population. This is important information for any clinical practitioners treating liver disorders in patients of Caribbean extraction.

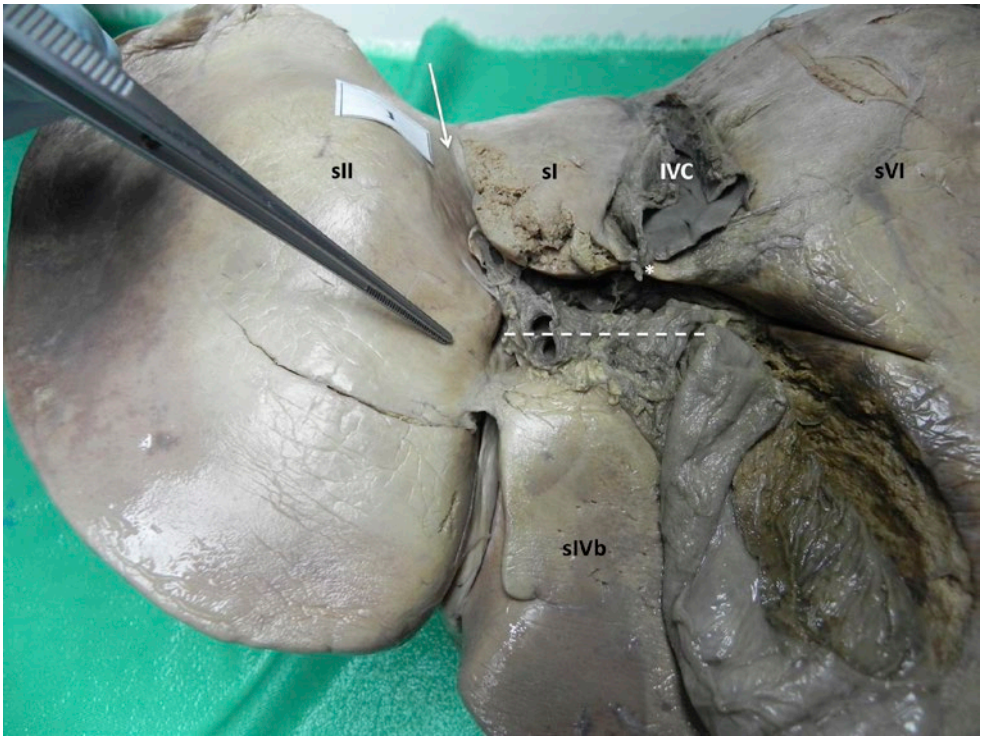


**Figure 1.** Normal caudate lobe (sI) displayed on the dissection bench, as seen from the visceral surface of the liver. The boundaries of the caudate lobe are labeled as follows: porta hepatis (broken line), fissure for sinus venosum (white arrow), groove for inferior vena cava (IVC), quadrate lobe (sIVb), segment II of left liver (sII), segment VI of right liver (sVI). The normal caudate process can be seen in this image (asterix).

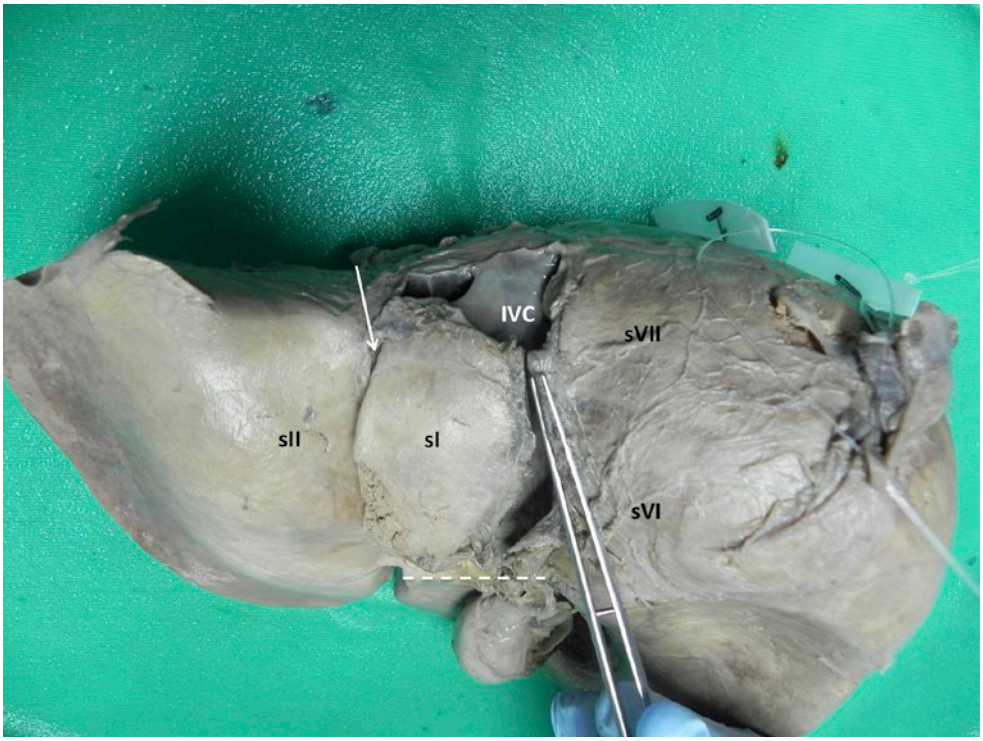


**Figure 2.** Normal caudate lobe (sI) displayed on the dissection bench, as seen from the retro-peritoneal bare area of the liver. The boundaries of the caudate lobe are marked: porta hepatis (broken line), fissure for sinus venosum (white arrow), groove for inferior vena cava (IVC), segment II of left liver (sII), segment VI of right liver (sVI) and segment VII of the right liver (sVII).

## Material and Methods

Cadaver dissections were performed to facilitate anatomical teaching for post-graduate surgical residents at the University of the West Indies in Jamaica. Two independent investigators observed all consecutive cadaveric dissections at this facility over a period of five years. Upon opening the abdomen, the liver was inspected in situ to evaluate any deviations from classic anatomy (Sibulesky et al., 2013). The hepato-duodenal ligament was transected at the upper border of the pancreas. The IVC was transected 5 cm superior and inferior to the liver surfaces. The ligamentous attachments were then dissected to completely explant each liver.

Once the liver was explanted, gross observation of each caudate lobe was carried out on the dissection bench. When observing the caudate lobe, the classic descriptions of caudate lobe anatomy were considered. We recorded the height, width and depth of the caudate lobe using electronic calipers (General Tools, MFg Co., New York, USA). Each dimension was measured independently by one of two investigators and the average measurement was used as the final dimension.

Standardized landmarks, as defined by Chavan and Wabale (2014), were used to perform measurements. The transverse diameter of the caudate lobe was measured from a vertical plane passing through the mid-point of the intra-hepatic IVC (used to mark the right extent of the caudate lobe) and the mid-point of the fissure for sinus venosum (used to make the left extent of the caudate lobe). The distance between these points was considered the width of the caudate lobe. The depth of the caudate lobe was measured from the right lateral margin of portal vein trunk at the bifurcation to the posterior-most projection from the liver. This allowed us to calculate the transverse dimension of caudate-to-right liver (CRL) ratio that is customarily measured in studies on caudate morphology (Chavan and Wabale, 2014; Arora et al., 2016).

We used standardized terminology to describe any anatomic variations that were encountered (Chang et al., 1989; Sagoo and Agnihotri, 2009, Sagoo et al., 2018) as outlined in Table 1. These variations included: caudate agenesis (Chavan and Wabale, 2014; Arora et al., 2016), the presence of a papillary process (Sagoo et al., 2018), the presence of a linguiform process (Chang et al., 1989; Sagoo and Agnihotri, 2009, Sahni et al, 2000), the presence of a caudate fissure (Auh et al., 1984) and the presence of a caudate notch (Auh et al., 1984).

Many authors also described variations in the shape of the caudate lobe (Auh et al., 1984; Kogure et al., 2000; Sahni et al., 2000; Sagoo and Agnihotri, 2009; Chavan and Wabale, 2014; Sarala et al., 2015; Arora et al., 2016). We used these standardized descriptions, as outlined in table 2, to describe the variations encountered in our dissections.

All data were entered into a Microsoft excel worksheet and then analyzed using the Statistical Package for Social Sciences (SPSS) version 14. Descriptive analyses were generated as appropriate. Data were expressed as frequencies or means, with standard deviations as appropriate. A two-tailed P value was calculated for variables of interest in each group using Fisher's exact test. Continuous variables in each group were compared using paired T-Test. A P value $<0.05$ was considered statistically significant.

## Results

There were 56 cadavers dissected over the study period and 20 (36%) demonstrated classic anatomy of the caudate lobe. In these cadavers, the caudate had a mean height of 52.6 mm (standard deviation +/-11.13), mean width of 32.17 mm (standard deviation ± 6.30) and mean antero-posterior diameter of 29.25 mm (standard deviation ± 9.69). The CRL ratio ranged from 0.21-0.48 (mean 0.34; standard deviation ± 0.066). When the mean CRL ratios were compared between cirrhotic and non-cirrhotic livers, we found no statistically significant difference between the groups (0.373 vs 0.330 respectively; P 0.2264; 95%CI -0.1126 to 0.0276). A caudate process was present in 40 (71.4%) cadavers.

There were variations from classic anatomy in 36 (64%) cadavers. There were no cadavers with caudate agenesis. Sixteen (28.6%) cadavers did not have a normal caudate process present.

A papillary process was present in 6 (10.7%) cadavers (figure 3). The papillary processes had a mean length of 21.4 mm (standard deviation ± 6.7) and mean thickness of 15.9 mm (standard deviation ± 5.5).

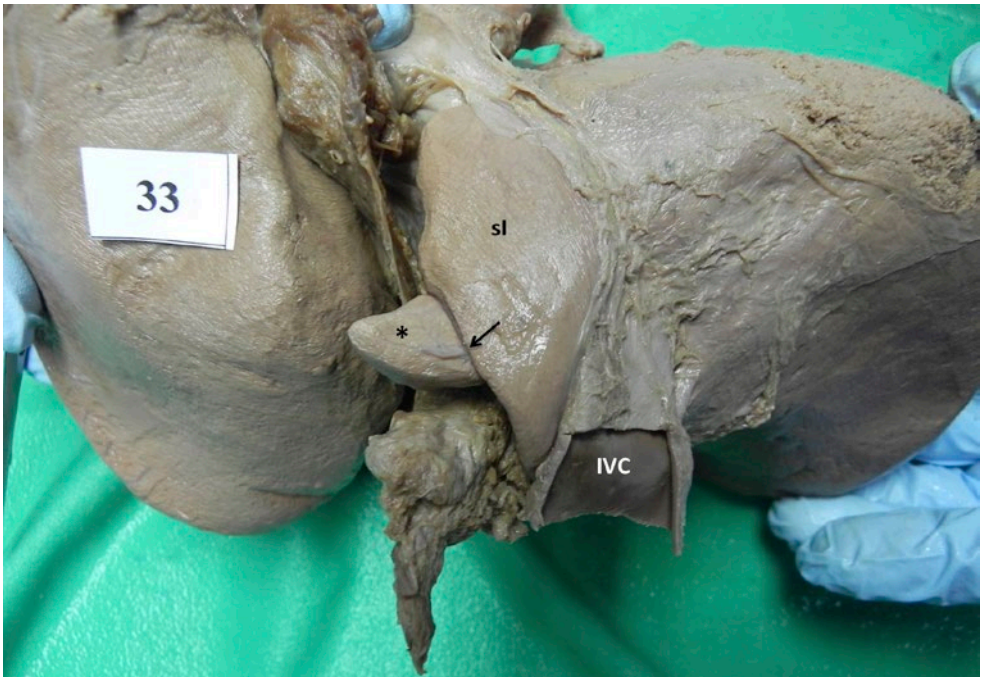


**Figure 3.** A well-developed papillary process (asterix) is seen extending from the infero-medial part of the caudate lobe proper (sl) and passing to the left into the region of the superior recess of the omental bursa. A caudate notch is also present in this specimen (arrow).

A linguiform process was identified in 36 (64.3%) cadaveric livers, covering the retro-hepatic IVC to varying degrees (figures 4, 5). The linguiform processes had a mean thickness of 2.75 mm (standard deviation ± 0.14).

There were 12 (21.4%) cadavers with (horizontal) caudate notches at the inferior border of the caudate (figures 3,4,6). The caudate notches had a mean depth of 10.3 mm (standard deviation ± 7.3). Eleven (19.6%) cadavers also had well-defined (vertical) caudate fissures that appeared to bisect the caudate lobe (figure 7). The vertical fissures had a mean height of 16.5 mm (standard deviation ± 1.52) and a depth of 6.52 mm (standard deviation ± 3.28).

A few caudate lobes were irregularly shaped as outlined in table 2. We encountered one shape (1.8%) for which we could not find an existing description. We could best describe it as "fish-tailed" (figure 8) and we have not seen a comparable finding in the literature.

## Discussion

Although variations in the caudate surface anatomy have been described (Auh et al., 1984; Chang et al, 1989; Dodds et al., 1990; Sahni et al., 2000; Murakami and Hata,

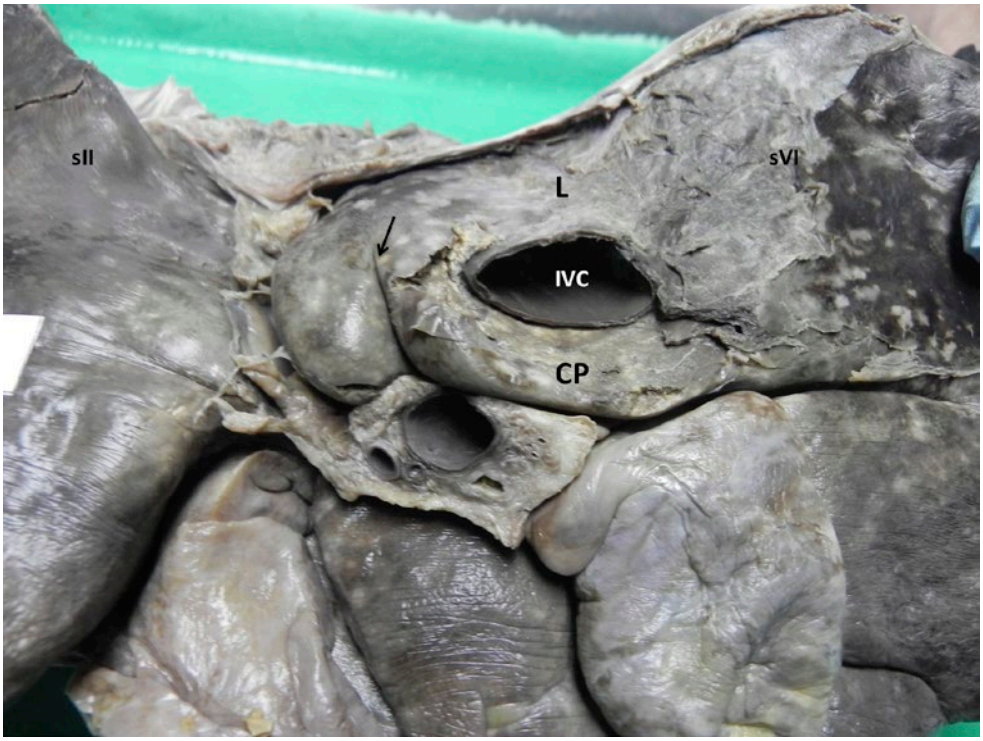


**Figure 4.** A well-developed linguiform process (L) that convers the groove for the inferior vena cava (IVC), completely turning it into a tunnel. A well-developed caudate process (CP) and caudate notch (arrow) are also present in this specimen.

2002; Sagoo and Agnihotri, 2009; Sibulesky et al., 2013; Chavan and Wabale, 2014, Sagoo et al., 2018), there are no existing data on variations in a Caribbean population. We found that classic anatomy of the caudate lobe was only present in 36% of unselected cadavers in this Caribbean population. The mean dimensions of the caudate lobe were generally comparable to existing literature.

An important clinical relationship is the ability to diagnose early degenerative liver conditions using the CRL ratio. Essentially, due to the independent vascular supply and biliary drainage, the caudate lobe is considered an independent part of the liver. Consequently, there will be compensatory caudate hypertrophy when the remaining liver is affected by cirrhosis. Therefore, the CRL ratio will increase to a value of greater than or equal to 0.65 in cirrhotic livers (Giorgio et al., 1986; Awaya and Mitchell, 2002; Chavan and Wabale, 2014 Arora et al., 2016). Most of the reports on caudate anatomy document the CRL ratio (Chavan and Wabale, 2014; Arora et al., 2016), but these are generally not clinically useful unless the absence / presence of cirrhotic change is noted. Chavan and Wabale (2014) documented a CRL ratio ranging between 0.28 and 0.46, Sahni et al (2000) documented a range of CRL ratios of 0.23-0.40 and Arora et al (2016) documented a CRL ratio range of 0.15-0.58 (average


**Figure 5.** A normal caudate lobe in which a linguiform lobe is absent. The groove for the IVC is not covered, leaving the IVC exposed. In this case, the IVC is accessible intra-operatively without dissection of linguiform parenchyma.

0.36). The range of CRL values in our study were generally comparable with previous ones. But in order for our study to be clinically relevant, we divided the livers into two groups: cirrhotic and non-cirrhotic livers. We found no statistically significant difference between the mean CRL in cirrhotic livers compared to non-cirrhotic livers.

In 64% unselected cadavers in this Caribbean population, variant anatomy of the caudate lobe was encountered. These included the following.

## Papillary process

Sagoo et al (2018) proposed that a papillary process should be considered present when there was a prominent elevation, sometimes separated from the caudate lobe proper by a notch and separated by the groove for the ligamentum venosum from the left lobe of the liver and by the porta hepatis inferiorly. Using these definitions, we found the papillary process in 10.7% of our study population. The prevalence of the papillary process varies widely, from as low as 0% at Ahmednagar in west-central India (Chavan and Wabale, 2014) to 52% at London in the United Kingdom (Sagoo et al., 2018). The prevalence in this Caribbean population more closely resembled the prevalence at Bareilli in North India (Arora et al., 2016).


**Figure 6.** A caudate notch (arrow) is seen in this specimen. It is a groove on the visceral surface (inferior border) of the caudate lying in a horizontal plane and separating caudate proper (sl) from the para-caval / caudate process (asterix).

The presence of a papillary process has clinical significance because it could be mistaken for extra-hepatic masses or enlarged porta-hepatis nodes (Auh et al., 1984) and it may also mimic a pancreatic tumor if it extends to the left and displaces the stomach anteriorly (Auh et al., 1984). It may also interfere with the performance of a hepato-caval shunt (Heloury et al., 1988). Additionally, depending on its size, a papillary process may prevent surgeons accessing the structures in the porta hepatis when performing anatomic major liver resections. Therefore, it is important for providers treating patients with liver diseases to be aware of the presence of a papillary process in 10.7% of unselected persons with no obvious chronic liver diseases.

## Linguiform process

The prevalence of a linguiform process in this population (64.3%) was greater than expected. Mamatha et al (2014) reported finding a linguiform process in 4% of persons from southwest India. Comparatively, Sagoo et al (2018) reported 40% prevalence in Caucasian populations from London. The highest prevalence was 56.7% in an observational study of 30 Parisian cadavers (Heloury et al., 1988).

It is unclear why the incidence was so high in this Caribbean population. It is tempting to think that there might be an ethnic predisposition since the major-

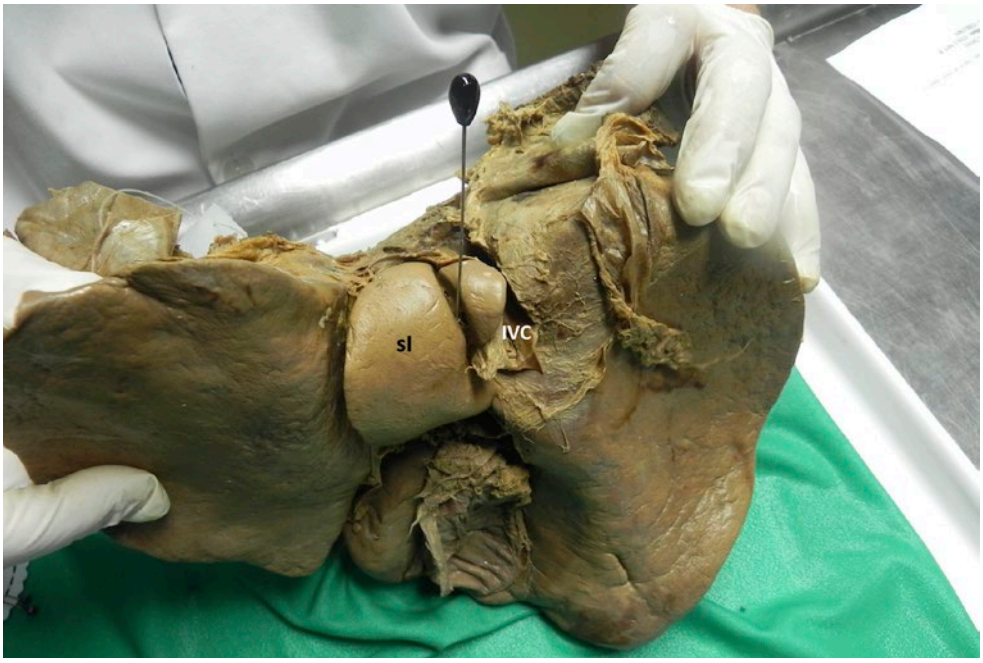


**Figure 7.** A caudate fissure (marked by black pin) is seen in this specimen, running in a vertical plane on the caudate proper (sl). In this image, the caudate fissure is continuous with a caudate notch inferiorly that is in a horizontal plane.

ity of cadavers in our study were of Afro-Caribbean ethnicity (91.1%). Most of the reports in print in the literature study mostly Indian (Sahni et al., 2000; Joshi et al., 2009; Sagoo et al., 2009; Chavan and Wabale, 2014; Mamatha et al., 2014; Sarala et al., 2015; Arora et al., 2016) and Caucasian populations (Heloury et al., 1988; Sagoo et al., 2018). We did not encounter any other reports that documented the prevalence of the linguiform process in predominantly black populations.

Regardless of the reason for the high prevalence, the linguiform process is an important feature because it makes access to the retro-hepatic IVC difficult during liver resections. A linguiform process is also disadvantageous during trauma operations because it makes control and repair of the IVC difficult in patients with retro-hepatic IVC injuries.

### Absence of caudate process

The caudate process is a bridge of parenchyma that extends anterior to the IVC toward the right half of the liver, joined to the caudate proper by a thin bridge of parenchyma known as the caudate isthmus. Occasionally, the caudate process may be elevated and form a relatively wide roof over the porta hepatis (Sagoo et al., 2018). The caudate process is a normal anatomic feature, but it was absent in 28.6% of unselected cadavers in our study.


**Figure 8.** A "fish-tail" caudate lobe.

The prevalence of the caudate process varies widely, from as low as 9% in at Karnataka in south-west India (Sarala et al., 2015) to 100% at Bareilly in Northern India (Arora et al., 2016). In our population, it was present in 71.4% of unselected cadavers. It is important to be aware of the presence of the caudate process because it may also cause diagnostic confusion, being mistaken for neoplastic disease on cross sectional imaging (Auh et al., 1984). In addition, during major anatomic liver resections, the presence of a well-developed caudate process would increase the technical difficulty of performing the hanging maneuver, where a surgical instrument is passed in the potential space anterior to the retro-hepatic IVC (Cawich et al., 2015)

### Inferior groove / notch of caudate

Occasionally, instead of a flat bridge of parenchyma (caudate isthmus) joining the caudate proper and the caudate process, a horizontal groove (the caudate notch) separates the caudate process from the caudate lobe proper on the visceral surface of the liver (Sagoo et al., 2018). The presence of an inferior caudate notch varies widely, with a reported prevalence ranging from 9% at Chandigarh in Northern India (Sahni et al., 2000) to 100% at Karnataka in Southwest India (Sarala et al., 2015). A caudate notch was seen in 21.4% of unselected cadavers in our population.

Kogure et al (2000) performed cast studies to study the notch at the inferior border of the caudate lobe and suggested that the notch corresponds to the presence of an underlying hepatic vein. Couinaud (1989) also reported that in 35% of cases the hepatic vein runs in this fissural plane. Therefore, the caudate notch may be used as a landmark to separate the caudate proper from the para-caval portions and to identify the presence of an underlying vein during liver resections involving the caudate lobe. Unfortunately, the notch is inconsistent and its prevalence reduces with age (Sahni et al., 2000).

### Caudate fissure

The caudate fissure is a well-defined fissure in a vertical plane separating the caudate proper from the remainder of the liver (Auh et al., 1984). There are wide variations in the reported prevalence of a caudate fissure, ranging from 3.7% at Vadodara in Western India (Chaudhari et al., 2017) to 32% at Maharashtra in West-Central India (Joshi et al., 2009). The prevalence of the caudate fissure in our population was in between at 19.6%. Often, but not always, the caudate fissure co-exists with the caudate notch. We found this relationship in 91.6% of our cadavers.

Again, there is inconsistent terminology. For example, Singh et al. (2013) reported on a male cadaver in whom the caudate lobe was "*divided into two lobes by a fissure having length of 2.5 cm along with a notch on superior surface of caudate lobe and another fissure of length, 2.0 cm located in inferiorly placed caudate lobe*" Although they described this as a duplicated caudate lobe, the images in their published case report appear to show a bi-cornuate caudate with an inferior caudate notch (groove) continuous with a deep vertical fissure as described above.

## Conclusions

There are morphologic anomalies of the caudate lobe in 64% of unselected persons in this Caribbean population. These included the presence of a linguiform process (64.3%), absence of a caudate process (28.6%), presence of a caudate notch (21.4%), the presence of a vertical caudate fissure (19.6%) and the presence of a papillary process (10.7%).

This population had the highest prevalence of a linguiform process (64.3%) to be reported in medical literature. It is unclear why the incidence was so high in this Caribbean population, but it is tempting to think that there might be an ethnic predisposition since the majority of cadavers in our study were of Afro-Caribbean ethnicity (91.1%).

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The authors confirm that there are no conflicts of interest to disclose.

## Authors' contributions

MG, SOC, RS, NP and VN conceptualized the study. MG and RS carried out observations and collected data; MG, SOC, RS, NP, and VN checked the manuscript and endorsed the academic content.

## References

Arora N.K., Srivastava S., Haque M., Khan A.Z., Singh K. (2016) Morphometric study of caudate lobe of liver. Ann. Int. Med. Dent. Res. 2: 275-79.

Auh Y.H., Rosen A., Rubenstein W.A., Englel I.A., Whalen J.P., Kazam E. (1984) CT of the papillary process of the caudate lobe of the liver. Am. J. Roentgenol. 142: 535-538.

Awaya H., Mitchell D. (2002) Cirrhosis: Modified caudate-right lobe ratio. Radiology 224: 769-774.

Cawich S.O., Thomas D., Ragoonanan V., Naraynsingh V. (2015) The hanging manoeuver to complete liver resection for a locally advanced angiosarcoma: A case report. Int. J. Surg. Case Rep. 16: 52-55.

Chang R.W.H., Sun S.Q., Yen W.W.C. (1989) An applied anatomical study of the ostia venae hepaticae and the retrohepatic segment of the inferior vena cava. J. Anat. 164: 41-47.

Chaudhari H.J., Ravat M.K., Vaniya V.H., Bhedi A.N. (2017) Morphological study of human liver and its surgical importance. J. Clin. Diagn. Res. 11: 9-12.

Chavan N.N., Wabale R.N. (2014) Morphological study of caudate lobe of liver. Indian J. Bas. Appl. Med. Res. 3: 204-211.

Couinaud C. (1957) The Liver. Anatomical and Surgical Investigations. Le Foie. Études Anatomiques et Chirurgicales. Paris, Masson.

Couinaud C. (1989) Posterior or dorsal liver. In: Couinaud C. Surgical Anatomy of the Liver Revisited. Paris, Couinaud. Pp. 123-134.

Dodds W.J., Erickson S.J., Taylor A.J., Lawson T.L., Stewart E.T. (1990) Caudate lobe of the liver: anatomy, embryology and pathology. Am. J. Roentgenol. 154: 87-93

Giorgio A., Amoroso P., Lettieri G., Fico P., de Stefano G., Finelli L., Scala V., Tarantino L., Pierri P., Pesce G. (1986) Value of caudate to right lobe ratio in diagnosis with ultrasound. Radiology 161: 443-445.

Glisson F. (1654) Anatomia Hepatis (Anatomy of the Liver). Vol. 3. Cambridge Wellcome. London,

Heloury Y., Leborgne J., Rogez J.M., Robert R., Barbin J.Y., Hureau J. (1988) The caudate lobe of the liver: Review of clinical anatomy. Surg. Radiol. Anat. 10: 83-91.

Joshi S.D., Joshi S.S., Athavale S.A. (2009) Some interesting observations on the surface features of the liver and their clinical implications. Singapore Med. J. 50: 715-719.

Kogure K., Kuwano H., Fujimaki N., Makuuchi M. (2000) Relation among portal segmentation, proper hepatic vein and external notch of the caudate lobe in the human liver. Ann. Surg. 231: 223-228.

Mamatha Y., Murthy C.K., Prakash B.A. (2014) Study on morphological surface variations in human liver. Int. J. Health Sci. Res. 4: 97-102.

Murakami G., Hata F. (2002) Human liver caudate lobe and liver segment. Anat.. Sci Int. 77: 211-224.
Sagoo M.G., Agnihotri G. (2009) The retrohepatic segment of inferior vena cava and the ostia venae hepaticae in a Northwest Indian population. Braz. J. Morphol. Sci. 26: 141-144.
Sagoo M.G., Aland R.C., Gosden E. (2018) Morphology and morphometry of the caudate lobe of the liver in two populations. Anat. Sci. Int. 93: 48-57.
Sahni D., Jit I., Sodhi L. (2000) Gross anatomy of the caudate lobe of the liver. J. Anat. Soc. India 49: 123-126.
Sarala H.S., Jyothilakshmi T.K., Shubha R. (2015) Morphological Variations Of Caudate Lobe Of The Liver And Their Clinical Implications. Int J Anat Res 3: 980-983.
Sibulesky L. (2013) Normal liver anatomy. Clin. Liver Dis. 2: 1-3.
Singh R., Singh K., Man S. (2013) Duplicate caudate lobe of liver with oblique fissure and hypoplastic left lobe of liver. J. Morphol. Sci. 30: 309-311.
van den Spieghel A., Casseri G.C. (1627) De Humani Corporis Fabrica Libri Decem. Venice, Evangelista Deuchino.