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ORIGINAL ARTICLE

Human liver umbilical fissure variants: pons hepatis (ligamentum teres tunnel)

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Abstract

Purpose In the classical description of normal liver anatomy, the umbilical fissure is a long, narrow groove that receives the ligamentum teres hepatis. The pons hepatis is an anatomic variant, where the umbilical fissure is converted into a tunnel by an overlying bridge of liver parenchyma. We carried out a study to evaluate the existing variations of the umbilical fissure in a Caribbean population.

Methods We observed all consecutive autopsies performed at a facility in Jamaica and selected cadavers with a pons hepatis for detailed study. A pons hepatis was considered present when the umbilical fissure was covered by hepatic parenchyma. We recognized two variants: an open-type (incomplete) pons hepatis in which the umbilical fissure was incompletely covered by parenchyma ≤ 2 cm in length and a closed type (complete) pons hepatis in which the umbilical fissure was covered by a parenchymal bridge > 2 cm and thus converted into a tunnel. We measured the length (distance from transverse fissure to anterior margin of the parenchymatous bridge), width (extension across the umbilical fissure in a coronal plane) and thickness (distance from the visceral surface to the hepatic surface measured at the mid-point of the parenchymal bridge in a sagittal plane) of each pons hepatis. A systematic literature review was also performed to retrieve data from relevant studies. The raw data from these retrieved studies was used to calculate the global point prevalence of pons hepatis and compared the prevalence in our population.

Results Of 66 autopsies observed, a pons hepatis was present in 27 (40.9%) cadavers. There were 15 complete variants, with a mean length of 34.66 mm, mean width of 16.98 mm and mean thickness of 10.98 mm. There were 12 incomplete variants, with a mean length of 17.02 mm, width of 17.03 mm and thickness of 9.56 mm. The global point prevalence of the pons hepatis (190/5515) was calculated to be or 3.45% of the global population.

Conclusions We have proposed a classification of the pons hepatis that is reproducible and clinically relevant. This allowed us to identify a high prevalence of pons hepatis (41%) in this Afro-Caribbean population that is significantly greater than the global prevalence (3.45%; $P < 0.0001$).

Keywords Liver · Anatomy · Variations · Tunnel · Ligamentum teres

Introduction

In classical descriptions, there are three fissures on the visceral surface of the liver: transverse, sagittal and umbilical fissures [10, 43, 47]. The umbilical fissure, sometimes called the fissure for ligamentum teres [10] or Rex recess [38], is a long, narrow groove that normally receives the ligamentum teres hepatis (Fig. 1). There have been reports of anatomic variants, where the umbilical fissure is converted into a tunnel by an overlying bridge of liver parenchyma. Many names have been ascribed to this variant, including pons hepatis [5, 16, 18, 25, 33, 35, 40, 46], absent fissure for ligamentum

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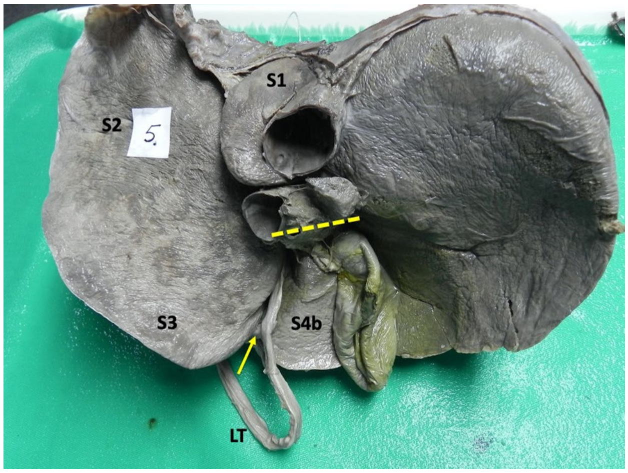

Fig. 1 View of the visceral surface of the liver demonstrating classic anatomic features. The umbilical fissure (arrow) divides the left hemi-liver into a left medial section, comprised of segments IVa and IVb (S4b), and a left lateral section comprised of segments II (S2) and III (S3). The umbilical fissure is a long, deep groove that receives the ligamentum teres hepatis (LT) at the anterior margin of the liver and extends posteriorly to the left lateral end of the transverse fissure (broken line)

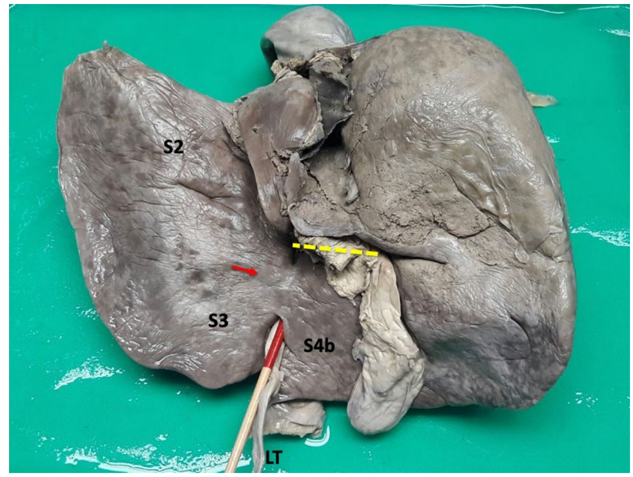

Fig. 2 Probe has been passed beside the ligamentum teres hepatis (LT) and enters into a tunnel created by a parenchymal bridge (red arrow) that obliterates the umbilical fissure, effectively joining segments III (S3) and IVb (S4b) and separating it from the transverse fissure (broken line)

teres [1, 15, 39, 41], absent ventral component of left sagittal fissure [8], absent quadrate lobe [3, 20, 39, 41], tunnel for ligamentum teres [20, 31, 32, 45], pont hepatique [49, 51] and peritoneal tunnel of the porta hepatis [50]. Regardless of the nomenclature, it is an important anatomic feature that surgeons must be familiar with when performing major liver resections.

It has already been established that in the Caribbean diaspora, there are many variations in liver gross morphology [10–12, 14, 21], venous drainage [13], arterial supply [23, 24] and ductal anatomy [44]. However, there has been no prior report on umbilical fissure variants in persons of Caribbean descent. Therefore, we carried out a study to evaluate the existing variations of the umbilical fissure in a Caribbean population.

Materials and methods

Cadaver dissections for anatomical teaching at the University of the West Indies were observed over a period of 5 years. Two independent investigators observed all consecutive cadaveric dissections. Each liver was inspected in situ upon opening the abdomen and then explanted for close examination on the dissection bench.

The investigators used classic anatomic descriptions to define "normal anatomy" of the liver [10, 43, 47]. Figure 1 illustrates the "normal anatomy", where the visceral liver surface is divided into four areas, roughly in the shape of the letter "H" by the three fissures, gallbladder bed and inferior vena cava [10, 43, 47]. The left hemi-liver is divided into a left lateral section (segments II/III) and left medial section (segments IVa/IVb) by the umbilical fissure [10]. The normal umbilical fissure is a long, deep groove that receives the ligamentum teres hepatis at the anterior margin of the liver and extends posteriorly to the left lateral end of the transverse fissure. In classic descriptions, it is an open furrow that is not covered by liver parenchyma [10, 43, 47].

In medical literature, many names, descriptions and definitions have been applied to the anatomic variation in which the umbilical fissure is converted into a tunnel by an overlying bridge of liver parenchyma (Fig. 2). However, a standardized robust definition was not encountered. For the purposes of our study, a pons hepatis was considered present when the umbilical fissure was covered by hepatic parenchyma. We recognized two variants: an open-type (incomplete) pons hepatis in which the umbilical fissure was incompletely covered by parenchyma ≤ 2 cm in length (Fig. 3) and a closed type (complete) pons hepatis in which the umbilical fissure was covered by a parenchymal bridge > 2 cm and thus converted into a tunnel (Fig. 4). We used this definition, because it was thought to have clinical significance, since a parenchymal bridge > 2 cm is more likely to be visible on imaging and would render some interventional procedures difficult.

Using these definitions, we identified all cadavers with a pons hepatis and selected them for detailed evaluation on the dissection bench. Relevant measurements were taken using electronic calipers (Mitutoyo ABS Digimatic Caliper Mitutoyo, USA) by two independent investigators. The average measurement was used as the final dimension. The following

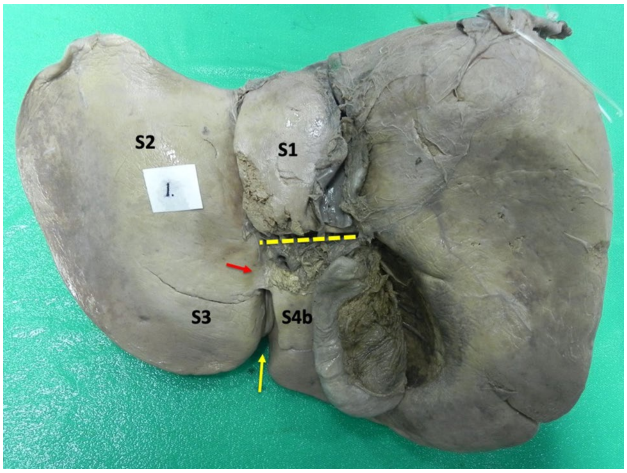

Fig. 3 Incomplete-type pons hepatis. The ligamentum teres hepatis can be seen lying in the umbilical fissure at the liver edge (yellow arrow). The pons hepatis (red arrow) is a parenchymal bridge partially covering the umbilical fissure before it joins the transverse fissure (broken line)

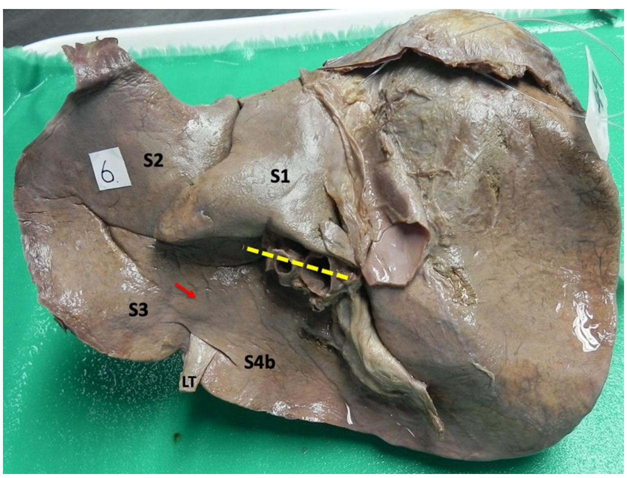

Fig. 4 Complete-type pons hepatis (red arrow). The umbilical fissure is completely covered by a parenchymal bridge joining segments III (S3) and IVb (S4b). The ligamentum teres hepatis (LT) enters a tunnel formed by the complete-type pons hepatis and is not visible en-route to the transverse fissure (broken line). Note the morphologic anomaly of the enlarged, "fish-tailed" caudate lobe (S1) that encroaches upon the transverse fissure

data were recorded: length (distance from transverse fissure to anterior margin of the parenchymatous bridge), width (extension across the umbilical fissure in a coronal plane) and thickness (distance from the visceral surface to the hepatic surface measured at the mid-point of the parenchymal bridge in a sagittal plane).

We then conducted a systematic literature search using medical archiving platforms, including Pubmed, Medline, Google Scholar and the Cochrane database of Systematic Reviews. We used the following search terms: "pons hepatis", "absent fissure for ligamentum teres", "obliterated fissure for ligamentum teres", "absent sagittal fissure", "absent quadrate lobe" and "tunnel for ligamentum teres. All relevant studies were retrieved and the data and images reviewed in detail. We used the raw data from these retrieved studies to calculate the global prevalence of pons hepatis and compared the prevalence in our population.

Results

There were 66 cadavers at a mean age of 68 years (range 60–85) dissected over the study period and a pons hepatis was present in 27 (40.9%) cadavers. Of these, there were 15 complete variants, with a mean length of 34.66 mm (range 21.22–66.43; median 29.45; SD ± 13.10), mean width of 16.98 mm (range 7.88–47.75; median 10.47; SD 12.35) and mean thickness of 10.98 mm (range 6.3–20.15; median 9.85; Mode 3.60). Table 1 documents the individual variations encountered.

There were 12 incomplete variants, with a mean length of 17.02 mm (range 10.45–19.88; median 17.41; SD ± 2.53), width of 17.03 mm (range 6.35–47.75; median 10.10; SD ± 14.32) and thickness of 9.56 mm (range 4.63–13.38; median 9.66; SD ± 3.05). Table 2 documents the individual variations encountered.

Discussion

The ligamentum teres hepatis, also known as the round ligament of the liver [31], contains the obliterated remnant of the umbilical vein. This vein delivered nutrient and oxygen rich placental blood to the foetal left portal vein in-utero [31]. The obliterated remnant lies in the free edge of the falciform ligament and then enters the umbilical fissure of the liver [10, 14, 31, 43, 47, 48]. The umbilical fissure is a "normal" feature of the visceral liver surface that extends from the free edge of the liver to the left margin of the transverse fissure [10, 14, 31, 43, 47, 48].

In this paper we have evaluated anatomic variants, where the umbilical fissure was covered by hepatic parenchyma—pons hepatis. Although there are pre-existing published reports of this anatomic variant, the inconsistent terminology used in the literature makes data analysis and comparisons difficult. This variant has been termed pons hepatis [5, 16, 18, 25, 33, 35, 40, 46, 48], absent fissure for ligamentum teres [1, 15, 39, 41, 48], absent ventral component of left sagittal fissure [8], absent quadrate lobe [3, 20, 39, 41], tunnel for ligamentum teres [20, 31, 32, 45], pont hepatique [49, 51] and peritoneal tunnel of the porta hepatis [50]. We proposed a classification of the pons hepatis that bears

Table 1 Cadavers with complete variants

Cadaver no.	Length (mm)	Width (mm)	Thickness (mm)	Special observations
1	50.76	10.47	7.40	None
2	66.43	12.14	8.90	None
3	43.00	9.46	11.60	None
4	43.62	15.75	13.50	Linguiform process
6	21.22	10.47	9.70	Fish tailed caudate lobe Absent Rouviere's sulcus
8	22.50	9.72	9.20	Caudate notch
10	24.75	7.88	8.80	None
11	40.24	23.2	5.30	None
12	43.23	13.68	15.66	Rouviere's sulcus absent
13	25.69	7.91	11.60	None
14	29.45	8.83	9.90	Fish tailed caudate
15	21.41	8.32	13.40	None
16	25.98	48.68	20.15	Papillary process S3
17	25.19	47.75	9.75	Caudate notch
18	36.35	53.46	9.85	Caudate notch

Table 2 Cadavers with incomplete variants

Cadaver no.	Length (mm)	Width (mm)	Thickness (mm)	Special observations
5	16.17	13.49	9.70	None
7	10.45	12.35	12.40	None
9	16.91	7.25	11.50	None
19	19.00	10.47	9.62	Variant: fissure at segment V Rouviere's sulcus is absent
20	18.40	6.35	6.61	Rouviere's sulcus is absent
21	18.90	9.72	13.38	Variant: fissure at segment V
22	15.60	38.68	5.91	None
23	17.90	47.75	4.63	None
24	15.50	33.46	7.31	None
25	16.70	9.72	12.34	Variant: fissure at segment V
26	19.88	7.25	7.98	None
27	18.88	7.88	13.29	None

clinical relevance. Using these standardized definitions, we identified a pons hepatis in 41% of unselected cadavers in this Afro-Caribbean population.

To compare the point prevalence of the pons hepatis in our population with the global point prevalence, we conducted a systematic literature search using medical archiving platforms, including Pubmed, Medline, Google Scholar and the Cochrane database of Systematic Reviews. We used the following search terms: "pons hepatis", "absent fissure for ligamentum teres", "obliterated fissure for ligamentum teres", "absent saggital fissure", "absent quadrate lobe" and "tunnel for ligamentum teres." We retrieved 25 articles that reported on the pons hepatis [1, 3, 5, 8, 15, 16, 18, 20, 25, 27, 30–35, 39–42, 45, 46, 49–51]. Table 3 summarizes the results of these studies. Many of the studies used different terminologies, but detailed review of the published descriptions and photographs within the published articles allowed us to extrapolate data for comparisons. The use of different terminologies makes direct comparisons difficult. Therefore, we propose that standardized descriptions should be defined, possibly those proposed within this paper.

The point prevalence of a pons hepatis in 41% of unselected cadavers in our population is, to the best of our knowledge, the highest reported to date. The prevalence in published literature ranged from 0.3% in Italy [34] to 30% in North India [25]. In one report, Chin et al. [16] reported a pons hepatis in 36.4% of 33 cadavers. However, in their study methodology two definitions of pons hepatis were used interchangeably. In their study methodology, they defined the pons hepatis as "hepatic tissue that surrounds the inferior vena cava" [16], but their published results are accompanied by images of a hepatic bridge covering the umbilical fissure

Table 3 Overview of studies describing the presence of pons hepatis

Author	Terminology used	Country	Study size (*n*)	Pons Hepatis, *n* (%)	Complete, *n* (%)	Incomplete, *n* (%)
Sato et al., 1998 [42]	"High insertion of round ligament"	Japan	1802	50 (2.8%)	NS	NS
Orlando et al., 2000 [34]	"High insertion of round ligament"	Italy	2650	8 (0.3%)	NS	NS
Aktan et al., 2001 [3]	"Hypoplasia /absence of left lobe" (used to describe complete variant "fusion of left and quadrate lobes" (used to describe incomplete variant)	India	437 (383 CT + 54 cadavers)	22 (5%)	14 (3.2%) [E]	8 (1.8%) [E]
Sanli et al., 2006 [39]	"Absence of fissure for round ligament" "Round ligament embedded inside liver parenchyma"	Turkey	1	1	1[E]	0
Joshi et al., 2009 [25]	"Pons hepatis" "Absent caudate lobe" and "completely bridging" (used to describe complete variant)[E]	North India	90	27 (30%)	25 (27.8%)	2 (2.2%)
Aysin et al., 2009 [8]	"Round ligament embedded in liver parenchyma" "High insertion of round ligament" "Liver not divided into lobes on visceral surface"	Turkey	1	1	1 [E]	0
Abdullahi et al., 2010 [1]	"Absence of Left Lobe"		1	1 [E]	1 [E]	0
Ebby et al., 2012 [20]	"Tunnel obscuring normal fissure for ligamentum teres" "Complete absence of caudate lobe"	United Arab Emirates	1	1	NS	NS
Nayak et al., 2013 [31]	"Tunnel for ligamentum teres"	South India	1	1	1[E]	0
Muktyaz et al., 2013 [29]	"Absent fissure for ligamentum teres"	North India	41	9.7%	NS	NS
Satheesha et al., 2013 [41]	"absent fissure for ligementum teres" "absent quadrate lobe"	North India	1	1	1 [E]	0
Patil et al., 2014 [35]	"Pons Hepatis" (used to describe incomplete variant) "absent fissure for ligamentum teres" (used to describe complete variants)	North India	50	7 (14%)	2 (4%) [E]	5 (10%) [E]
Khedekar et al., 2014 [27]	"Abnormal connection between left and caudate lobes"	Central India	50	7 (14%)	NS	NS
Saritha et al., 2015 [40]	"Pons hepatis"	Central India	50	2 (4%)	NS	NS

Table 3 (continued)

Author	Terminology used	Country	Study size (*n*)	Pons Hepatis, *n* (%)	Complete, *n* (%)	Incomplete, *n* (%)
Nune et al., 2015 [32]	"Tunnel for ligamentum teres"	Central India	2	1	NS	NS
Chaudhari et al., 2017 [15]	"Pons hepatis" (used to describe incomplete variant) "Absent fissure for ligamentum teres" (used to describe complete variant)	Central India	80	10 (12.5%)[E]	1 (1.25%)	9 (11.2%)
Singh et al., 2018 [45]	"Tunnel for ligamentum teres"	North India	40	1 (2.5%)	1 (2.5%)[E]	0
Singh et al., 2019 [46]	"Pons Hepatis"	South India	70	16 (22.9%)	NS	NS
Anbumani et al., 2020 [5]	"Pons Hepatis" "Tissue of pons hepatis left no boundaries for quadrate lobe" (used to describe complete variant)	South India	30	5 (16.7%)	3 (10%)	2 (6.7%)
Chin et al., 2018 [16]	"Pons Hepatis" *	U.S.A	33	12 (36.4%)	NS	NS
Onitsuka et al., 2003 [33]	"Pons Hepatis"	Japan	125	31 (25%)	NS	NS
Donmez et al., 2009 [18]	"Pons Hepatis"	Turkey	2	2	1	1

NS not specified, *ND* not defined, *CLP* Caudate linguiform process, *E* extrapolated from raw data and/or published images

*This study used two different definitions of pons hepatis interchangeably

as well as images of hepatic tissue behind the vena cava. It appeared that they used these definitions interchangeably and likely confused the terms "pons hepatis" with "ponticulus hepatis" (presence of a parenchymal bridge over the fossa for the IVC) [14]. Therefore, we did not include the results from this paper to calculate the global point prevalence of the pons hepatis.

The global point prevalence of the pons hepatis was calculated with raw data extracted from existing published case series. Individual case reports were not included in the calculations. The point prevalence was defined as the total number of individuals with a pons hepatis divided by the sum of the total number of individuals in each study (Table 4). The global point prevalence of the pons hepatis was calculated to be 190/5515 or 3.45% of the global population.

The prevalence of the pons hepatis in our population (40.9% vs 3.45%; $P < 0.0001$) was significantly greater than the global point prevalence. It is tempting to think that there may be a genetic predilection, since 64 (97%) of our cadavers were from the African diaspora, but we concede that our study methodology did not allow us to scientifically determine whether this was a cause. We had no data for comparison, because no other published studies examined the African diaspora. This may be an area for further study.

It is important for clinicians to be aware of the pons hepatis. Firstly, it may be the site of disease. Onitsuka et al. [33] reported a case of a patient initially mis-diagnosed with an extra-hepatic mass on ultrasound and CT scans, who actually had a final diagnosis of metastatic carcinoma arising from the pons hepatis. Kollmar et al. [28] also noted that fissure variations influenced metastasis implantation and growth in experimental models.

Secondly, radiologists who are unaware of its presence may mistake the pons hepatis for pathologic lesions such as liver metastases [6, 10], haematomas [7], hepatic pseudo-lesions of Sappey veins [22], primary liver neoplasms [7] or neoplasms of the ligamentum teres [2, 9, 36].

Thirdly, it may reduce reliability of diagnostic imaging [19, 48]. Cho et al. [17] reported a series of cases in which the presence of air trapped in the umbilical fissure was a reliable and early indicator of a pneumoperitoneum. The complete-type pons hepatis would prevent air from accumulating and prevents radiologists from identifying a pneumoperitoneum in this manner. In addition, a pons hepatis may limit pre-operative ultrasound evaluation of the umbilical segment of the left portal vein in the umbilical fissure [37] during preparation for a Rex shunt—the implantation of a vascular graft between the superior

Table 4 Global point prevalence of the pons hepatis

Author	Sample size	Pons Hepatis	Complete	Incomplete
Sato et al., 1998 [42]	1802	50	NS	NS
Orlando et al., 2000 [34]	2650	8	NS	NS
Aktan et al., 2001 [3]	437	22	14	8
Joshi et al., 2009 [25]	90	27	25	2
Muktyaz et al., 2013 [29]	41	4	NS	NS
Patil et al., 2014 [35]	50	7	2	5
Khedekar et al., 2014 [27]	50	7	NS	NS
Saritha et al., 2015 [40]	50	2	NS	NS
Chaudhari et al., 2017 [15]	80	10	1	9
Singh et al., 2018 [45]	40	1	1	0
Singh et al., 2019 [46]	70	16	NS	NS
Anbumani et al., 2020 [5]	30	5	3	2
Onitsuka et al., 2003 [33]	125	31	NS	NS
Global point prevalence	5515	190/5515 (3.45%)	46/72 (63.9%)	26/72 (36.1%)
Cawich et al.	66	27/66 (40.9%)	15/27 (55.6%)	12/27 (44.4%)
P value		< 0.0001	0.45	0.45

mesenteric vein and the umbilical branch of the left portal vein to relive portal hypertension.

Surgeons should also be aware of the pons hepatis, because it may affect surgical procedures. Hepatobiliary surgeons often use the umbilical fissure as a landmark to plan liver resections [4, 19, 26] and this is not possible when a complete-type pons hepatis obliterates the umbilical fissure. A pons hepatis also reduces surgeons' access to the umbilical branch of the left portal vein during a mesenterico-portal bypass operation (Rex shunt) to relieve portal hypertension and prevent variceal bleeding [37]. It also reduces access to the vertical part of the left portal vein during extended liver resections for hilar cholangiocarcinoma, particularly when a 'jump graft' or anastomosis is needed between the main portal vein and the vertical part of the left portal vein. Cytoreductive surgery with hyperthermic intra-peritoneal chemotherapy (HIPEC) is an important procedure to treat patients with metastatic peritoneal malignancies. In these procedures, it has been recognized that the tunnel created under a complete-type pons hepatis can hide malignant cells that can be the focus of disease recurrence [26–27]. Therefore, surgical oncologists must be able to recognize the pons hepatis and many authorities recommend deliberate division and dissection of the pons hepatis as a standard step [49–51]. This is important not only to achieve clearance of peritoneal disease in cytoreductive surgery, but also to allow the HIPEC fluid to work its way into the depths of the fissure to address all peritoneal disease. Finally, minimally invasive liver surgeons often grasp the ligamentum teres hepatis to use it as a retractor during laparoscopic liver resections. In our experience, we have found that this maneuver may cause bleeding when the pons hepatis is traumatized. In these cases, we have had to divide the pons hepatis to control bleeding – adding operating time and morbidity.

Conclusion

We have proposed a classification of the pons hepatis that is reproducible and clinically relevant. This allowed us to identify a high prevalence of pons hepatis (41%) in this Afro-Caribbean population that is significantly greater than the global prevalence (3.45%).

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Data availability All data will be made available to the editorial board upon request.

Compliance with ethical standards

Conflict of interest The authors have no competing interests to declare that may serve as conflicts of interest.

Ethics approval This research was approved by the local institutional board.

Consent to participate The research does not include living patients and, therefore, consent to participate is not necessary.

Consent for publication The authors all give consent for publication of this work.

References

1. Abdullahi DZ, Tadros AA, Usman JD, Bello A (2010) Absence of the left lobe of the liver in a cadaver: case report. J Med Trop 12(1):45–47
2. Abedalthagafi M (2012) Gastrointestinal stromal tumour originating from the hepatic falciform ligament. BMJ Case Rep 2012:bcr032012613
3. Aktan ZA, Savas R, Pinar Y, Arslan O (2001) Lobe and segment anomaly of the liver. J Anat Soc India 50(1):15–16
4. Alonso-Torres A, Fernandez-Cuadrado J, Pinilla I, Parron M, de Vicente E, Lopez-Santamaria M (2005) Multidetector CT in the evaluation of potential living donors for liver transplantation. Radiographics 25:1017–1030
5. Anbumani L, Pavazhakkurinji TN, Thamaraiselvi A (2020) Morphological study on variation of external surface of liver. Int J Anat Res 8(2.2):7481–7485
6. Auh YH, Rubenstein WA, Zirinsky K, Kneeland JB, Pardes JC, Engel IA, Whalen JP, Kazam E (1984) Accessory fissures of the liver: CT and sonographic appearance. Am J Roentgenol 143:565–572
7. Auh YH, Lim JH, Kim KW et al (1994) Loculated fluid collections in hepatic fissures and recesses: CT appearance and potential pitfalls. Radiographics 14:529–540
8. Aysin K, Ozcam G, Adnan O, Bulent B, Ahmet U, Iike Ali G (2009) A rare variation of round ligament of the liver. Int J Anat Var 2:62–64
9. Ayyappan AP, Singh SE, Shah A (2007) Mature cystic teratoma in the falciform ligament of the liver. J Postgrad Med 53:48–49
10. Cawich SO, Gardner MT, Barrow M, Barrrow S, Thomas D, Ragoonanan V, Mahabir A, Ali R, Naraynsingh V (2020) Inferior hepatic fissures: anatomic variants in Trinidad & Tobago. Cureus 12(5):8369. https://doi.org/10.7759/cureus.8369
11. Cawich SO, Gardner MT, Shetty R, Pearce NW, Naraynsingh V (2016) Accessory inferior sulci of the liver in Afro-Caribbean populations. Int J Biomed Sci 12(2):58–64
12. Cawich SO, Gardner MT, Pearce NW, Shetty R, Naraynsingh V (2017) Association between hepatic surface grooves and diaphragmatic slips. Ital J Anat Embyrol 122(1):64–66
13. Cawich SO, Johnson P, Gardner MT, Pearce NW, Sinanan A, Gosein M, Shah S (2020) Venous drainage of the left liver: an evaluation of anatomical variants and their clinical relevance. Clin Radiol 75(12):961–964. https://doi.org/10.1016/j.crad.2020.07.039
14. Cawich SO, Ali RRA, Gardner MT, Charles J, Sandy S, Pearce NW, Naraynsingh V (2020) Hepatic surface grooves in Trinidad and Tobago. Surg Radiol Anat 42:1435–1440. https://doi.org/10.1007/s00276-020-02540-5
15. Chaudhari HJ, Ravat MK, Vania VH, Bhedi AN (2017) Morphological study of human liver and its surgical importance. J Clin Diagn Res 11(6):9–12. https://doi.org/10.7860/JCDR/2017/24467.10020
16. Chin J, O'Toole P, Lin J, Velavan SS (2018) Hepatic morphology: variations and its clinical importance. Eur J Anat 22(3):195–201
17. Cho KC, Baker SR (1991) Air in the fissure for ligamentum teres: new sign of intra-peritoneal air on plain radiographs. Radiology 178(2):489–492
18. Donmez BO, Sarikcioglu L, Gokhan G, Elpik GO, Ucar Y (2009) Pons hepatis: report of two cases. Acta Gastroenterol Belg 72(2):279–280
19. Duparc F, Grignon B, Bonnel F, Macchi V, Douard R (2020) Liver anatomy: from Couinaud to the transplantation. Surg Radiol Anat 42:1405. https://doi.org/10.1007/s00276-020-02609-1
20. Ebby S, Ambike MV (2012) Anatomical variation of ligamentum teres of liver - a case report. Webmed Cent Anat 3(5):WMC003389
21. Gardner MT, Cawich SO, Shetty R, Pearce NW, Naraynsingh V (2015) hepatic surface grooves in an Afro Caribbean population. Ital J Anat Embyrol 210(2):117–126
22. Gordionok DM, Denisov SD (2020) Caval–portal anastomosis via Sappey superior veins with pseudolesion in segment IV a of the liver: a case report. Surg Radiol Anat 42:1421–1423. https://doi.org/10.1007/s00276-020-02462-2
23. Johnson PB, Cawich SO, Roberts P, Shah S, Gardner MT, Gordon-Strachan G, Pearce NW (2013) Variants of hepatic arterial supply in a Caribbean population: a computed tomography-based study. Clin Radiol 68(8):823–827
24. Johnson PB, Cawich SO, Shah S, Gardner MT, Roberts P, Stedman B, Pearce NW (2013) Vascular supply to the liver: report of a rare arterial variant. Case Rep Radiol 969327:1–3
25. Joshi SD, Joshi SS, Athavale S (2009) Some interesting observations on the surface features of the liver and their clinical implications. Singapore Med J 50(7):715–717
26. Kamel IR, Kruskal JB, Pomfret EA, Keogan MT, Warmbrand G, Raptopoulos V (2001) Impact of multidetector CT on donor selection and surgical planning before living adult right lobe liver transplantation. AJR Am J Roentgenol 176:193–200
27. Khedekar DN, Hattangdi SS (2014) Some interesting morphological features of liver lobes in Mumbai population. Int J Med Res Health Sci 3:656–659
28. Kollmar O, Schilling MK, Menger MD (2004) Experimental liver metastasis: standards for local cell implantation to study isolated tumor growth in mice. Clin Exp Metastasis 21(5):453–460. https://doi.org/10.1007/s10585-004-2696-3
29. Mamatha Y, Murthy CK, Prakash BA (2014) Study on morphological surface variations in human liver. Int J Health Sci Res. 4(11):97–102
30. Muktyaz H, Nema U (2013) Morphological variations of liver lobes and its clinical significance in north Indian population. GJMMS 1(1):1–5
31. Nayak BS, Kumar N, Srinivasa Rao S, Reghunathan D, Patil J, Swamy Ravindra S (2013) Tunnel for ligamentum teres: a rare variation of the liver. OA Case Rep 2(10):95
32. Nune GKR, Mohanty SR, Patra M (2015) Tunnel for ligamentum teres: a rare variation of the liver seen in 2 cadaveric livers—a case report. Indian J Res 4(6):239–240
33. Onitsuka A, Katagiri Y, Miyauchi T et al (2003) Metastatic hepatoma originating from the pons hepatis presenting extrahepatic growth—classification of different patterns covering REX's recessus. Hepatogastroenterology 50(49):235–237
34. Orlando R, Lirussi F (2000) Congenital anomalies of the liver: laparoscopic observations. Gastrointest Endosc 51(1):115–116. https://doi.org/10.1016/S0016-5107(00)70147-7

35. Patil S, Sethi M, Kakar S (2014) Morphological study of human liver and its surgical importance. Int J Anat Res 2(2):310–314
36. Poilblanc M, Coquaz S, Welschbillig K et al (2005) A case report of stromal tumor in the ligamentum teres hepatis. Gastroenterol Clin Biol 29(2):204–205
37. Puppala S, Patel J, Woodley H, Alizai NK, Kessel D (2009) Preoperative imaging of left portal vein at the Rex recess for Rex shunt formation using wedged hepatic vein carbon dioxide portography. J Pediatr Surg 44(10):2043–2047. https://doi.org/10.1016/j.jpedsurg.2009.06.004
38. Rela M, Rajalingam R, Shanmugam V, O'Sullivan A, Reddy MS, Heaton N (2014) Novel en-bloc resection of locally advanced hilar cholangiocarcinoma: the Rex recess approach. Hepatobiliary Pancreat Dis Int 13:93–97
39. Sanli EC, Kurtoglu Z, Kara A, Uzmansel D (2006) Left sided-right portal joined round ligament with an anomaly of the intrahepatic portal vein. Saudi Med J 27(12):1897–1900
40. Saritha S, Ramani D, Nagajyothi D, Yesender D (2015) Cadaveric study of morphological variations in the human liver and its clinical importance. Int J Med Sci Clin Interv 2(6):1020–1031 http://valleyinternational.net/index.php/ijmsci/article/view/289/284 Accessed 15 Nov 2020
41. Satheesha BN, Snigdha M, Bincy MG, Surekha DS, Kumar N, Guru A et al (2013) A peculiar liver with surgically and radiologically important variations: a case report. Anat Cell Biol 46(1):82–84
42. Sato S, Watanabe M, Nagasawa S, Niigaki M, Sakai S, Akagi S (1998) Laparoscopic observations of congenital anomalies of the liver. Gastrointest Endosc 47:136–140
43. Sibulesky L (2013) Normal liver anatomy. Clin Liver 2:1–3
44. Sinanan A, Cawich SO, Thornton A, Maharaj P (2017) Study of anatomic variants and congenital anomalies in the biliary tree in a Caribbean population. HPB 19(1):S82. https://doi.org/10.1016/j.hpb.2017.02.411
45. Singh H, Diwan RK, Rani A, Rani A, Sehgal G, Singh R (2018) Tunnel for ligamentum teres hepatis—a case report. EJMR 6(1):1–7
46. Singh HR, Rabi S (2019) Study of morphological variations of liver in human. Transl Res Anat 14:1–5
47. Skandalakis JE, Skandalakis LJ, Skandalakis PN, Mirilas P (2004) Hepatic surgical anatomy. Surg Clin N Am 84:413–435
48. Srimani P, Saha A (2020) Liver morphology: anatomical study about the outer aspects. Surg Radiol Anat 42:1425–1434. https://doi.org/10.1007/s00276-020-02485-9
49. Sugarbaker PH (2010) Pont hepatique (hepatic bridge), an important anatomic structure in cytoreductive surgery. J Surg Oncol 101(3):251–252
50. Sugarbaker PH (2019) Peritoneal tunnels: a site at risk for treatment failure when performing treatments for peritoneal metastases. A case series of 2 patients. Int J Surg Case Rep 61:309–312
51. Verrapong J, Solomon H, Helm CW (2013) Division of the pont hepatique of the liver in cytoreductive surgery for peritoneal malignancy. Gynecol Oncol 128(1):133