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# Hepatic morphology: variations and its clinical importance

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**SUMMARY**

Emergent technologies and advances in the fields of diagnostic radiology and gastroenterology have created a need to better understand the morphological features of the liver. Variations in these features are a potential source for diagnostic errors, which can lead to costly follow-up testing and detrimental health outcomes. In the present study, the morphological features of human cadaveric liver specimens were evaluated via macroscopic examination and measurements to asses for variations in accessory fissures/sulci, accessory lobes, and the pons hepatis. The study was conducted on 33 specimens obtained from cadavers utilized for routine dissection for first year medical students in the 2016-2017 academic year in the Department of Clinical Anatomy and Embryology at the Touro College of Osteopathic Medicine. Out of 33 specimens, 12 were considered normal without any accessory fissures, lobes, or presence of a pons hepatis. 21 livers had 1 or more morphological variations, which included but were not limited to: multiple accessory fissures, Riedel's lobe, and varying degrees of pons hepatis. The study aims to throw greater light to the field of hepatic morphology and its variations.

Key words: Liver – Hepatic variation – Hepatic morphology – Riedel's lobe – Pons hepatis – Accessory lobe – Fissure – Sulci

## INTRODUCTION

The liver is the largest viscera in the abdominal cavity as it occupies the right hypochondriac, epigastric, and left hypochondriac regions. Under non-pathological conditions, the liver has a homogenous parenchyma and is divided into 4 anatomical lobes by peritoneal and ligamentous attachments (Patil et al., 2014). Age, body size, and sex contribute to the vast variations in liver size and weight, with adult livers weighing approximately 2% of the total body weight (Vinnakota and Jayasree, 2013).

Divisions of the liver in functional anatomy are based on Couinaud's classification, utilizing an imaginary plane and hepatic vasculature distribution to divide the liver into 8 segments (Couinaud, 1957; Joshi, et al. 2009; Patil et al., 2014; Vinnakota and Jayasree, 2013). While segmental liver anatomy research receives the greatest attention, there are also studies that focus on common/rare morphological variants. With increasing dependence on radiological imaging for disease diagnosis and laparoscopic procedures, knowledge of common anatomical surface variations of the liver is critical for the best patient outcomes (Rumack et al., 2016; Sato et al., 1998). Furthermore, although most hepatic variants are quiescent, there have been documented cases of clinical manifestations caused by variant morphology (Vinnakota and Jayasree, 2013; Glenisson et al., 2014; Kudo, 2000; Akbulut et al., 2011; Fitzgerald et al., 1993).

The aim of this study was to examine common gross surface variations of liver and review the literature on its clinical impact and implications.

## MATERIALS AND METHODS

Dissections were performed on 33 cadavers in

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the gross anatomy lab at Touro College of Osteopathic Medicine. Age range of the cadavers was 54 to 96 years old with a gender distribution of 9 males and 24 females, with the presence of Riedel's lobe being a gender specific variation seen on initial examination. All the cadavers were of Caucasian origin, with no associated gross pathological changes or surgical scars present in the cadavers.

Utilizing standard dissection methods (Detton and Tank, 2012), the coronary, falciform, and triangular ligaments of the liver were detached at their attachments to the liver. Surrounding connective tissue and hepatic nerve plexus were removed to clear the dissection plane. The inferior vena cava was cut at its entry to and exit from the liver, with care taken to preserve the pons hepatis if present. Gross measurements of liver size and weight were taken to ensure that all specimens adhered to a standard average adult liver size. The gallbladder, biliary system, and hepatic vasculature were dissected away from the surrounding liver.

The lobes of the liver —right, left, caudate, and quadrate— were studied in detail and photographed, with attention paid to size, shape, accessory fissures, and accessory lobes.

## RESULTS

In the present study of the 33 liver specimens, the average liver size was approximately 15.5 cm in width and the average weight was 1.1 kg. Even distribution of liver variations was present across genders with the exception of Riedel's lobe (Table 1). No gross anatomical variations were noted in the gallbladder, biliary system, and surrounding hepatic vasculature. 12 livers were observed with normal surfaces, fissures, and borders without any additional accessory fissures or malformations (36%). Of the remaining 21 specimens, hepatic variations were documented and broadly grouped as having accessory fissures, accessory lobes, and/or the presence of a pons hepatis (hepatic bridge or 'pont hepatique'). In several of the specimens, multiple anatomical variations were documented (i.e. having an accessory lobe and pons hepatis).

Accessory sulci/fissures were present in 9 livers (27%), with 7 having fissures on the superior surface of the right lobe (Fig. 1). Of the superior sulci, 4 appeared to be deep diaphragmatic grooves while 3 had multiple fissures (Figs. 2 and 3). One liver was noted to have fissures on the right ventral lobe surface while another had a fissure on the right dorsal lobe surface (Figs. 4 and 5). Accessory lobes were identified on 8 specimens (24%), with 6 indicating the presence or establishment of Riedel's lobe and 2 livers having miniature accessory lobes on the caudate (Figs. 6 and 7). One liver had a prominent Riedel's lobe extending inferiorly as well as a left liver lobe projection (Fig. 8). Other various liver projections were also documented on 4 livers, but were not representative of true accessory lobes (Fig. 9). Pons hepatis with variable levels of inferior vena cava encapsulation were seen in 12 specimens (36%) (Fig. 10).

**Table 1 Liver variations across genders.**

| Classification | Male | Female | Total |
|---|---|---|---|
| Normal | 6 | 6 | 12 |
| Accessory Fissures | 2 | 7 | 9 |
| Accessory Lobes | 2 | 6 | 8 |
| *Pons Hepatis* | 1 | 11 | 12 |

## DISCUSSION

External morphology of the liver is highly varied, creating a wide array of presentations on physical examination, radiologic imaging, and post-mortem cadaveric studies (Bradley, 1908; Kudo, 1918; Loth, 1931; Thomson, 1985; Sato et al., 1998; Joshi et al., 2009; Patil et al., 2014). These variations are broadly defined as acquired versus congenital malformations, each with their own clinical presentation and impact (Ruge, 1907; Joshi et al., 2009; Covantev, 2013). Congenital liver defects that affect the external morphology are largely rare, but tend to have a more predictable clinical presentation as they often impact the biliary system (Sato et al., 1998; Aktan et al., 2001). Acquired liver defects will also affect the external morphology, but their clinical effects are typically quiescent unless there are inciting stimuli such as torsion, trauma, or tumors (Aktan et al., 2001; Covantev, 2013). Accessory hepatic fissures/sulci, accessory lobes, and the pons hepatis are some of the most common hepatic variations that are most likely to be seen on clinical examination (Vinnakota and Jayasree, 2013; Sato et al., 1998).

### *Accessory hepatic fissures/sulci*

Various studies have described diaphragmatic sulci, which is the primary hepatic sulci that can be found in 40% of all liver observations (Figs. 1-5) (Thomson, 1899; Kanchan et al., 2014; Lim et al., 1987). In comparison, only 27% of the livers in this study contained a measurable fissure or sulci, which could be attributed to the small sample size. Traditionally, it was understood that diaphragmatic sulci resulted from hypertrophic diaphragm muscle bands, which created variable resistances and thus promoted uneven hepatic parenchymal growth (Kanchan et al., 2014). Recent radiological and corrosion cast studies, however, have also attributed the formation of sulci to the existence of weakened zones of hepatic parenchyma. These zones offer a lower resistance to external pressure of the diaphragm and are represented by the portal fissures between the adjacent sagittal portal territories (Macchi et al., 2005; Malarkey et al., 2010).

Clinically, diaphragmatic sulci have been suggested to represent a useful landmark in surgery for surface projections of portal fissures with hepatic veins and their tributaries (Malarkey et al., 2010; Yadav and Deka, 2008). In particular, identification of Rouviere's sulcus/fissure of Ganz (Fig. 4) can be used as a signpost to avoid bile duct injury during laparoscopic cholecystectomy, but is typically not relied upon due to its reported inconstancy (Rouviere, 1924, Dahmane et al. 2013).

In general, accessory hepatic fissures/sulci are potential sources of diagnostic errors during imaging. On ultrasound or computerized tomography, any collection of fluid in these fissures may be mistaken for a liver cyst, intrahepatic hematoma, or liver abscess, which would require further radiologic workup (Auh et al., 1984, 1994). Implantation of peritoneal-disseminated tumor cells into these spaces may also imitate intrahepatic focal lesions (Joo, 2015). In cases of abdominal trauma, imaging or direct palpation of sulcus prior to laparotomy may give a false impression of a liver laceration (Mehta et al., 2010).

### *Accessory lobes*

Accessory lobes are composed of normal parenchyma in continuity with the main liver mass and are supernumerary in nature (Figs. 6-9). This contrasts with ectopic liver lobes which do not have this continuity. Found commonly in the right intrahepatic region, accessory lobes have varied form, localization, size, and attachment (Glenisson et al., 2014). Accessory lobes are grossly underreported as they are often asymptomatic, with various studies indicating a prevalence of 1-12% (Malarkey et

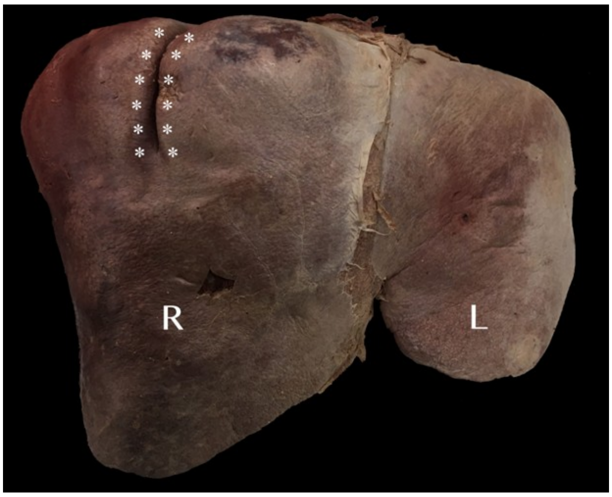


**Fig 1.** Right superior lobe fissure on an otherwise unremarkable liver. In many of the livers, there were possible beginnings of a Riedel's lobe, but were difficult to determine.


**Fig 2.** Multiple deep diaphragmatic grooves on the right superior surface with a definite


**Fig 3.** Deep diaphragmatic groove with accompanying inset demonstrating deep depression of the diaphragm (D) caused by the right lung, which in turn manifested in the groove found on the liver.

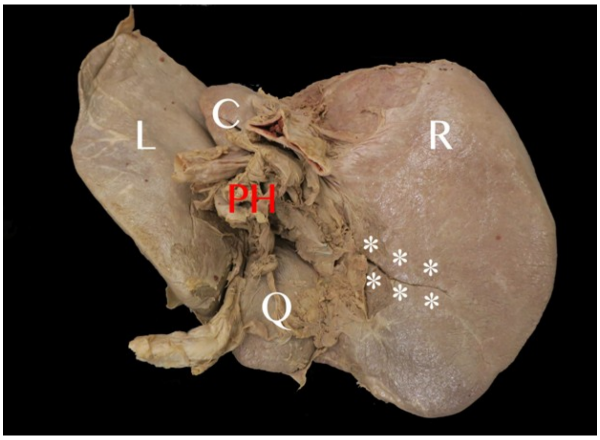


**Fig 4.** Posterior view of liver, *porta hepatis* (PH) for orientation, there is a fissure on the dorsal aspect of the right lobe, which may correspond to Rouviere's sulcus/ fissure of Ganz.

al., 2010). The most well-known of these is Riedel's lobe, which is a sessile projection from hepatic segments V and VI.

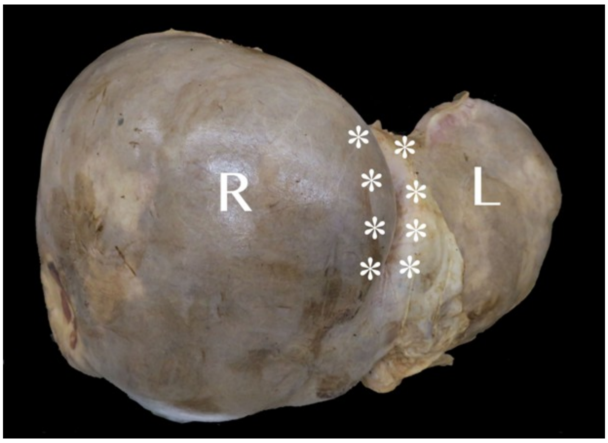


**Fig 5.** Fissure on right ventral aspect of liver.


**Fig 6.** Beginning of Riedel's lobe on the right. As noted previously, many specimens exhibit multiple surface modifications from the standard liver morphology.

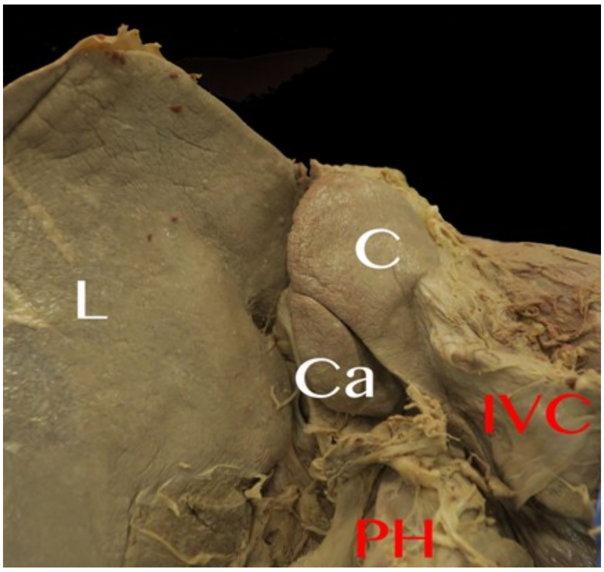


**Fig 7.** Posterior view of liver, inferior vena cava (IVC) and *porta hepatis* (PH) labeled as reference, with accessory lobe on the caudate (Ca) next to caudate lobe (C).

Riedel's lobe was described by Corbin in 1830 and defined by Riedel in 1888 as a "round tumor on the anterior side of the liver, the gallbladder, to its right" (Corbin, 1830; Riedel, 1888; Gillard et al., 1998). The prevalence of Riedel's lobe ranges from 3.3-31%, with a higher incidence in females than males (Glenisson et al., 2014). In our study, 24% of livers had a Riedel's lobe.

Although this coincides with previous studies, it is important to note the greater proportion of female to male cadavers as well as fewer specimens compared to other studies. The etiology of Riedel's lobe has been widely debated, with studies supporting a congenital or acquired origin. The congenital origin is supported by possible defects in the development of the hepatic bud, which can lead to the formation of infra-hepatic accessory lobes. The acquired origin, however, has its roots with Riedel, who attributed the lobe's presence to age-related hepatic modifications, secondary injury from surgical intervention, and intraperitoneal inflammation/chronic cholecystitis, especially with the gallbladder's anatomical relation (Kudo, 2000).

Minimal research has been done on the etiology of left lobe projections and might be an area for future research and studies. As such, case reports with left adrenal masses, lesser omental lymphadenopathy, and hepatocellular carcinoma, which ultimately resulted in a left lobe projection has emphasized the need for inclusion in a physician's differential (Akbulut et al., 2011; Fitzgerald et al., 1993). Of note, no studies were found regarding livers that contain both Riedel's lobe and other liver projections, which could represent a unique finding that is not normally seen or diagnosed.

Riedel's lobe and other liver projections are typically asymptomatic and clinically latent. Inflammation or torsion of these areas may elicit right hypochondriac and/or epigastric pain, which can easily be attributed to more common origins or be mistakenly attributed as idiopathic (Lefaucher et al.,

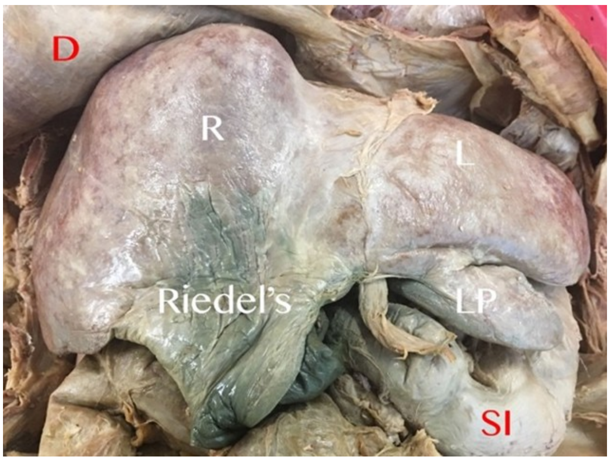


**Fig 8.** In-situ view of unique liver in cadaver with pronounced Riedel's lobe (Riedel's) and left lobe projection (LP). The diaphragm (D) and small intestine (SI) are labeled for orientation.

1978; Kudo, 2000; Khan et al., 2006). Other non-specific symptoms include constipation, emesis, and hemorrhage. Even rarer are pedunculated hepatocellular tumors, which have an unclear relationship with accessory lobes, with an incidence of 0.2-4.2% (Yeh et al., 2002). For definitive diagnosis, common tests include ultrasound, computerized tomography (CT), and magnetic resonance imaging (MRI). Radionuclide imaging and arteriographic examination may also be appropriate to depict possible cancerous lesions and abnormal vascular/cystic features (Yeh et al., 2002; Yano et al., 2000).

***Pons hepatis***

First described by von Haller in 1743, the pons hepatis (hepatic bridge or 'pont hepatique') is a segment of hepatic tissue connecting the quadrate lobe to left lobe over the ligamentum teres fissure (Fig. 10) (von Haller, 2012). In this study, the pons hepatis refers to hepatic tissue that surrounds the inferior vena cava. As seen in figure 10, it has a wide range in morphology, which can complicate visualization and standardization of radiological reporting. Reflecting its seemingly benign nature, minimal information can be found on its prevalence, with reports ranging from 4-30% (Reddy et al., 2017). In comparison, cadaveric observation in this study shows a slight increase in the prevalence of the pons hepatis (36%), which may be due to fewer specimens analyzed in this study. Clinically, metastatic hepatomas have been found originating from the pons hepatis as well as harboring site of peritoneal disseminated tumor cells (Onitsuka et al., 2003). It is also an important site and landmark for cryoreductive surgeries of the liver (Sugarbaker, 2010; Verrapong et al., 2013).

In conclusion, hepatic surface variations are common and must be taken into the differential diagnosis by radiologists and gastroenterologists. These variations may have clinical implications that may be overlooked due to their typically quiescent nature. Furthermore, there is also a wide distribution in prevalence of these variations in both living and cadaveric specimens within the literature. It is evident that future studies are needed to better associate surface morphological variants of the liver to its functionality and clinical presentations.

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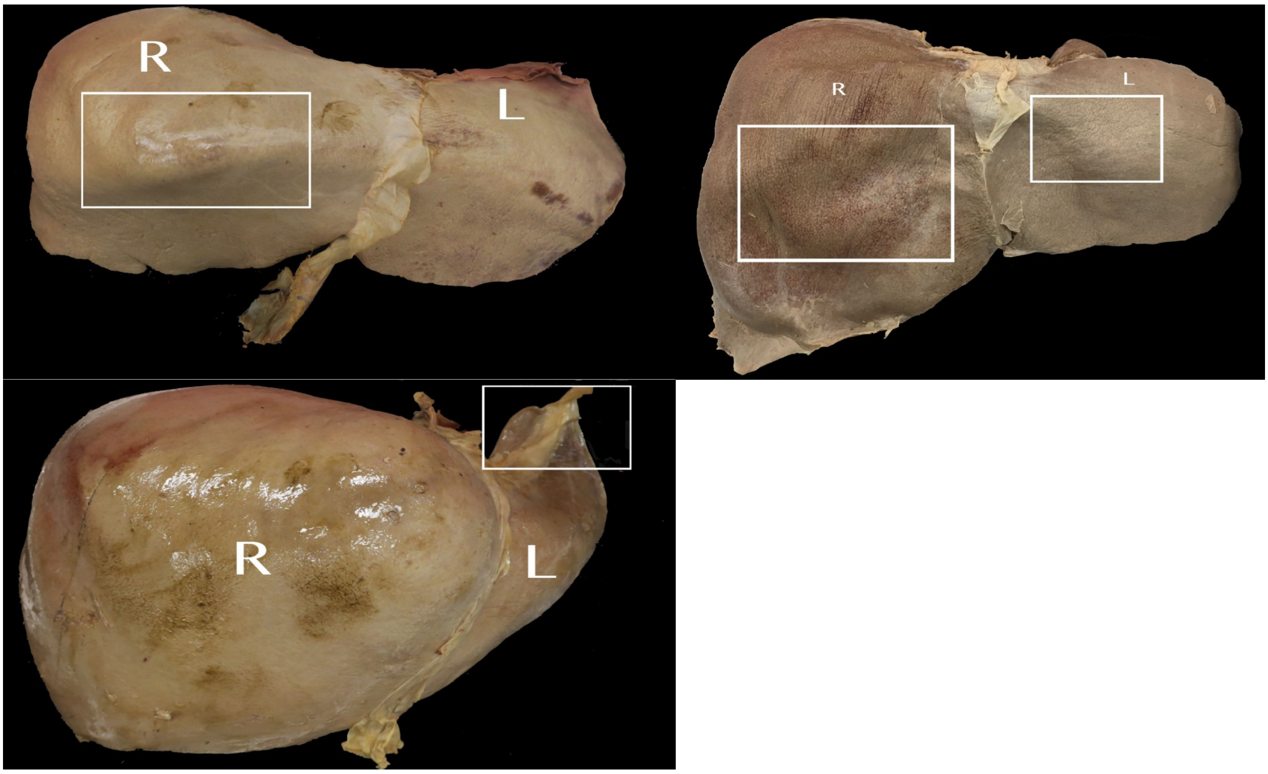


**Fig 9.** Various boxed examples of liver projections that are not discrete accessory lobes.

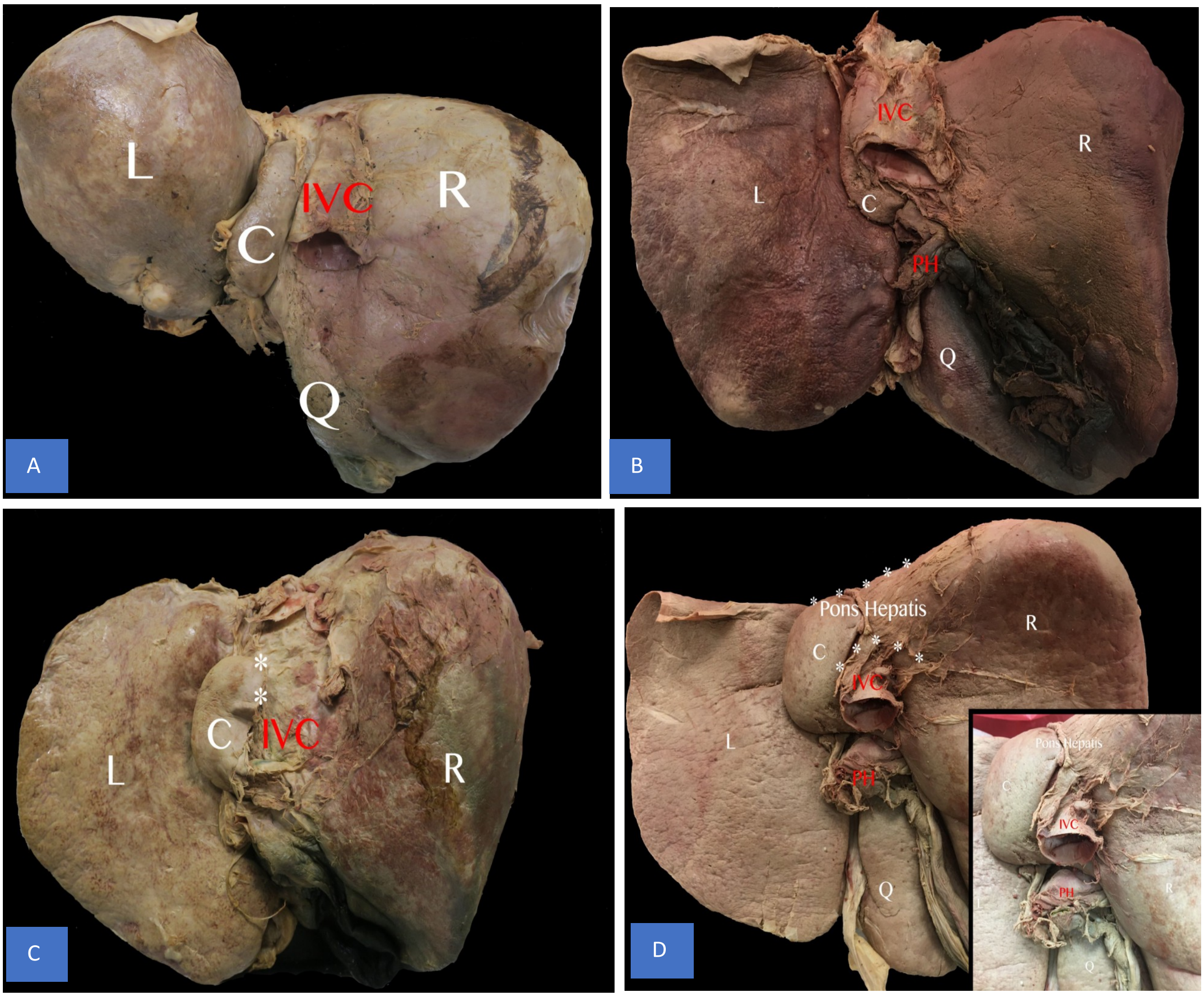


**Fig 10.** Posterior view of liver, with various stages of encapsulation of the inferior vena cava (IVC) by the pons hepatis. (A) Non-encapsulated with discrete IVC. (B) Non-encapsulated with IVC covering the caudate lobe. (C) Partially encapsulated IVC with possible pons hepatis (**) beginning to form. (D) Completely encapsulated IVC by the pons hepatis. Inset illustrates magnified area of the pons hepatis.

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