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Hepatic surgical anatomy

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> In the strangely beautiful dynamism of embryology, the liver appears as a tree that grows out of the virgin land of the foregut in order to increase its metabolic and digestive function.
> R. Seltzer, *Mortal Lessons* [1]

The liver is the largest internal organ in the body, accounting for approximately 2% to 3% of the total body weight of an adult. Despite its multiple vital functions and its regenerative abilities, the liver has been misunderstood at nearly all levels of organization and in almost every period of time since Galen. The most paradoxical aspect of the understanding of hepatic anatomy has not been lack of knowledge but questions of interpretation; there is a tendency to ignore details that do not fit preconceived ideas. Furthermore, mistaken ideas about the liver seem to have taken longer to correct than misconceptions about most of the other organs of the body, with the exception of the brain. Anatomists and surgeons have almost willfully misinterpreted the anatomic and functional lobar structure of the liver as well as its segmental anatomy. Accordingly, details of the intra- and extrahepatic vasculature and the biliary tract need to be reviewed.

Longmire [2], who devoted his life to the study of the liver, called it a "hostile" organ because it welcomes malignant cells and sepsis so warmly, because it bleeds so copiously, and because it is often the first organ to be

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injured in blunt abdominal trauma. To balance these negative factors, the liver has two great attributes: its ability to regenerate after massive loss of substance, and its ability, in many cases, to forgive insult.

The liver is one of the first organs to develop in the embryo, and it rapidly becomes one of the largest organs in the fetus [3]. A presentation of the embryology and congenital anomalies of the liver is beyond the scope of this article, as is a discussion of the extrahepatic system biliary ducts. The intrahepatic network is discussed briefly.

Hepatic surgical anatomy

> A good knowledge of the anatomy of the liver is a prerequisite for modern surgery of the liver.
> H. Bismuth [4]

The liver is covered with the capsule of Glisson, which envelops the hepatic artery, portal vein, and bile duct at the hilum of the liver.

Peritoneal attachments to the liver

Folds, ligaments, and peritoneal attachments of the liver are terms that confuse hepatic anatomists as well as medical students. The falciform, coronary, round, ligamentum venosum, and the two triangular ligaments, presented as ligaments or folds in the literature, are not ligaments [5,6]. Ligaments are composed of regular connective tissue [7], usually providing support between bony elements [8]. The authors propose using the term peritoneal attachment rather than ligament when referring to the liver [6].

It is often surgically convenient to distinguish a right and a left coronary ligament. Anatomically, however, there is only the coronary ligament [6,9], or there are only the left triangular ligament and the complex of coronary and right triangular ligament; the latter is the lateral unification of the layers of the coronary ligament. The coronary ligament has superior and inferior layers, not anterior and posterior layers [6]. Because of the original quadruped stance of human ancestors, the liver is located posteriorly (not cranially as often misunderstood). Where the bare area of the liver connects to the diaphragm, the liver is suspended mostly by fibrous attachments and by the hepatic veins [10].

Peritoneal attachments of the liver are shown in Fig. 1. The double layer of the parietal peritoneum continues to the falciform ligament and surrounds the liver except for the bare area, where the two layers separate to form the coronary ligament and the left triangular ligament. The left layer of the falciform ligament becomes the superior layer of the left coronary ligament. The right layer becomes the upper layer of the coronary ligament, which meets the lower layer to form the right triangular ligament. The lower layer of the coronary ligament continues on the posterior surface of the liver and can reflect on the upper part of the right kidney to form the hepatorenal

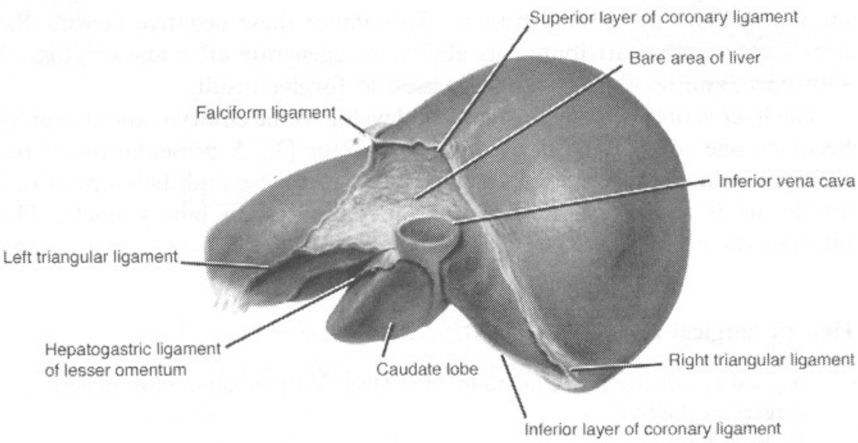

Fig. 1. Posterior aspect of the liver. The distinction between the left and right layers of the falciform ligament is slightly exaggerated to emphasize the contributions of these layers to the left triangular ligament and the coronary ligament respectively. (*From* Skandalakis JE, Gray SW, Skandalakis LJ, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 2 – surgical anatomy of the liver. Contemp Surg 1987;30:26; with permission.)

ligament. Then it passes in front of the groove for the inferior vena cava (IVC), and, after a semicircular course in front of the caudate lobe, it meets the right leaf of the lesser omentum. The leaf of the lesser omentum continues in the posterior leaf of the left triangular ligament.

Surfaces of the liver and their relations

The three surfaces of the liver in sagittal section are the posterior surface, the anterosuperior surface, and the inferior surface.

Posterior surface

The posterior surface is related to the vertical part of the diaphragm and, for all practical purposes, is retroperitoneal. Three anatomic entities are related to the posterior surface: the retrohepatic part of the IVC, the right adrenal gland, and the upper pole of the right kidney. The IVC travels through the hepatic parenchyma. The bare area of the liver may also be considered part of the posterior surface.

Anterosuperior surface

The anterosuperior surface is related to the diaphragmatic dome. To be more specific, the anterosuperior surface is located behind the ribs and cartilages, part of the diaphragm, pericardium, the pleurae, and the pulmonary parenchyma. This superior surface is covered by peritoneum except for the attachment of the falciform ligament and where, more dorsally, the superior reflection of the coronary ligament bounds the bare area of the liver.

Inferior surface

The inferior surface is the visceral hepatic surface. It is related to several intraperitoneal anatomic entities and spaces. The space under the right lobe is the subhepatic space of Morison; the space under the left is the lesser sac. The inferior visceral hepatic surface under the right lobe is related to the gallbladder, right adrenal gland, right kidney, right renal vessels, head of pancreas, proximal part of the pancreatic neck, first and second parts of the duodenum, common bile duct, portal vein, hepatic artery, IVC, and hepatic colonic flexure.

A capital H configuration (Fig. 2) is shaped in the inferior surface by fissures for the following entities: right limb, anteriorly for the gallbladder and posteriorly for the IVC; the left limb for the round ligament and posteriorly for the ligamentum venosum. The cross bar of the H is the porta hepatis (the hilum of the liver); it contains the hepatic artery, the hepatic duct and the branches of the portal vein (Fig. 3) [11]. A capital L is formed by the attachment of the lesser omentum to the visceral surface of the liver: the vertical limb is the fissure for the ligamentum venosum; the horizontal limb is the porta hepatis [11].

Hepatic margins

The right lateral margin is located under the right chest wall (eighth, ninth, and tenth ribs) and the related diaphragmatic part. The anterior margin is the border where the posterior and inferior hepatic surfaces merge. The anterior hepatic surface is located between the inferior and superior margin.

Fissures

The hepatic fissures are enigmatic and confusing because of their multiple names (eg, principal, accessory, portal fissures). Only one fissure can be seen. The other fissures, although not based on external appearance, are anatomically related to the three hepatic veins, producing segments (ie, vascular areas) that may be approached surgically with fewer anatomic complications (Fig. 4). Many classic texts present the lobes and segments without presenting the pathway of the fissures, which are co-responsible for the lobation and segmentation of the hepatic parenchyma. Ger [10], however, presents the pathway of the four fissures in a correct surgico-anatomic way.

> Right fissure – This fissure commences at the right margin of the inferior vena cava and follows the attachment of the right superior coronary ligament to about 3 to 4 cm from the junction of the latter with the right inferior layer. The fissure then curves anteriorly to a point on the inferior margin about midway between the gallbladder fossa and the right margin of the liver. Passing posteriorly, the fissure follows a line that runs parallel to the gallbladder fossa and crosses the caudate process to reach the right side of the inferior vena cava.

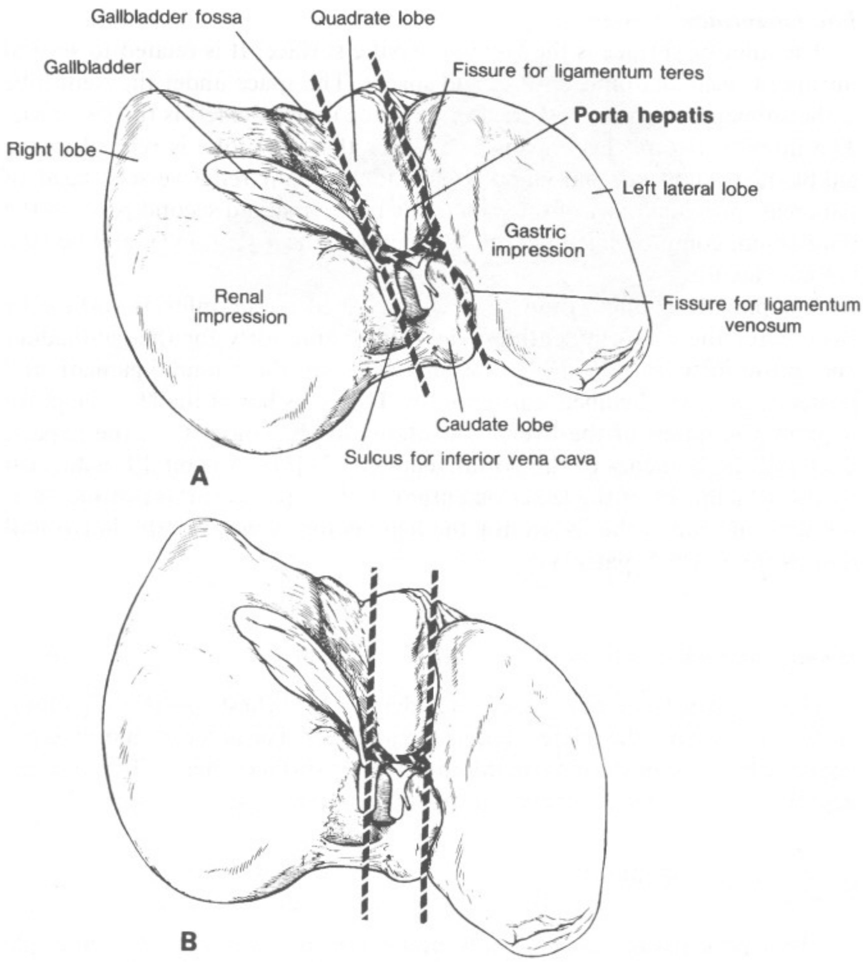

Fig. 2. Porta hepatis and features of the visceral surface of the liver. (*A*) Typical orientation of the H configuration of the portal structures. (*B*) Common but incorrect depiction of relationship of the H configurations parallel with the midsagittal plane of the body. (*From* Skandalakis JE, Gray SW, Skandalakis LJ, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 2 – surgical anatomy of the liver. Contemp Surg 1987;30:26; with permission.)

Median fissure – This fissure passes from the gallbladder fossa to the left margin of the inferior vena cava. Posteroinferiorly, the fissure is represented by a line from the gallbladder fossa to the main bifurcation of the hepatic pedicle (portal triad) and, thence, to the retrohepatic inferior vena cava.

Left fissure – This fissure runs from the left side of the inferior vena cava to a point between the dorsal one third and ventral two thirds of the left margin of the liver. Inferiorly, the fissure passes to the commencement of the ligamentum venosum.

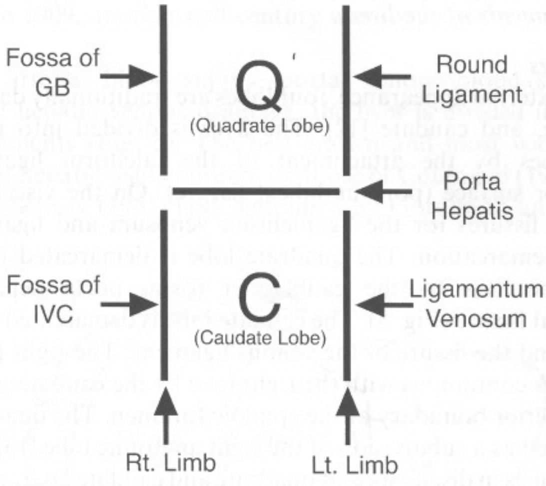

Fig. 3. The H configuration of the visceral surface. GB, gallbladder; IVC, inferior vena cava.

Portoumbilical fissure – This fissure is marked superficially by the attachment of the falciform ligament, which contains the ligamentum teres hepatis in its inferior border. Angled less generously than the right fissure, it meets the inferior margin of the liver at an angle of about 50°.

The authors have observed that in rare cases the pathway of the left hepatic vein is located too laterally (to the left), just behind the portoumbilical fissure.

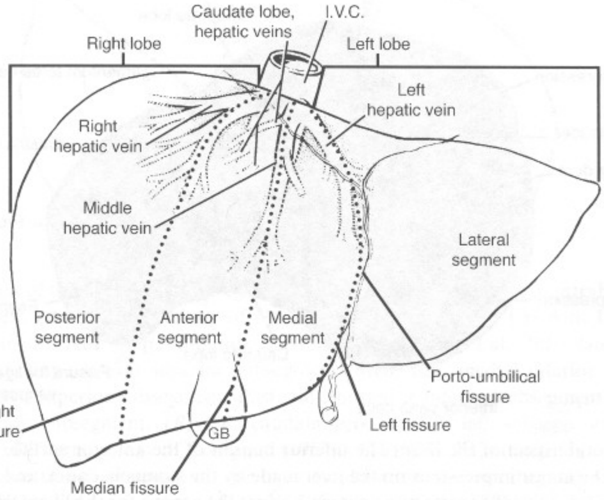

Fig. 4. The four fissures. GB, gallbladder; IVC inferior vena cava. (*Adapted from* Colburn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 3 – surgical anatomy of the liver. Contemp Surg 1987;31:25; with permission.)

Lobes and segments of the liver

Anatomic lobes

Based on external appearance, four lobes are traditionally described: right, left, quadrate, and caudate [12]. The liver is divided into right and left anatomic lobes by the attachment of the falciform ligament on the anterosuperior surface (portoumbilical fissure). On the visceral surface of the liver, the fissures for the ligamentum venosum and ligamentum teres provide the demarcation. The quadrate lobe is demarcated in the visceral surface of the liver by the gallbladder fossa, porta hepatis, and the portoumbilical fissure (Fig. 5). The caudate lobe is demarcated by the groove for the IVC and the fissure of the venous ligament. The right portion of the caudate lobe is continuous with the right lobe by the caudate process, which forms the superior boundary of the epiploic foramen. The quadrate lobe has been considered as a subdivision of the right anatomic lobe [13]. The authors use the term lobes in discussions of quadrate and caudate anatomy as a matter of convenience; these structures are not true lobes.

Functional lobes and segments

In 1888 Rex [14] showed that the right and left lobes of the liver are of equal size. The plane of division is not the obvious falciform ligament but rather a plane passing through the bed of the gallbladder and the notch of the IVC, without other surface indications. This observation received little attention at the time. Although confirmed by Cantlie [15] in 1897 and

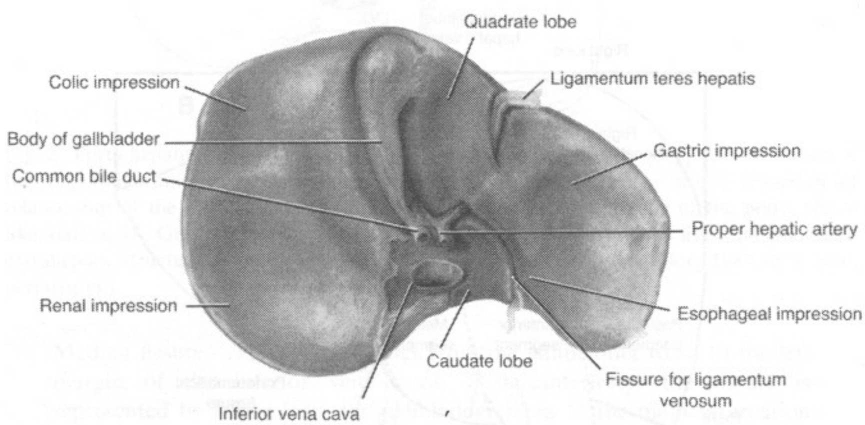

Fig. 5. Visceral aspect of the liver. The inferior margin of the anterior surface is uppermost in the figure. The major impressions on the liver made by the stomach, colon, and right kidney are seen clearly. A bridge of hepatic parenchyma bridges the groove for the ligamentum venosum in this specimen. (*From* Skandalakis JE, Gray SW, Skandalakis LJ, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 2 – surgical anatomy of the liver. Contemp Surg 1987;30:26; with permission.)

Bradley [16] in 1909, another half century was required for wide acceptance [17–23].

Based on arterial blood supply, portal venous blood supply, biliary drainage, and hepatic venous drainage, the liver is divided into functional lobes and segments (Fig. 6). The best-known and most widely employed conceptions of hepatic segmentation are those of Couinaud (1954) [21]; those of Healy and Schroy (1953) [19], simplified by Goldsmith and Woodburne

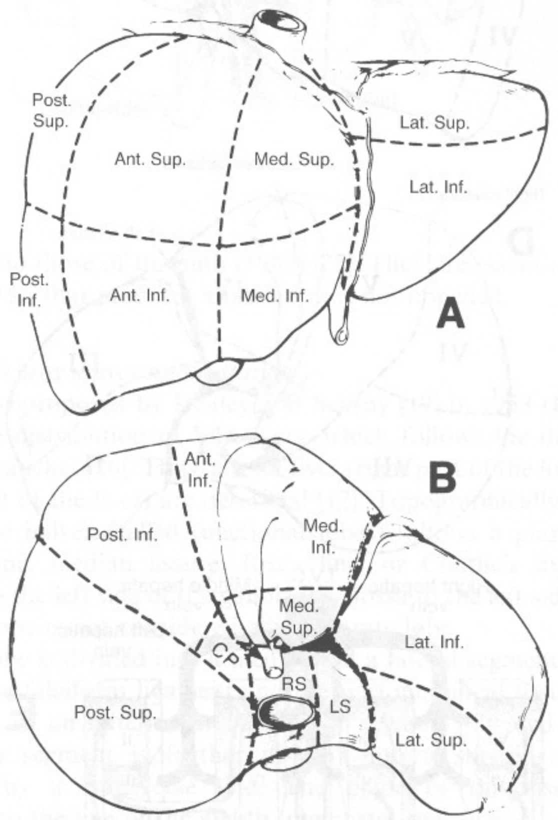

Fig. 6. Projection of the liver lobes and segments based on the distribution of intrahepatic ducts and blood vessels. (*A, B*) Terminology of Healey and Schroy (1959). (*A*) Ant. Inf., anterior inferior subsegment; Ant. Sup., anterior superior subsegment; Lat. Inf., lateral inferior subsegment; Lat. Sup., lateral superior subsegment; Med. Inf., medial inferior subsegment; Med. Sup., medial superior subsegment; Post. Inf., posterior inferior subsegment; Post. Sup., posterior superior subsegment. (*B*) CP, caudate process; LS, left subsegment; RS, right subsegment. (*C, D*) Terminology of Couinaud (1954). (*E*) Highly diagrammatic presentation of the segmental functional anatomy of the liver emphasizing the intrahepatic anatomy and hepatic veins. IVC, inferior vena cava. (*F*) Exploded segmental view of the liver emphasizing the intrahepatic anatomy and hepatic veins. (*From* Skandalakis JE, Gray SW, Skandalakis LJ, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 2 – surgical anatomy of the liver. Contemp Surg 1987;30:26; with permission.)

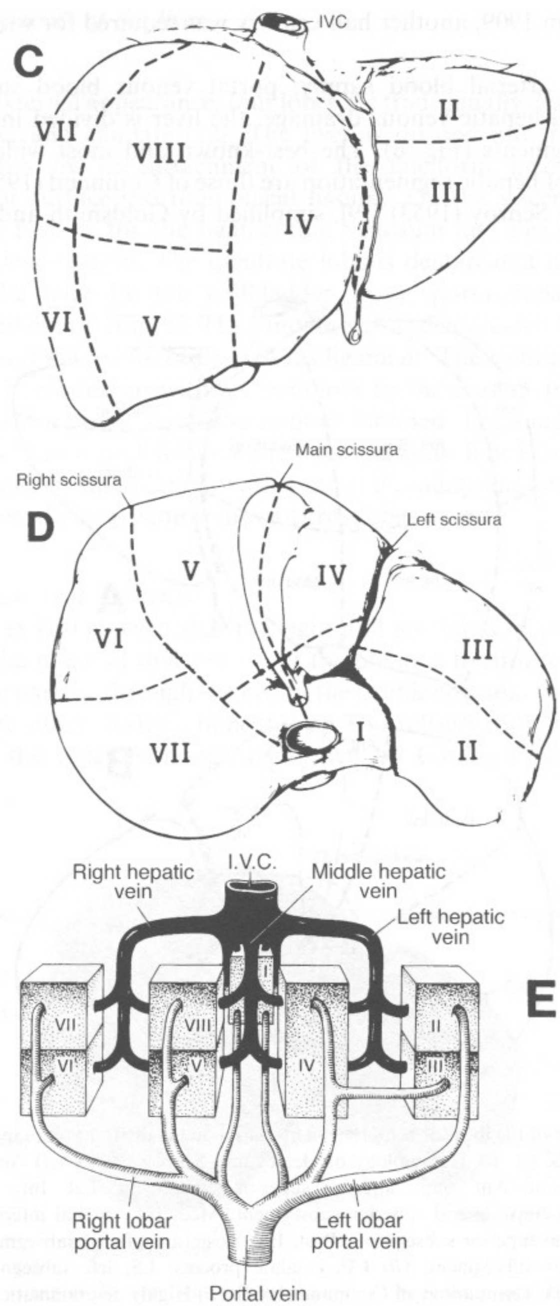

Fig. 6 (*continued*)

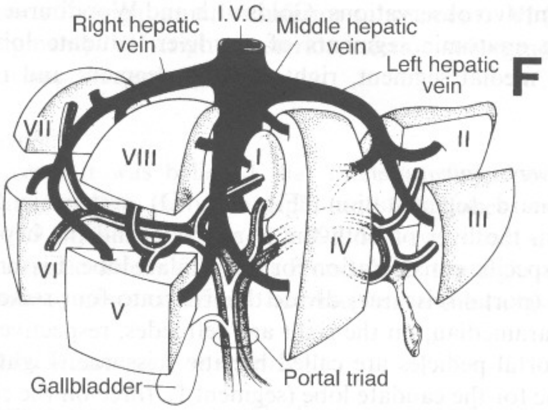

Fig. 6 (*continued*)

(1957) [24]; and those of Bismuth (1982) [25]. They are essentially very close to each other so that practical application is not impeded.

Healey and Schroy's liver segmentation

The system proposed by Healey and Schroy [19] in 1953 (Fig. 6A, B) is based on the distribution of bile ducts, which follows the distribution of portal vein branches [26]. Thus, a right liver (right part of the liver) and a left liver (left part of the liver) are described [12]. Topographically, the division between these halves (called functional lobes) follows a plane (called the principal plane, median fissure, Rex's line, or Cantlie's line) extending forward from the left side of the gallbladder fossa to the left side of the IVC. The caudal lobe is not considered as a separate lobe.

The left lobe is divided into a medial and a lateral segment by the plane defined by the falciform ligament and the portoumbilical fissure. The right lobe consists of an anterior and posterior segment, divided by the right fissure. Each segment is further divided into a superior and inferior subsegment by a transverse line. The plane of this fissure perhaps corresponds to the line of the eighth intercostal space.

Saxena et al [27] report that the quadrate lobe and the greater part of the caudate belong functionally to the left lobe of the liver, quoting the work of Hjortsjo [18] and Mizumoto and Suzuki [28]. Topographically, the quadrate lobe is a portion of the inferior half of the medial segment of the left lobe. Most of the topography of the caudate lobe is in the medial segment of the left lobe, but the caudate process continues into the right lobe. The caudate lobe is divided by the median fissure (interlobar plane) into right and left subsegments. Its bile ducts, arteries, and portal veins arise from both right and left main branches. The caudate lobe is drained by two small, fairly constant hepatic veins that enter the left side of the vena cava.

Based on in vivo observations, Goldsmith and Woodburne [24] described the following anatomic segments of the liver: caudate lobe, left lateral segment, left medial segment, right anterior segment and right posterior segment.

Couinaud's liver segmentation

The Couinard segmentation (Fig. 6C, D) system is based on the distribution in the liver of both the portal vein and the hepatic veins [26] and shows a specific consideration for the caudate lobe. Fissures of the three hepatic veins (portal scissurae) divide the liver into four sectors (segments), lateral and paramedian, on the right and left sides, respectively. The planes containing portal pedicles are called hepatic scissurae. Eight segments are described, one for the caudate lobe (segment I), three on the right (segments II, III, and IV), and four on the left (segments V, VI, VII, and VIII). In general, the segments of this classification correspond to subsegments of Healey and Schroy [19].

Couinaud's system of liver segmentation differs from Healey and Schroy's [19] system in several ways, however. According to Couinaud [22,26], a subdivision of segment IV and the caudate lobe into two parts is not justified. Furthermore, Couinaud asserted that a study of organogenesis and comparative anatomy suggests that the umbilical fissure is the hepatic scissura between segments III and IV [22]. For Healy and Schroy [19], however, the umbilical fissure is the plane of separation between territories of biliary (and consequently portal vein) branches between the medial and lateral segment of the left lobe [26].

At the close of the last century, several investigators, including Couinaud and coworkers, used the term segment IX for an area of the dorsal sector of the liver close to the IVC [29–32]. In 2002, however, Abdalla, Vauthey and Couinaud [33] wrote, "Because no separate veins, arteries, or ducts can be defined for the right paracaval portion of the posterior liver and because pedicles cross the proposed division between the right and left caudate, the concept of segment IX is abandoned." The genesis and death of segment IX is found in articles by Couinaud and other investigators [30–33].

Bismuth's liver segmentation

Bismuth [25] brought together his system of liver segmentation from the cadaveric system of Couinaud [21] and the in vivo system of Goldsmith and Woodburne [24]. He used the three fissures (scissurae) hosting the hepatic veins and a transverse fissure passing through the right and left portal branches. Bismuth described a right and left hemiliver divided by the median fissure, with each hemiliver having anterior (topographically medial) and posterior (topographically lateral) sectors (segments). He took into specific consideration the caudate lobe (segment I). The left lobe is thus divided into three segments: II (left lateral superior subsegment), III (left lateral inferior subsegment), and IV (left medial subsegment). The right lobe has four segments: V (right anterior inferior subsegment), VI (right anterior superior subsegment), VII (right posterior inferior subsegment), and VIII (right posterior superior subsegment).

Points to remember

For many years it was believed that there are few, inconsistant, and insignificant anastomoses between right and left lobes, except for the caudate lobe [19,24,34–36]. Mays [37–39], however, has shown that an occluded left hepatic artery fills with blood from the right side, and vice versa. These anastomoses could not be observed in the cadaveric studies.

Extrahepatic and intrahepatic vasculature

The liver has a dual blood supply from the portal vein and common hepatic artery. The portal vein is responsible for approximately 70% and the hepatic artery for 30% of the blood flow of the liver. In the liver, arteries, portal veins, and bile ducts are surrounded by a fibrous sheath, the Glissonian sheath [22]. Hepatic veins in the hepatic parenchyma lack such protection [10,26].

Arteries

Common hepatic artery

The common hepatic artery (Fig. 7A) takes origin from the celiac trunk (86%); other sources are the superior mesenteric artery (2.9%), the aorta (1.1%), and, very rarely, the left gastric artery [40]. The common hepatic artery then runs horizontally along the upper border of the head of the pancreas covered by the peritoneum of the posterior wall of the omental bursa. The gastroduodenal artery branches off the common hepatic artery posterior and superior to the duodenum. The common hepatic artery continues as the proper hepatic artery and turns upward to ascend in the lesser omentum, enveloped by the hepatoduodenal ligament, in front of the epiploic (Winslow's) foramen. Within the hepatoduodenal ligament, the proper hepatic artery lies to the left of the common bile duct and anterior to the portal vein. The portal vein, however, is located posteriorly or deeper to the proper hepatic artery and the common bile duct. Within the ligament the proper hepatic artery divides into right and left branches, called right and left hepatic arteries. Arterial distribution to different functional segments is identical to the distribution of portal vein [26].

Left hepatic artery

In 25% to 30% of cases, the left hepatic artery arises from the left gastric artery [35,40]. In 40% of subjects [41] the left hepatic artery branches into a median and a lateral segmental artery [12]. Other patterns often occur, however (Fig. 8A, B, C). The medial segmental artery supplies the quadrate lobe. The lateral segmental artery divides into superior and inferior arteries

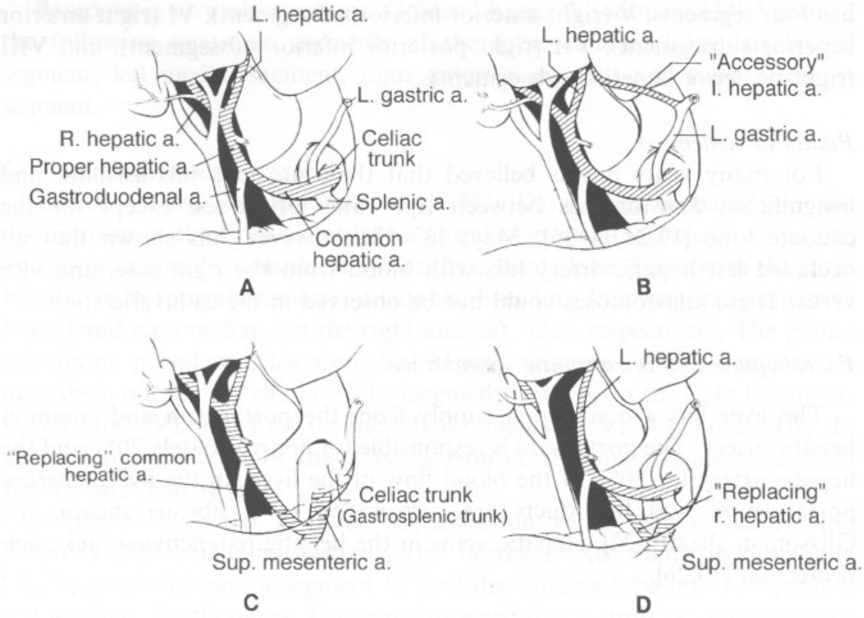

Fig. 7. Hepatic arteries. (*A*) "Normal" hepatic artery arising from the celiac trunk. (*B*) "Accessory" left hepatic artery arising from the left gastric artery. (*C*) "Replacing" common hepatic artery arising from the superior mesenteric artery. (*D*) "Replacing" right hepatic artery arising from the superior mesenteric artery. (*From* Skandalakis LJ, Gray SW, Colborn GL, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 4 – surgical anatomy of the hepatic vessels and the extrahepatic biliary tract. Contemp Surg 1987;31:25; with permission.)

for the respective subsegments as described by the Bismuth classification. Furthermore, the left hepatic artery gives off a branch for the caudate lobe, supplying its left side.

Right hepatic artery

In about 17% of subjects, the right hepatic artery branches from the superior mesenteric artery [35,42]. The right hepatic artery passes to the right behind (or occasionally in front of) the hepatic duct in front of the portal vein. Before entering the liver, the right hepatic artery gives off the cystic artery in the hepatocystic triangle located between the cystic duct and the common bile duct (Fig. 7A).

Within the liver or extrahepatically in the porta, the right hepatic artery divides into anterior and posterior segmental arteries [12], which divide further into superior and inferior arteries to supply the respective subsegments [4,25]. An artery for the caudate lobe also originates from the right hepatic artery and supplies the caudate process and the right side of the caudate lobe. These arteries are found under the respective bile duct branches [42].

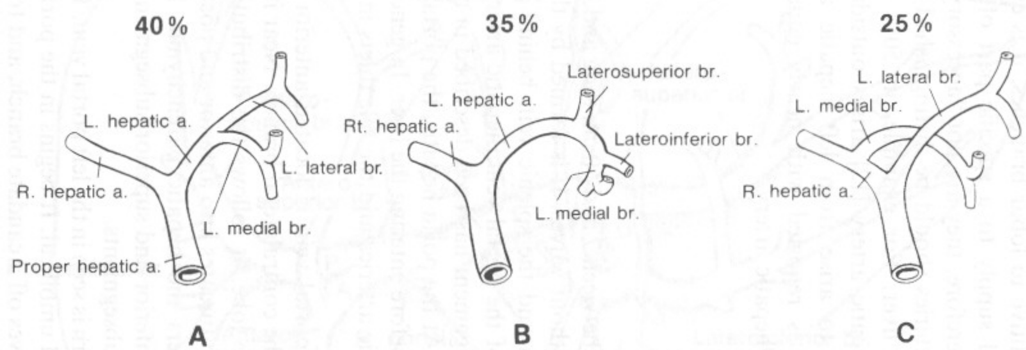

Fig. 8. Variations in the branching of the left hepatic artery. (*A*) Bifurcation into medial and lateral segmental arteries. (*B*) Division of the lateral segmental artery into laterosuperior and lateroinferior branches to the right of median fissure. The medial segmental artery arises from the lateroinferior branch. (*C*) The left medial segmental artery arises from the right hepatic artery, crossing the median fissure to reach the medial segment of the left lobe. (*From* Colburn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver. Part 3 – surgical anatomy of the liver and associated extrahepatic structures. Contemp Surg 1987;31:25; with permission.)

Aberrant hepatic arteries

Aberrant hepatic arteries (Fig. 7B–D) are found in about 45% of subjects [43]. If the arteries arise entirely from some source other than the celiac arterial distribution, they are called "replacing" arteries and can supply an entire lobe of the liver or even the entire liver. Although atypical hepatic arteries are commonly called "accessory" arteries if they arise from some aberrant source and are additive to lobar branches, it is evident that they provide the primary arterial supply to a specific part of the liver (lobe, segment, or subsegment); therefore, they are not "accessory" arteries.

These aberrant hepatic arteries should be distinguished from segmental arteries arising outside the liver. For example, in 50% of subjects the intermediate (or medial) hepatic artery [12] arises outside the liver [11]. Although it is considered to arise from left hepatic artery [12], the intermediate hepatic artery is reported with nearly equal frequency as a branch of the left or right hepatic artery.

Veins

Portal vein

The portal vein (Fig. 9) is between 7 and 10 cm long and between 0.8 and 1.4 cm in diameter and is without valves. It is formed by the confluence of the superior mesenteric vein and the splenic vein behind the neck of the pancreas. The relationship of the portal vein, hepatic artery, and bile duct within the hepatoduodenal ligament has been described in the discussion of the common hepatic artery. At the porta hepatis, the portal vein bifurcates into right and left branches before entering the liver. In general, portal veins are found posterior to hepatic arteries and the bile ducts in their lobar and segmental distribution.

The right branch of the portal vein is located anterior to the caudate process and is shorter than the contralateral branch. Near its origin it gives off a branch for the caudate lobe. It follows the distribution of the right hepatic artery and duct and bifurcates into anterior and posterior segmental branches as soon as it enters the hepatic parenchyma. Each segmental branch further divides into inferior and superior subsegmental branches for its respective parenchymal subsegments.

A different anatomic pattern is seen in the left portal vein. This long branch has two parts, transverse and umbilical. It begins in the porta hepatis as the transverse part [12], which gives off a caudate branch, and travels to the left. At the level of the umbilical fissure, the umbilical part turns sharply. It courses anteriorly in the direction of the round ligament and terminates in a cul-de-sac proximally to the inferior border of the liver [26]. Here it is joined anteriorly by the round ligament (ligamentum teres hepatis) [10]. Further on, the left portal vein divides into medial and lateral segmental branches, each with superior and inferior subsegmental branches. This anatomic pattern

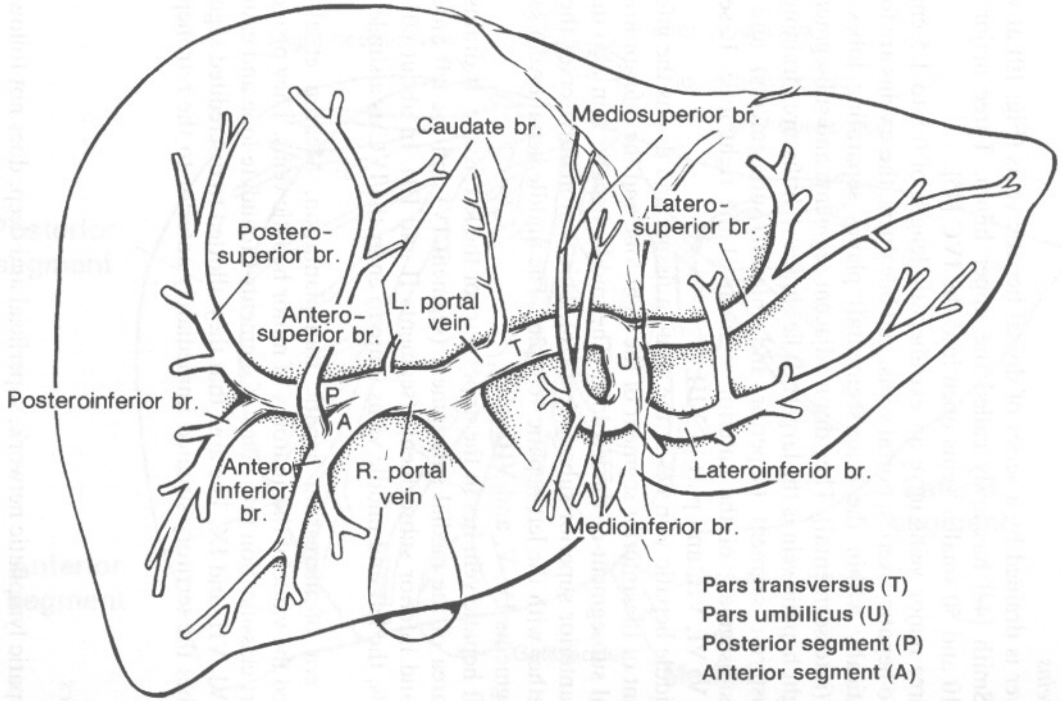

Fig. 9. Intrahepatic distribution of the hepatic portal vein. A, anterior segment; br, branch; P, posterior segment; T, pars transversus; U, pars umbilicus, the site of the embryonic ductus venosus. (*From* Colborn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 3 – surgical anatomy of the liver. Contemp Surg 1987;31:25; with permission.)

distinguishes the left portal vein from the left hepatic artery and bile duct: the umbilical part provides the superior and inferior subsegmental veins for the lateral segment and also provides the medial segmental veins from its right side [19].

Hepatic veins

The liver is drained by a series of dorsal hepatic veins (Fig. 10) at what Rodney Smith [44] has aptly called the upper hilum. Three major and between 10 and 50 smaller veins open into the IVC [45].

The three major veins have an extrahepatic length of 0.5 to 1.5 cm. In contrast to hepatic arteries, portal veins, and bile ducts, these veins are found intrahepatically within the (intersegmental) planes separating lobes and segments (intersegmental). They drain adjacent segments and subsegments.

The right hepatic vein is the largest. It lies in the right fissure, draining the entire posterior segment (superior and inferior subsegments) and the superior subsegment of the anterior segment of the right lobe. It serves segments V, VI, VII, and part of VIII.

The middle hepatic vein lies in the median fissure and drains the inferior subsegment of the anterior segment of the right lobe and the inferior area of the medial subsegment of the left lobe. The middle hepatic vein also drains the right anterior superior subsegment [26]. This vein mainly serves the left liver, together with the left hepatic vein [26]. The middle hepatic vein serves mainly segments IV, V, and VIII.

The left hepatic vein lies in the upper part of the left fissure. It drains the superior area of the medial subsegment (segment IV) and the left anterior superior and inferior subsegments (segments II and III). In about 60% of individuals, the left and middle veins unite to enter the IVC as a single vein [42].

In the era of increasing hepatic transplantation, Mehran et al [46] emphasized the value of the anatomy of minor hepatic veins. They proposed a four-part classification into veins of segments I (caudate lobe and caudate process), VI, VII, and IX. The area that they allotted to discredited segment IX describes the territory situated immediately anterior to the retrohepatic IVC.

Lymphatics

The hepatic lymphatic network, superficial and deep, does not follow the functional vasculobiliary organization. The superficial lymphatic system, located within the Glissonian sheath, travels toward the thorax and the abdominal regional lymph nodes. Lymph vessels pass the diaphragm mainly in the bare area or through Morgagni's foramen to reach anterior or lateral phrenic nodes (Fig. 11). These trunks join the internal thoracic artery lymph pathway as well as anterior and posterior mediastinal lymphatics [26].

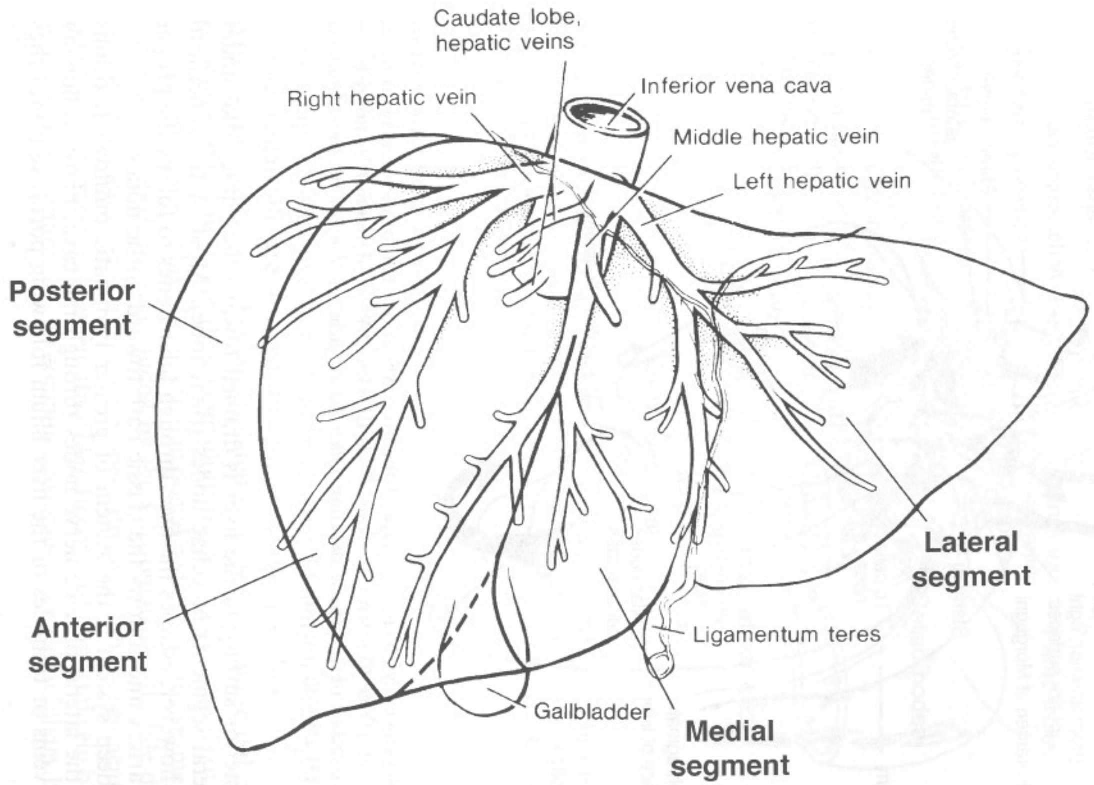

Fig. 10. Diagram of the intrahepatic distribution of the hepatic veins. The hepatic veins are located between lobes and segments rather than in them. (*From* Colborn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 3 – surgical anatomy of the liver. Contemp Surg 1987;31:25; with permission.)

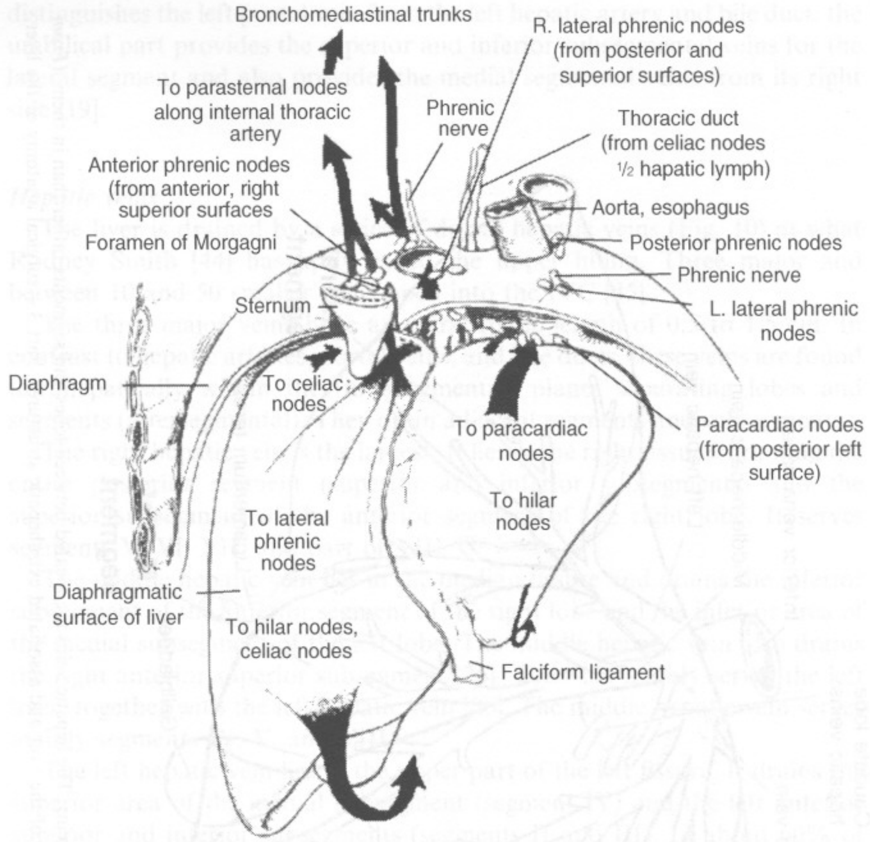

Fig. 11. Superficial lymphatic drainage of the liver. About one half of the drainage is to the thoracic duct. (*From* Colborn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 3 – surgical anatomy of the liver. Contemp Surg 1987;31:25; with permission.)

The posterior surface of the liver is drained toward the paracardial nodes (left lateral segment) or celiac nodes (right lobe). Most of the superficial stream, however, escapes the liver through hilar nodes to follow the proper hepatic artery and follows the classic path toward aortic nodes.

The deep system is the system of greater lymphatic outflow. It drains toward the lateral phrenic nerve nodes through the caval hiatus following hepatic veins or to nodes of the liver hilum following portal vein branches (Fig. 12).

Remember, however, that with hepatic venous obstruction, the trans-diaphragmatic pathway of hepatic lymph will reach the internal mammary and diaphragmatic lymph nodes. Niden and Yamada [47] report that part of the hepatic lymph reaches the tracheobronchial lymph nodes and then goes to the right lymphatic duct.

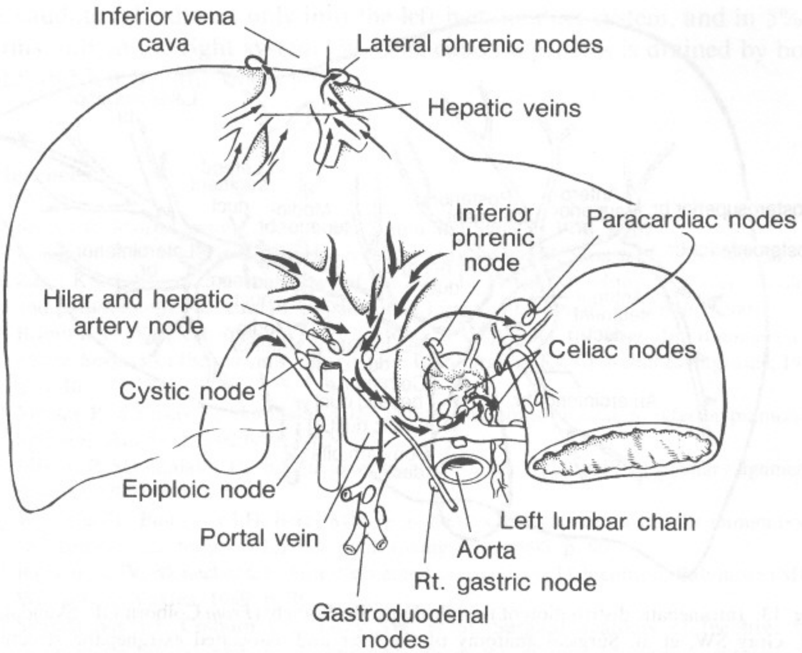

Fig. 12. Deep lymphatic drainage of the liver. The superficial and deep lymphatics anastomose freely. (*From* Colborn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 3 – surgical anatomy of the liver. Contemp Surg 1987;31:25; with permission.)

Intrahepatic biliary tract

Understanding the surgical anatomy of the biliary ductal system, including the gallbladder, is of great consequence in the study of hepatic anatomy. Following is a brief overview of the intrahepatic biliary tract (Fig. 13).

Bile canaliculi are formed by parts of the membrane of adjacent parenchymal cells, and they are isolated from the perisinusoidal space by junctions. Bile flows from the canaliculi through ductules (canals of Hering) into the interlobular bile ducts found in portal pedicles. In the segmental and subsegmental pedicles surrounded by the Glissonian sheath, bile ducts are found above and veins and arteries beneath [48]. Biliary segmentation is identical to portal vein segmentation [48]. In contrast to portal vein branches, which may communicate, no communication is observed in biliary branches [49].

The right hepatic duct

The right hepatic duct has an average length of 0.9 cm and is formed by the union of the anterior and posterior branches at the porta hepatis. Each branch is further bifurcated into superior and inferior branches to drain the

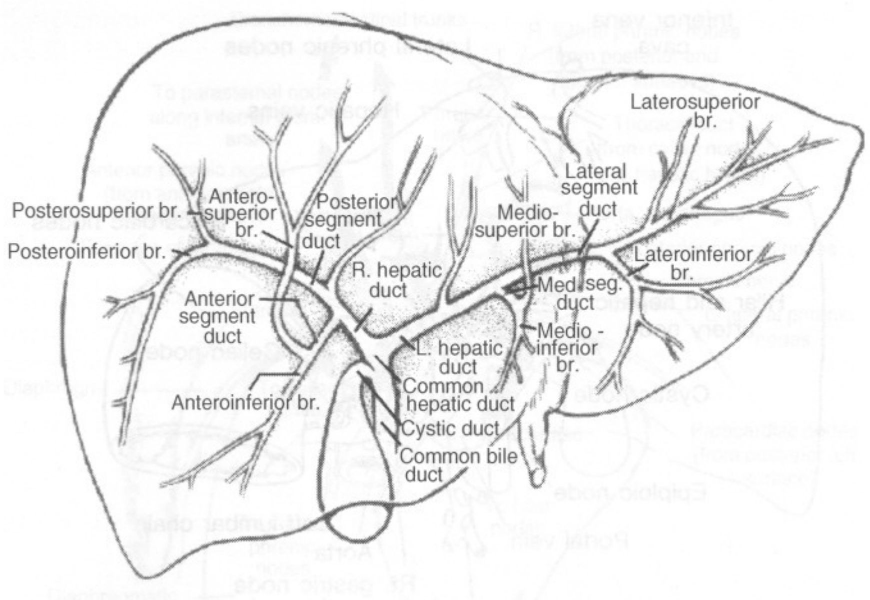

Fig. 13. Intrahepatic distribution of the bile ducts. Br, branch. (*From* Colborn GL, Skandalakis LJ, Gray SW, et al. Surgical anatomy of the liver and associated extrahepatic structures. Part 3 – surgical anatomy of the liver. Contemp Surg 1987;31:25; with permission.)

four subsegments of the right lobe: V (right anterior inferior subsegment), VI (right anterior superior subsegment), VII (right posterior inferior subsegment), and VIII (right posterior superior subsegment). This is the usual pattern, present in 72% of specimens examined by Healey and Schroy [19]. In the remainder, the posterior branch or, rarely, the anterior branch crosses the segmental fissure to empty into the left hepatic duct or one of its tributaries. In these cases the right hepatic duct is absent.

The left hepatic duct

Medial and lateral branches converge to form the left hepatic duct, which has as average length of 1.7 cm. Each branch is formed by superior and inferior branches of the respective subsegments. The left hepatic duct drains the three segments of the left lobe: II (left lateral superior subsegment), III (left lateral inferior subsegment), and IV (left medial subsegment). Segment IV is drained by mediosuperior and medioinferior branches. This typical pattern was met in 67% of Healey and Schroy's specimens [19]. The medial and lateral branches unite in the left fissure (50%), to the right of the fissure (42%), or to the left of the fissure (8%).

Caudate lobe drainage

The biliary drainage of the caudate lobe (segment I) enters both the right and the left hepatic duct systems in 80% of individuals [50]. In 15% of cases the caudate lobe drains only into the left hepatic duct system, and in 5% it drains only in the right system [50]. The caudate process is drained by both right and left hepatic ducts [10].

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