Surgery of the BILIARY PASSAGES AND THE PANCREAS

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ANATOMY AND PHYSIOLOGY

Surgical Anatomy

The area where surgery of the biliary passages takes place is one of the most complicated regions of the human body. It is not only a very vascular region, but one where injuries to vessels may be disastrous. Here anatomical variations are very common; some of them may be surgically important.

A thorough knowledge of its anatomy is as important for operative technique as for understanding pathogenetic interrelations.

We distinguish the *main biliary passage*—hepatic and common ducts, also called hepatocholedochus—and the *accessory biliary passage* —gallbladder and cystic duct; the first is linked to the liver by the *intrahepatic duct system,* and to the *pancreas* (embryologically a second accessory attachment) where it joins the duodenum. At the juncture is a physiologically very important and highly differentiated structure, the *sphincter apparatus of the papilla of Vater.*

The Main Biliary Passage

Topography

The main biliary passage is divided into five segments (Fig. 1):

1. The *hepatic duct:* from the juncture of the hepatic radicles to the juncture with the cystic duct.
2. The *supraduodenal part of the common duct:* from the entry of the cystic duct to the superior edge of the duodenum.
3. The *retroduodenal part* of the common duct.
4. The *retro- and intrapancreatic* part of the common duct.
5. The *intramural part* of the common duct which corresponds essentially to the Papilla of Vater.

The topographic relations of this tube in each of its five segments are important.

- In the *hilum of the liver* (Fig. 1) the hepatic duct lies ventral to and to the right of all the other structures in the hepatoduodenal ligament. It is formed outside of the liver parenchyma by the confluence of the right and left hepatic ducts. Their angle varies from 45 to 180°. Dorsal to this confluence there are two other bifurcations; namely, that of the portal vein and that of the hepatic artery. Dorsal and a little to the left from the confluence of the hepatic ducts, there is the bifurcation of the portal vein. In a layer between the portal vein and hepatic duct, there is the site of bifurcation of the *Arteria hepatica propria,* immediately ventral to the bifurcation of the portal vein. As the confluence of the hepatic duct is somewhat to the right of the two vascular bifurcations, it lies ventral to the right branch of the portal vein. The right branch of the hepatic artery crosses behind it; frequently the cystic artery originates there. The cystic artery runs with the right branch of the portal vein to the right, attaches itself ventrally to the cystic duct, and enters the gallbladder at the border of infundibulum and gallbladder neck.
- In the *hepatoduodenal ligament* (Fig. 1) the main bile passage forms the free edge of the ligament. A chain of lymphnodes accompanies it. The portal vein is dorsal to, and gradually draws away from, the common duct, turning toward the left. It forms the ventral border of the foramen of Winslow. The hepatic artery, accompanied by the hepatic plexus, follows the portal vein; attached to its ventral surface. At the superior contour of the duodenum, the hepatic artery and the portal vein separate. The hepatic artery does not go behind the duodenum, but gives off the gastroduodenal artery and the right gastric artery at the superior border of the duodenum. The stem of the common hepatic artery reaches the hepatoduodenal ligament from left and cranial in an arcade.
- In the *retroduodenal part* the structures of the hepatoduodenal ligament split up altogether. The common duct curves toward the right, is attached, for a short distance, to the posterior wall of the duodenum, and finally reaches the pancreas, which sometimes sends a few glandular lobules into the space between it and the duodenum. The portal vein comes from left and posterior to the head of the pancreas.
- In the *retropancreatic part* the common duct runs within the fibrous capsule of the pancreas and, in 90% of the cases, also within the paren-

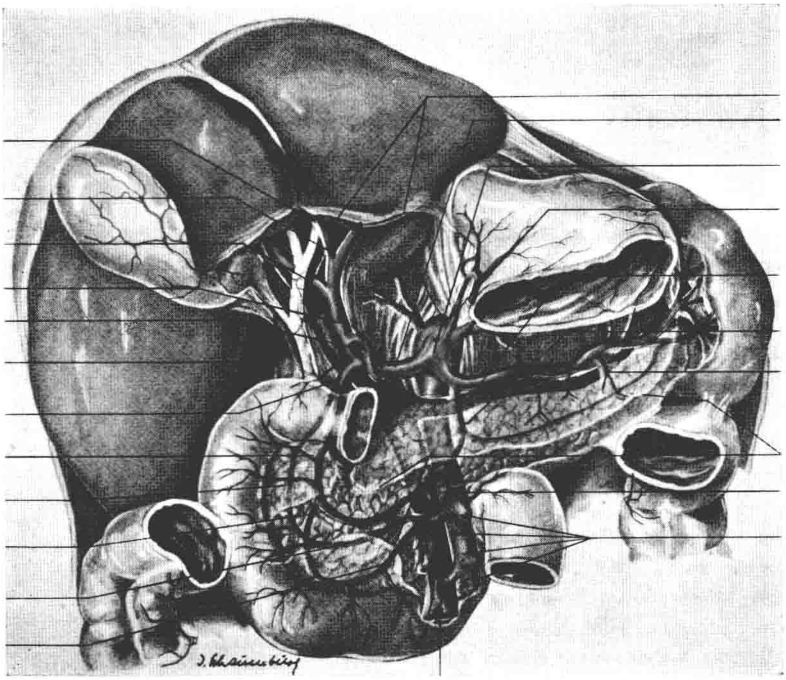


Fig. 1. *Topography of the bilio-pancreatic organ systems. Survey of the arterial blood supply.* The omental bursa has been opened by removing the stomach and the hepatogastric ligament. The transverse mesocolon has been detached from pancreas and duodenum. Note the course of the severed peritoneal reflections.

chyma of the pancreas. The portal vein and the superior mesenteric vein lie to the left and dorsal to it. It has no direct relations to other organs. The superior pancreaticoduodenal artery lies to the right of and ventral to the choledochus, and crosses it somewhat farther below, again to anastomose, running toward the left, with the inferior pancreaticoduodenal artery.

Toward posterior, the common duct touches the vena cava and the right renal vein, separated from them only by Treitz's fascia. Toward ventral, the head of the pancreas covers it and the pancreatic duct crosses it ventrally within the parenchyma of the pancreas.

- The *intraduodenal (intramural) part* of the choledochus pierces the three layers of the wall of the duodenum obliquely. This part is from 10 to 30 mm long, usually less than 15 mm. *The site where the choledochus enters the duodenum varies considerably.* The middle of the descending part of the duodenum is considered the normal site of the papilla; however, it may be as close as 2 cm to the pylorus (in which case there is no retroduodenal or pancreatic part) or, more frequently, it is displaced caudally, close to the duodeno-jejunal flexure. Finally, the choledochus projects with its terminal part into the lumen of the duodenum forming the papilla proper, whose length ranges from 2 to 12 mm.

Histology

The inside of the main biliary passage is covered with columnar epithelium. There is a subepithelial layer with numerous tough connective tissue fibers, which makes for the solid consistency of the wall. This fibro-elastic layer may contain scant smooth *muscle fibers,* but Negri found no muscular elements in 85% of the hepatic and in 65% of the common ducts he examined. Their significance is debated: while some animals show true peristalsis of the common duct [dogs (Audigé, Laborde), guinea pigs and rabbits (Westphal)], their occurrence in man is doubtful. Cholangiograms occasionally show muscular contractions of the choledochus in its lower part but their physiological significance is debatable. Also we still do not know whether there is a *sphincter of the common hepatic duct* as Mirizzi assumed on the basis of cholangiograms. He felt it prevented reflux into the liver when the gallbladder contracted actively. One often does find on cholangiograms a sphincter-like structure above the juncture with the cystic duct. Newer anatomical studies (Schreiber, Lang) have demonstrated circular and spiral muscle fibers in this area, but we cannot be sure about their functional importance, the less so as these findings are inconstant, and because artifacts, kinks, etc., frequently make pictures resembling those that led to the concept of Mirizzi's sphincter.

In the deeper parts of the fibro-elastic layer there are *mucous glands* whose apertures (crypts) appear as regularly spaced stipples on the whitish mucous membrane.

In the adventitia there is a rich network of vegetative fibers and a well-developed *lymphatic system,* as well as numerous arterial and venous branches, which supply the duct, and which sometimes make annoying bleeding when one exposes it. A fine fat layer, 1 to 2 mm thick, is covered by the serosa of the hepatoduodenal ligament.

Anatomical Variants

Duplication of the choledochus is very rare as is the bifurcation into two ducts terminating separately in the duodenum. In the few cases observed there were no clinical disturbances (Whipple, Mentzer, Flint, Eisendrath, Boyden).

The congenital cyst of the common duct is discussed on page 107.

Diverticula of the choledochus are also very rare. We have seen two cases in 1654 cholangiograms. They are almost always in the retropancreatic part. One must not confuse them with *pseudodiverticula* created by stones (see page 62).

Accessory hepatic ducts are of practical importance. According to Michels they occur in 18% of all people. We found nearly as high an incidence (15%) in cholangiographic studies. The caliber of accessory hepatic ducts varies from that of a capillary to 2 to 3 mm. They are remnants of the embryonal hepatoduodenal ducts (Fig. 2). Strangely, they occur much more frequently to the right of the hepatocholedochus than to the left. Out of 42 observed cases:

25 terminated into the common hepatic duct,
6 into the right hepatic duct,
2 into the left hepatic duct,
4 into the cystic duct,
4 into the common duct, and
once there was a double accessory hepatic duct terminating into the common duct and into the common hepatic duct.

Of such accessory ducts, those running to the cystic duct and to the right hepatic duct are of surgical importance. They can be confused with the cystic duct and tied, the more so as they often do not represent isolated structures but

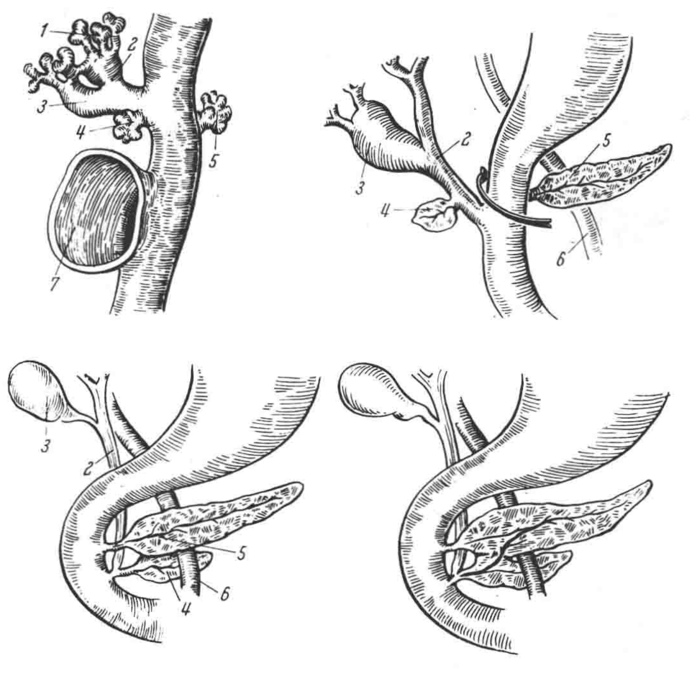
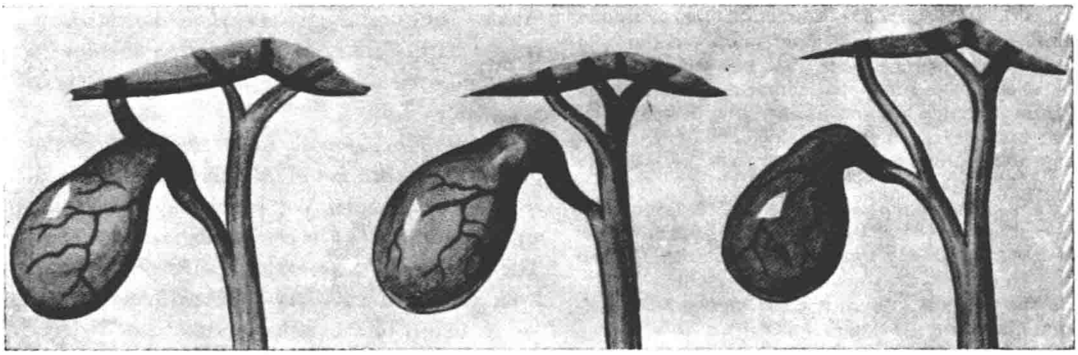


Fig. 2. *Embryonal development of biliary passages and pancreas* (modified after K. Ludwig: "Zur Entwicklungsgeschichte der Leber, des Pankreas and des Vorderdarmes," Anat. Hefte, *61:* 515 (1919), and after Netter, F. H.: "Liver, Biliary Tract and Pancreas," CIBA Collection of Medical Illustrations, 1958). 1. Anlage of the liver. 2. Anlage of the hepatocholedochus. 3. Anlage of the gallbladder. 4. Ventral pancreas anlage. 5. Dorsal pancreas anlage. 6. Portal vein. 7. Omphaloenteric duct.



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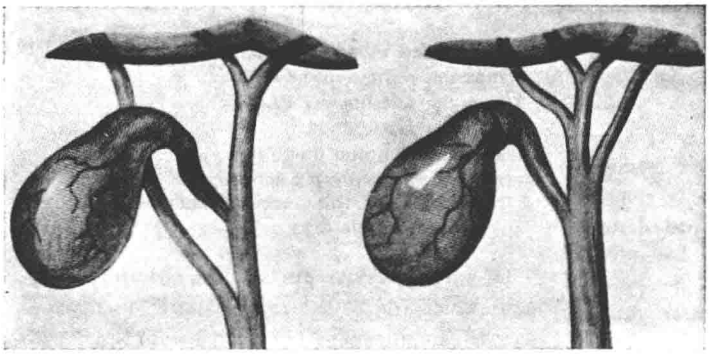

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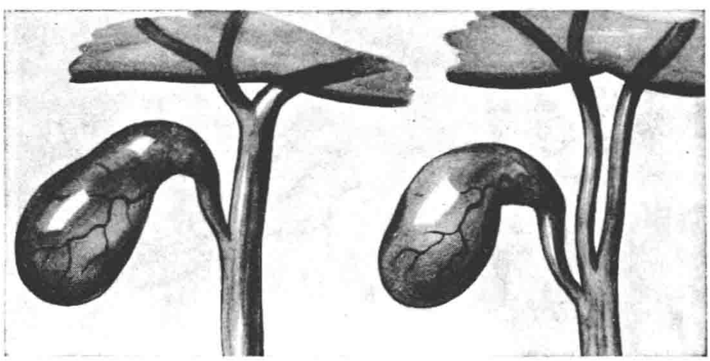

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Fig. 3. *Variants of the hepatic duct.* a) Accessory hepatic duct terminating into the cystic duct (special case of hepatocystic duct), also described as absence of the cystic duct with termination of the gallbladder directly in the right hepatic duct. b) Accessory right hepatic duct terminating into the common hepatic duct. c) Accessory right hepatic duct terminating into the cystic duct. d) Accessory right hepatic duct terminating into the choledochus. e) Accessory right and left hepatic ducts both terminating into the common hepatic duct. f) Accessory left hepatic duct. g) So-called deep bifurcation of the hepatic duct.

are hidden in the gallbladder bed (*subvesicular ducts*). Tying them off is practically unimportant unless the accessory hepatic duct drains a large part of the liver; if such were the case the secretion pressure might become high, the ligature might slip, and a biliary fistula might develop. Ligature of an accessory hepatic duct does not result in jaundice.

The Choledochoduodenal Sphincter Apparatus (Sphincter of Oddi)

This anatomically and functionally differentiated structure includes the confluence of choledochus and pancreatic duct as well as, in some cases, their joint continuation, the ampulla, the muscle apparatus surrounding these ducts, and finally the mucosa, which is the duodenal covering of the papilla. This structure pierces the wall of the duodenum whose musculature opens at this place like a window. The passage is oblique to the axis of the duodenum if it is located in the vertical part of the duodenum, however, it is nearly perpendicular to it if the papilla lies in the lower horizontal part of the duodenum.

The Confluence of the Choledochus and Pancreatic Duct

The confluence of the choledochus and the duct of Wirsung is quite variable in height of entry, angle of entry and formation of an ampulla. The numerous studies (Millbourn 1944, Schmieden and Sebening 1927, Judd 1931, Holzapfel 1930, Mann and Giordano 1923, Hjorth 1947, Couvelaire 1934, Werthemann 1931, Nätäänen 1941, Mehnen 1938, Caroli and Nora 1951), of these variants have elucidated the frequency of the various forms. The best subdivision is that of Millbourn who distinguishes *three types* (Fig. 17):

1. *Juncture of choledochus and pancreatic duct; joint passage* to the tip of the papilla (86%).
2. *Juncture only in the tip of the papilla;* both ducts enter the duodenum in a *joint opening* (6%).
3. *No juncture at all;* each duct has its *own opening* into the duodenum: the two openings may be a few millimeters apart from each other (8%).

The *first type* has four subgroups:

a) *there is an ampulla* into which both ducts enter (6%)
b) *only the choledochus forms an ampulla* into which the pancreatic ducts enter from the side (4%)
c) *there is no ampulla.* The *pancreatic duct enters from the side* (72%)
d) *there is no ampulla, the choledochus entering the pancreatic duct from the side* (4%).

All these subdivisions, of course, are somewhat arbitrary and all kinds of transitional arrangements occur. There seem to be also racial differences (for instance, between Japanese and Americans, Nagai and Sawada 1925). The above figures, based on analysis of our cholangiograms, *show a communication of both duct systems in 86%;* however, bile does not enter the pancreatic duct nor does pancreatic secretion enter the biliary passages in that high a percentage. To what extent fluid passes from one system into the other depends largely on the activity of the sphincter muscles and on abnormal changes that may be present.

Functionally the various anatomical variants do not appear to be very important; the presence or absence of a true papilla particularly, is of no obvious importance. Caroli has even shown that bilio-pancreatic reflux is not limited to the first type, but occurs also in the other two types, namely by way of the duodenum.

The Sphincter Muscle

The long history of Oddi's sphincter is dominated by the discussion of whether it is an independent muscle or part of the duodenal musculature. The newer studies of Dardinsky, Boyden and Kreilkamp, and of Negri have established that it is an independent muscle. Negri and Boyden's detailed research has also shown that this sphincter consists of *three systems:*

1. *A sphincter of the papilla proper* with circular, semicircular, and longitudinal fibers (the so-called "pylorulus" of Westphal), which reaches to the tip of the papilla and closes it against the lumen of the duodenum.
2. *A sphincter of the choledochus,* the most powerful part of the muscle apparatus, 8–15 mm wide; its lower part lies intramural, and the upper part extramural. The lower fibers partially surround the ampulla or the pancreatic duct also; its contraction seals one system against the other. The upper part of its fibers forms the sphincter choledochus proprius, nearly always easily recognizable on cholangiograms by a constriction corresponding to its upper edge.
3. *A pancreatic sphincter,* weak and probably inconstant. According to Negri's anatomical studies, it occurs only in 20% of all cases. However, cholangiograms show a certain narrowing of the terminal pancreatic duct much more often (62%).

It seems that the action of the musculature varies with the type of termination of the ducts (see page 16). According to the height and the size of the confluence angle, for instance, a contraction of the muscle can promote or inhibit bilio-pancreatic reflux. Therefore, physiologic conclusions from the anatomical picture of the sphincter apparatus are permissible only within limits.

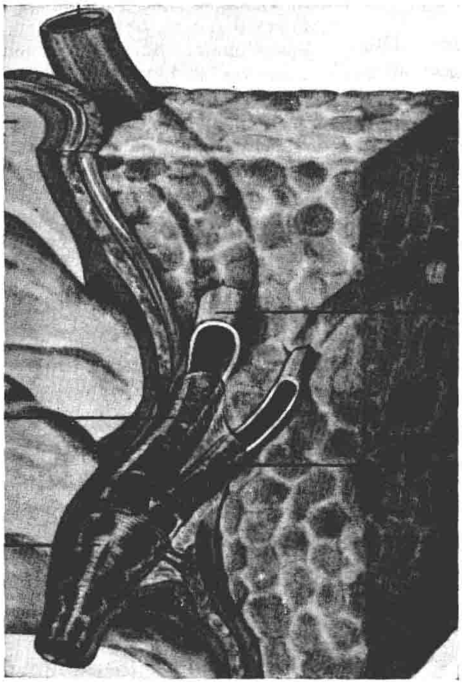


Fig. 4. *Cross-section through the papilla of Vater* (modified after E. A. Boyden, Surgery *10:* 569 [1941]). Semidiagrammatic.

The Mucosa

The mucosa of the intramural part is quite different from that of the rest of the common duct. While it is smooth in its extraduodenal course, there are longitudinal mucosal folds, 2 to 4 cm long, in its terminal parts, sometimes giving the impression of *villi* or small polyps. They are absent in the last 2 mm of the papilla. No doubt they are normal. Together with the musculature they make for physiologic narrowing of the lumen of the papilla; one must keep this in mind when one interprets cholangiograms. The folds and *villi* are visible on many cholangiograms.

Mucous glands occur in the entire choledochus but are especially outspoken in its terminal part (Letulle, Nattan-Larrier, Matsuna). Their glandular bodies are larger here, and are so far away from the lumen that they enter into close anatomical relations to the smooth musculature of the sphincter. "Few organs, except maybe the prostate," says Letulle, "show so rich a combination of musculature and grape-like glandular bodies." In older people, especially in men, there may occur a true hyperplasia, an *adenomyomatosis* (Fig. 33) (Baggenstoss, Caroli).

The mucous membrane covering the exterior of the papilla also shows strong fold formation. A constant fold (plica duodenalis major) covers the papilla like a roof. Usually there is also another, less conspicuous fold, vertical, about 2 cm long, drawing from above toward the opening of the papilla and continuing below the papilla and soon splitting up like a fork. All these folds tend to hide the site of the papilla rather than to emphasize it. In fact, it is often difficult to find the papilla from the lumen of the duodenum even on very careful search. At best the palpating finger may feel the prominence of the intraduodenal part, but this prominence varies also because often it is no larger than 1 or 2 mm. Only rarely does one see a trunk-shaped papilla 1 to 2 cm long.

The Variable Site of the Papilla

Anatomy texts state that the papilla is found normally in the descending part of the duodenum. *Only in about 40% is the papilla found in the classical position.*

The papilla may appear cranial to this site, as close as 2 to 3 cm to the pylorus. In a few cases it was even found in the stomach. More common is caudal "displacement" of the papilla, into the neighborhood of the lower knee of the duodenum or the lower, horizontal part of the duodenum and even close to the duodeno-jejunal flexure.

These variants are not rare; caudal displacement occurs in 4.8%.

Practically, this means that it is altogether impossible to predict the site of the papilla. The papilla is located wherever it pleases. If one has to look for it, one has to locate it by cholangiogram or by a probe. The site of the papilla is also functionally important. In high as well as in low implantation, the choledochus approaches the duodenum nearly at a right angle, and the intramural part is not oblique but perpendicular to its wall. This often produces an *insufficient closure of the biliary passage against the duodenum,* and on X-ray pictures one often finds *duodeno-biliary reflux,* especially in high implantation.

The Accessory Biliary Passage: Gallbladder and Cystic Duct

The Gallbladder

About one-third of the surface of the gallbladder is attached to the inferior surface of the liver; two-thirds are covered by serosa. We distinguish the *fundus, corpus* (the part that is attached to the liver), and *infundibulum* (the part that is not attached to the liver and is comparatively motile between two leaves of peritoneum, also called Hartmann's pouch). It blends into the *collum,* which is characterized by a kink toward the right, corresponding to an interior mucosal fold. The cystic duct again emerges with a kink toward the left from the collum, which results in an s-shaped curvature of the entire system (*siphon*).

There are topographical relations of the fundus to the transverse colon, and of the corpus and collum to the duodenum.

The normal gallbladder holds 30 to 50 ml, but when dilated, up to 200 ml and more. Its mucosa has a columnar epithelium arranged in regular folds giving a net-like appearance. A certain cholesterol content (0.5 to 1.7%, Boyd) is normal. The gallbladder has no submucosa; the mucosa lies on a fibromuscular layer consisting of musculature and a rich elastic fiber system. The musculature, studied in detail by Hendrickson 1898, Lütkens 1926, and Nuboer 1931, is not a continuous layer as in the gut but consists of longitudinal internal and spiral external fiber systems, especially well developed in the fundus and in the infundibulum.

The gallbladder wall contains a few formations of surgical importance: *mucous glands* are especially numerous in neck and fundus. Their glandular body is tubuloalveolar and lies outside the muscle layer that is pierced by the ducts. Inflammatory hyperplasia can convert them into diverticulum-like structures, the so-called pseudodiverticula or sinuses of Rokitansky-Aschoff (Rokitansky 1842). They may become surgically important (see page 66).

Occasionally aberrant biliary ducts run from the liver into the adventitia. They are called *true ducts of Luschka.* They do not communicate with the lumen of the gallbladder. They have been confused at times with accessory cystic ducts (see page 14). They are of little pathologic importance.

The Cystic Duct

The cystic duct is extremely variable in length, course, and shape.

Usually it is 3 to 4 cm long but it may be as long as 8 or as short as 1 cm. Near the collum, in the *pars spiralis,* it is narrow and has folds, and is, therefore, barely soundable. Its lower part, the *pars glabra,* is wide, has a smooth mucosa, and is easily soundable.

Leaving the collum at an acute angle, the cystic duct runs obliquely toward the left, toward caudal, and toward anterior. Its origin is close to the hilum of the liver, its course often nearly parallel to the infundibulum. It is hard to describe a normal type because there are innumerable variants. The cystic duct may form large loops toward the hilum of the liver or toward the infundibulum; it may be short and straight, running directly from the collum toward the hepatic duct. In general, short cystic ducts terminate high, and long ones low. Also, the cystic duct may be absent altogether. In that case, the collum is attached to the main biliary passage like a diverticulum.

The Valvulomuscular Collum-Cystic Duct System

Collum and cystic duct bear a functionally very important sphincter mechanism. As early as 1853 Tobien had demonstrated a thickening of the muscularis in the area of the collum, but

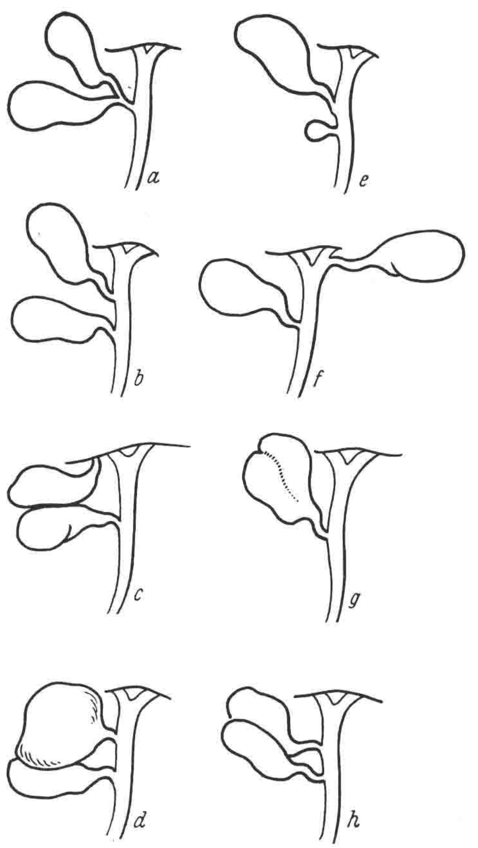


Fig. 5. *Various types of double gallbladders.* a) Double gallbladder with common cystic duct. b) Double gallbladder with two independent cystic ducts. c) Double gallbladder, one with a hepatocystic duct. d) Double gallbladder, one with an evacuation obstacle. e) Double gallbladder, one rudimentary. f) Double gallbladder, one terminating into the left hepatic duct. g) Double gallbladder with common serosa cover (septate gallbladder), common gallbladder neck and common cystic duct. h) Double gallbladder, fused externally, but with two cystic ducts.

not until 1926 did Lütkens describe in detail the collum-cystic duct sphincter, now named after him. This, however, is a sphincter much more in a physiologic than in an anatomical sense. There is an increase of muscle fibers only in the collum and in the first part of the cystic duct, very variable in extent, site, and length (Nuboer, Negri, and Ferracini). In order to understand fully the importance of these muscular components, one must consider them in connection with the spiral valve system, which originates from the terminal fold between collum and cystic duct, and which fills the duct near the collum. These spiral valves give the lumen the shape of an irregular corkscrew. The normal difference in pressure between the gallbladder and the common duct is produced by the collaboration of the musculature and the spiral valves and probably also by the angle of the kink between collum and cystic duct.

The *height of the termination of the cystic duct* also varies a great deal. In about two-thirds of all cases (71% of our cholangiograms) the cystic duct terminates "normally": running obliquely downward to the hepatocholedochus, and thus dividing it into the shorter hepaticus and the longer common duct. In another 18% its downward course is steeper, and it terminates so low that the hepatic duct is longer than the common duct. In 2% the cystic duct joins the main biliary passage in a right angle. In 1.5% the cystic duct runs not downward but upward and terminates close to the bifurcation (0.5%), or even in the bifurcation itself (0.25%), or in the right hepatic radicle (0.75%). The remaining cases are true variants discussed on page 14.

The Triangle of Calot

The space between the liver, the main biliary passage, and the accessory biliary passage, the triangle of Calot, is very important topographically. Its confines are the liver, the cystic duct, together with the collum of the gallbladder, and the main biliary passage, usually the common hepatic duct or, in the case of a deep bifurcation, the right hepatic duct. This space may be large or small according to the height of the termination of the cystic duct. In this space the surgeon has to look for the cystic artery; *in the majority of cases, it leaves the right hepatic artery within this triangle.* The hepatic artery crosses the upper left corner of this triangle. *In the depths of the triangle* runs the *right branch of the portal vein.* Nearly always there is also a fairly large lymphnode (node of Mascagni) within this triangle. In the depth of the triangle one finds a part of the fibers of the posterior hepatic plexus.

Besides these normal structures one often finds abnormal structures in this area: aberrant hepatic ducts (see page 6), or aberrant hepatic arteries (see page 19).

Anatomical Variants of the Gallbladder

a) Isolated Agenesis of the Gallbladder

Agenesis has been described in several hundred cases. In a collective statistic covering 1,352,000 autopsies, Monroe has found 181 cases, *i.e.,* one out of 7,500 autopsies. Two-thirds of these also show other malformations (one-fourth of them malformations of the biliary passages and of the pancreas). In the remaining one-third, agenesis was the only malformation, and did not always cause clinical symptoms. In a few cases (12) there were common duct stones; in others, pancreatitis. As a rule there is no vicarious dilation of the common duct. *Not every absence of the gallbladder is a congenital agenesis;* it is hard to believe, but shrinkage may result in complete disappearance of this organ.

b) Duplication of the Gallbladder (Fig. 5)

Duplication occurs about once in every 4,000 cases. It is quite common in the cat (12%). Rarely is it of pathological importance. The various types are shown in Fig. 5. Usually there are two cystic ducts entering separately into the choledochus or, more rarely, joining into one duct before reaching the common duct. Both gallbladders may be of normal shape, each having its own cystic artery. In other cases one organ may be dilated, malformed, or, as in one of our cases, attached like a diverticulum to the cystic duct of a normal gallbladder.

c) Vesica fellea divisa (Fig. 5g)

The longitudinally divided gallbladder is rare. It is a special form of double gallbladder: the two structures are covered by one coat of serosa-muscularis. On the outside one sees only a faint crease. On the inside, however, there is a mucosal septum that divides the organ into two halves, usually down to the collum.

d) Septate Gallbladder

Transverse septa are much more frequent (1:800). They usually lie toward the fundus and separate about one-third of the lumen from the main lumen as a transverse septum. They consist of connective tissue, and bear mucosa on both sides. The smaller compartment communicates with the main lumen by an opening that may be large or small; its size seems to determine whether there are clinical symptoms (Fig. 6). *Most described cases were asymptomatic.* However, occasionally, so also in one of our cases, patients had *colics* and one could demonstrate by radiomanometry during surgery a pressure difference between the two lumina, suggesting a stenosis, overcome only when the pressure had risen to a pain-producing level. Presumably this has also been described occasionally as a fundal diverticulum of the gallbladder (Toida). This septum cannot be seen from the outside of the gallbladder but is easily demonstrable radiologically (Figs. 55, 56). Occasionally one finds chronic cholecystitis in one or in both chambers, but patients may have

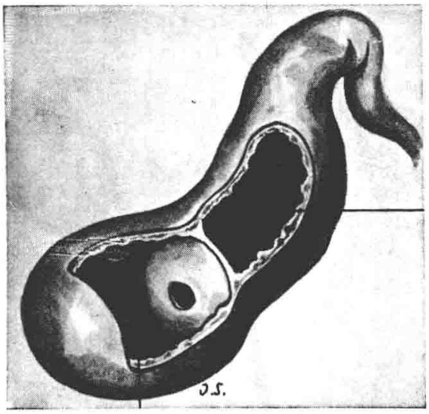


Fig. 6. *Gallbladder with a transverse septum* (own observation). The passage from the fundal chamber to the main cavity, through a perforated septum, occurred only under abnormally high pressure and with pain; the main cavity emptied normally through the cystic duct.

complaints even though the walls are perfectly normal in either chamber.

e) Diverticula of the Gallbladder

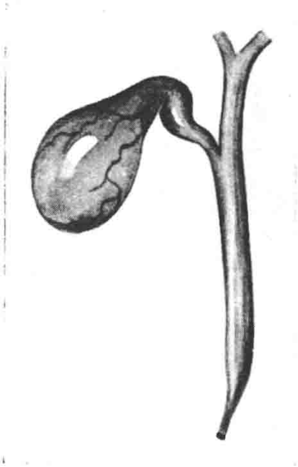
True diverticula are rare. We found only 2 in 1400 cholecystectomies. The Mayo Clinic found 25 in 29,701 cases. They must be distinguished from *pseudodiverticula,* which are the deep niches of mural ulcers produced by stones, and also from septate gallbladders and hypertrophic Rokitansky-Aschoff's sinuses. Most true diverticula are in the neighborhood of the gallbladder neck and are asymptomatic; Gross thinks they are *remnants of embryonal hepatocystic ducts.* Stones can form in diverticula.

f) Trabeculated Gallbladder

Frequently one finds trabecula in the fundus of the gallbladder. Possibly they are not basically different from gallbladder septa; they may represent a less pronounced form of the same developmental disturbance. This form makes no symptoms. However, trabecula, true fold formations in the area of the collum and infundibulum, which are not at all rare, may often result in disturbances of the evacuation of the gallbladder (see page 116).

g) The "Phrygian Cap"

This is by far the most frequent malformation of the gallbladder and is, at the same time, the least important one. Boyden found it in 18% of all gallbladders. It consists of a strange kink at the extreme fundus, which produces a very characteristic radiologic picture. When pronounced, the gallbladder is hook-shaped. This malformation is surely congenital even though it is mostly diagnosed in adults.



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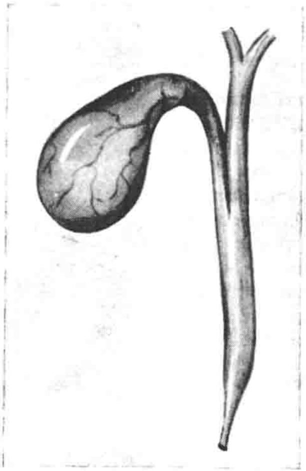

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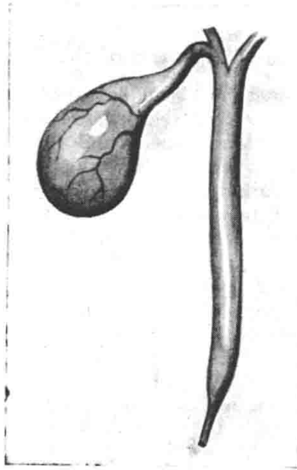

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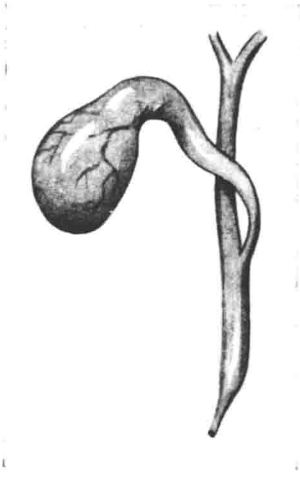

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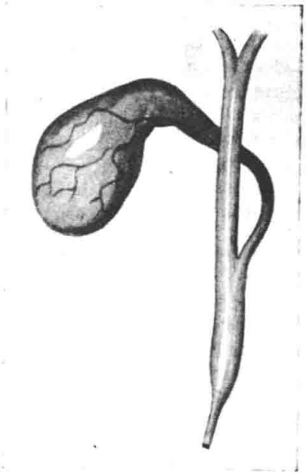

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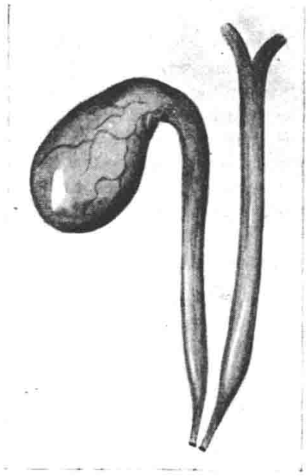

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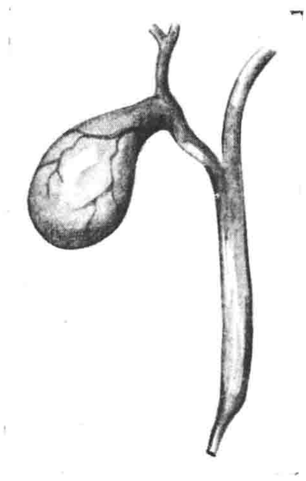

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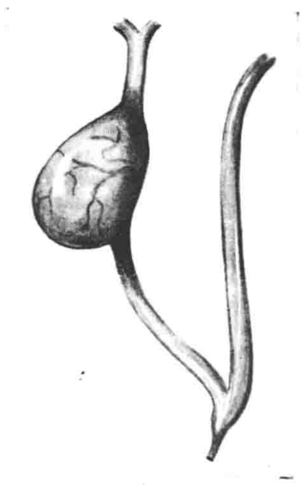

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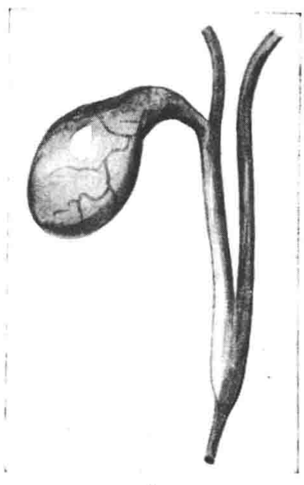

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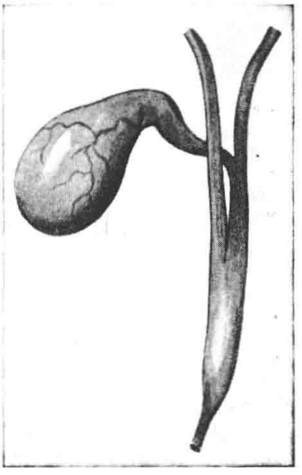

k

Fig. 7. *Variants of the cystic duct.* a) So-called normal situation. b) Deep termination of the cystic duct. c) High termination of cystic duct into right hepatic duct. d) Anterior spiral course of the cystic duct. e) Posterior spiral course of the cystic duct. f) The cystic duct terminates directly into the duodenum (very rare) g) Termination of the right hepatic duct as a strong hepatocystic duct into the infundibulum. h) The gallbladder is formed as a diverticulum of the right hepatic duct, there is no true cystic duct (compare Fig. 3a). i) Termination of the cystic duct into the right hepatic duct with deep confluence of the hepatic ducts. k) Termination of the cystic duct into the left hepatic duct with dorsal crossing of the right hepatic duct.

Since Barthel first described it in 1916, there has been an endless discussion on the Phrygian cap's clinical significance. We know now that it does not cause symptoms. Contrary to Barthel's original assumption, a Phrygian cap gallbladder is not likely to lead to stone formation. Demonstration of this anomaly alone does not justify operation.

h) Micro- and Macrogallbladders

Bulgarelli and Bertolotti have found that size deviations of the gallbladder occur relatively often in prematurely newborn infants; later they tend to become normal; sometimes they persist. Oversized and undersized gallbladders occur. In 502 cases these authors found *11 macro- and 19 microgallbladders.* Neither of these abnormalities needs to impair function. In the congenital macrogallbladder, however, the musculature is poorly developed in relation to the size of the organ. This poses the still unsettled question whether some of the atonic gallbladders in adults go back to congenital macrogallbladders.

i) Intrahepatic Gallbladder (Parenchymal Gallbladder)

Gallbladders entirely hidden in the parenchyma of the liver are quite rare but *partially intrahepatic position is found often.* Intrahepatic position is not diagnosable by X-ray and is discovered only on surgical exploration. To find such a gallbladder is difficult, and to remove it is even more so. *Sixty per cent of adults with this anomaly have gallstones;* it appears proven that intrahepatic gallbladders are more often afflicted with stone disease than normally placed gallbladders, possibly through impeded emptying; however, one should keep in mind that in many animals the gallbladder is normally intrahepatic. Probably this anomaly is an *inhibition malformation,* as in early embryonal life the gallbladder always first lies within the liver and only later migrates to the surface. Intrahepatic gallbladders, therefore, are *often found in children.*

j) The Pendulous Gallbladder

If the gallbladder has lost its fixation to the undersurface of the liver altogether, and has become mobile in its entire extent, suspended on a true *mesentery* ("mesocystium"), we call it a pendulous gallbladder. In surgery we find this in about 4% of the cases. The mesentery may extend over the entire length of the gallbladder or it may involve only its fundal and corporal part. Then, the fundus is especially freely mobile. *This form predisposes to torsion of the gallbladder* (see page 111). A tendency to stone formation in pendulous gallbladders has not been proven.

k) Aberrant Pancreatic Tissue in the Wall of the Gallbladder

Such tissue has been described in only seven cases. None of them had symptoms. This is surprising because of the alleged importance of pancreatic juice for the etiology of chronic cholecystitis.

l) Transposition of the Gallbladder

Transposition to the left (in patients without situs inversus) has been described so far in only eleven cases; nine times the cystic duct terminated in the right hepatic and twice in the left hepatic. Only in one case was there a normal right anlage besides the left transposed gallbladder. A gallbladder that is transposed to the left usually lies under the falciform ligament, leaving the gallbladder fossa empty. This anomaly is compatible with normal function.

Hepatocystic Ducts and Variants of the Cystic Duct

a) Hepatocystic Ducts

These ducts are *liver ducts* that terminate in the gallbladder itself, unlike Luschka's ducts that *penetrate only into the wall of the gallbladder.* One can consider them *special cases of accessory hepatic ducts.* Figure 2 explains their embryonal origin.

Their caliber may be large or small, according to the size of the liver territory they drain. Most of them are less than 1 mm in caliber. Hepatocystic ducts of small caliber are probably normal; they are usually ignored in cholecystectomy. However, they may explain postoperative bile drainage. Rarely hepatocystic ducts are large ducts draining a large area of the liver; they must be ligated. They are easy to demonstrate in intraoperative cholangiograms, unless the gallbladder is full of stones.

b) Duplication of the Cystic Duct

Duplication without simultaneous duplication of the gallbladder is extremely rare.

c) Parallelity of the Cystic Duct

Instead of joining the hepatic duct in an acute angle, the cystic duct may run parallel to the hepatic duct and join it only retroduodenally or even intrapancreatically. Usually both ducts are firmly grown to each other and often the septum consists of mucosa only, so one may easily mistake the structure for the choledochus. This anatomical variant does not interfere with function but is important because it almost necessarily makes for a long cystic duct stump in cholecystectomy. This variant occurs in about 11% of all operative cases.

d) Spiral Course of the Cystic Duct

Instead of terminating into the choledochohepatic duct on the right side, the cystic duct may terminate on its anterior wall, on its left side, or even on its back side by running in a spiral course around the hepatic duct, usually posterior to it. One finds this in 4.6% of operative cases. Although spirality does not interfere with emptying of the gallbladder, operative dissection, especially in posterior spirality, may lead to an injury of the hepatic duct.

The Pancreas

Topographic Relations

The head of the pancreas is firmly grown to the duodenum with its convexity that points toward the right; only about half of the first (horizontal) part of the duodenum is free and is covered all over with serosa; all the rest of the duodenum is firmly joined to the pancreas. This relation ceases only at the duodeno-jejunal flexure. Attachment of the pancreas begins where the *gastroduodenal artery* crosses the duodenum posteriorly. This vessel gives off the two *vascular arcades* between pancreas and duodenum that supply blood to both these organs; therefore, surgically the pancreas and the duodenum cannot be treated separately.

The upper mesenteric vessels run *behind the head of the pancreas.* They emerge at the uncinate process under the pancreas to *cross the duodenum.* Behind the head of the pancreas the mesenteric vein and the splenic vein (the latter coming down from the upper edge of the pancreas) form the *portal vein,* which appears at the superior edge of the head of the pancreas to enter the hepatoduodenal ligament. The pancreas crosses the spinal column at the level of the first lumbar vertebra, however, without touching the vertebra directly. Between its posterior surface and the vertebrae there is, on the right, the *inferior vena cava,* just touched by the head of the pancreas and separated from it by loose connective tissue and on the left, the aorta, which gives off there the superior mesenteric artery. *Between the pancreas and the aorta* lies the *celiac plexus* and its continuation, the superior mesenteric plexus. Toward the left the posterior surface of the pancreas is related to the *left kidney* and especially to the *left adrenal,* which is attached rather firmly to the tail of the pancreas.

The *anterior surface of the pancreas* forms a part of the *posterior wall* of the *omental bursa* and is covered by serosa. Therefore, a large part of the anterior aspect of the pancreas is closely related to the posterior wall of the stomach. One reaches the anterior aspect of the pancreas by severing the gastrocolic ligament and turning the stomach toward cranial. A limited part of the body of the pancreas can be inspected easily by bluntly severing the flaccid part of the gastrohepatic ligament, entering