
South College PA 5530
Fundamentals of Surgery

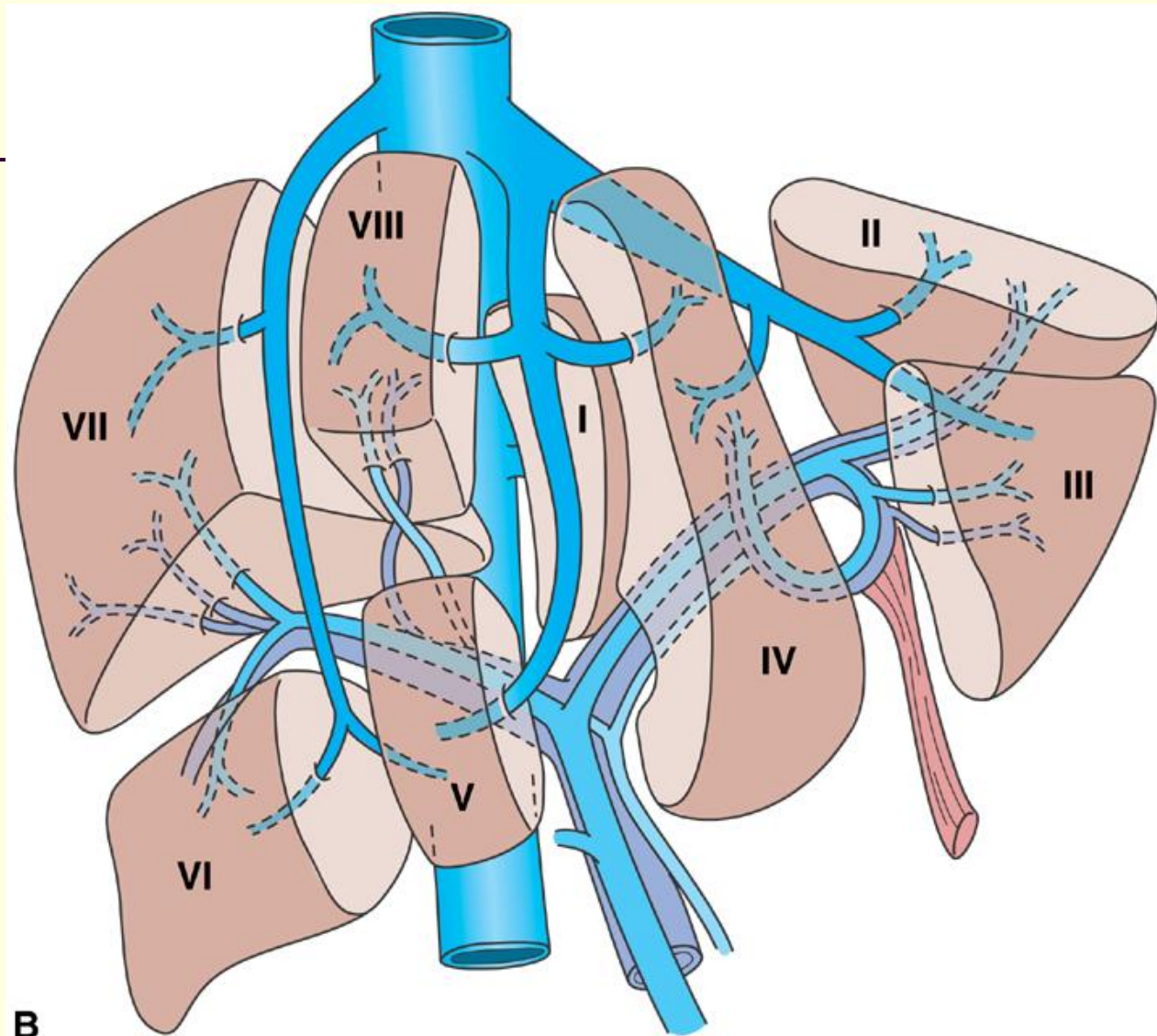
Liver

ANATOMY

- The liver is the largest solid organ in the body, weighing about 1.5 kg in the adult.
- Lies in the right upper quadrant of the abdomen and is completely protected by the thoracic rib cage.
- Completely surrounded by a peritoneal membrane, known as Glisson's capsule.

Segments

- One of the greatest advances in hepatic surgery is understanding of segmental anatomy of the liver.
- The translation of understanding surgical segmental anatomy to axial radiologic imaging is important in evaluating diagnostic computed tomographic (CT) or magnetic resonance imaging (MRI)



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FIGURE 58.4B Functional divisions of the liver and liver segments according to Couinaud's nomenclature.

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Portal Vein/Hepatic Veins

- The portal vein is a valveless structure that is formed by superior mesenteric vein and the splenic vein.
- The portal vein provides approximately 75% of the total liver blood supply by volume.
- The normal pressure in the portal vein is between 3 and 5 mm Hg.
- The majority of the venous drainage of the liver occurs through three hepatic veins.

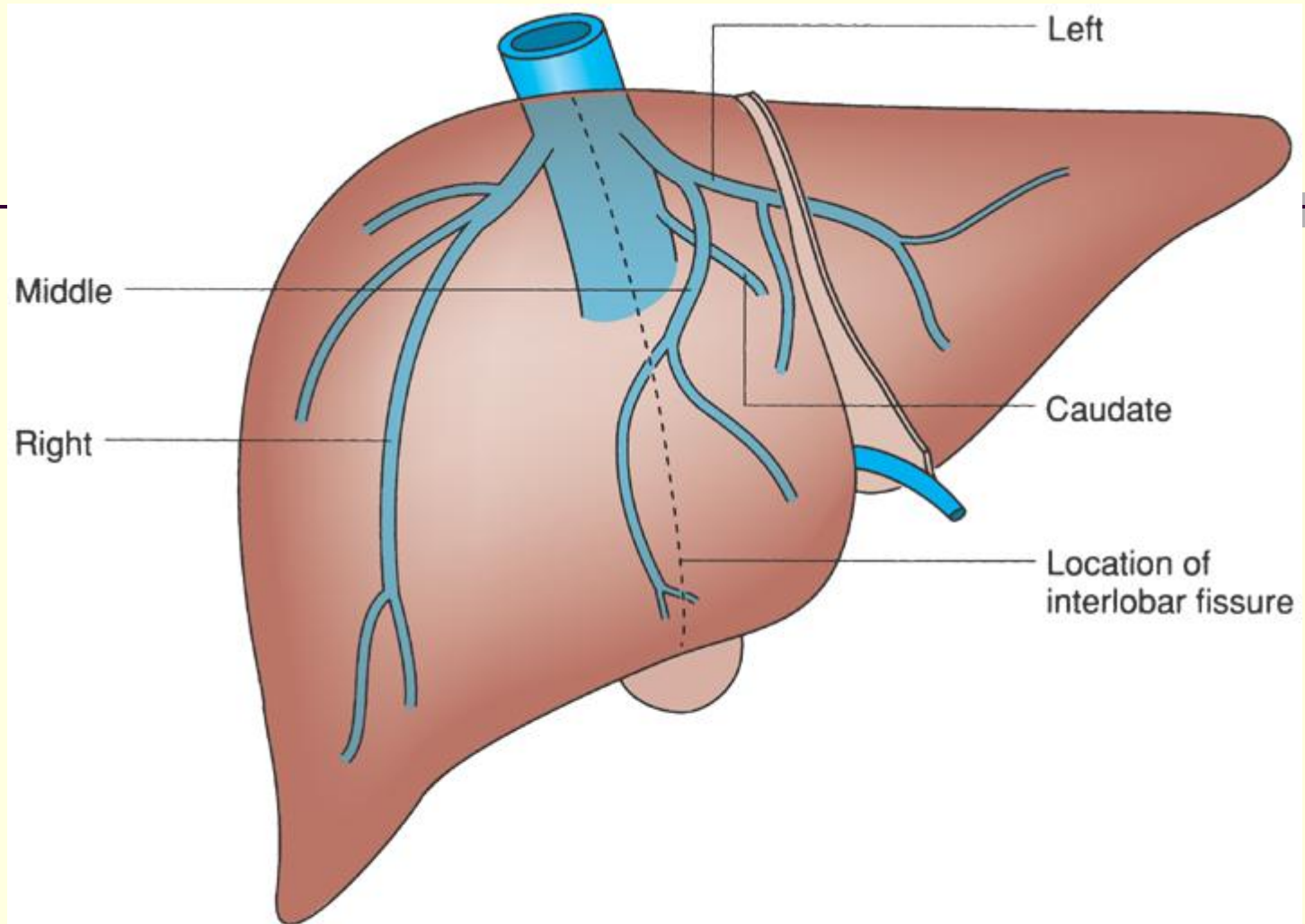


FIGURE 58.5 Three major hepatic veins drain the liver. The caudate segment of the liver usually drains directly into the inferior vena cava.

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Hepatic Artery

- Hepatic arterial anatomy is part of the portal triad and follows the segmental anatomy.
- Replaced hepatic arteries are lobar vessels that arise from either the superior mesenteric artery (replaced right hepatic artery) or left gastric artery (replaced left hepatic artery).

Biliary System

- The bile duct arises at the cellular level from the hepatocyte membrane, coalesces to form canaliculi.
- Canal of Hering results from the coalescence of canaliculi. Larger collections form small ducts.
- The hepatic bile duct confluence gives rise to the common hepatic duct
- A normal common bile duct is less than 10 mm in diameter in the adult.

D Replaced right hepatic artery

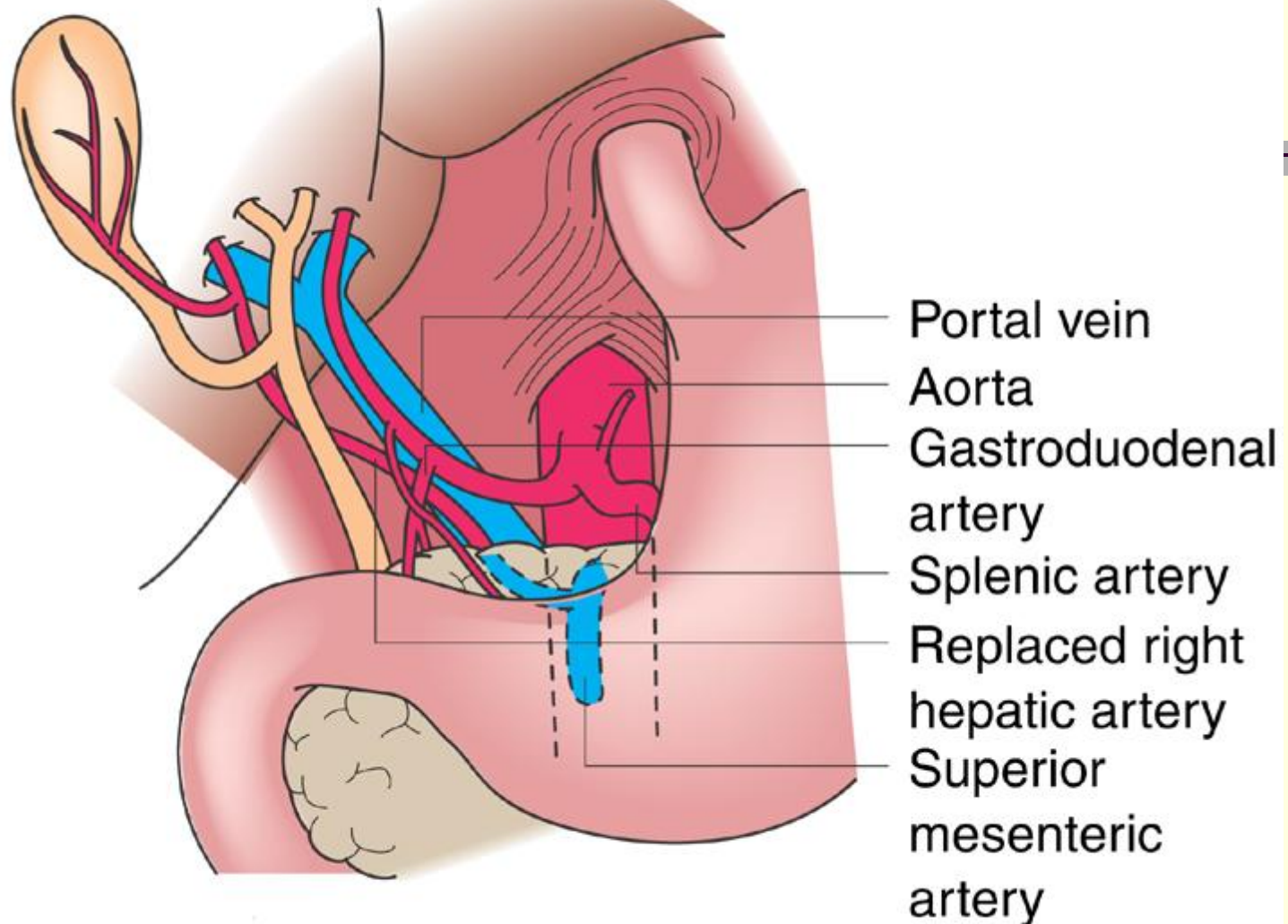


FIGURE 58.13D Variations in the origin and course of the hepatic artery and its relationship to the bile ducts.

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Lymphatics

- The spaces of Disse and clefts of Mall produce lymph fluid at the cellular level

Neural Innervation

- Parasympathetic fibers from hepatic branches of vagus and both parasympathetic and sympathetic

Microscopic Liver Anatomy

- The microscopic anatomy of the liver is best understood through the description of the acinar unit
- Construct involves an afferent portal venule, hepatic arteriole, and a bile ductule flowing antegrade
- While hepatic venules feed the sinusoids most directly, the hepatic arterioles are more closely adherent to biliary ductule structures and may play an important role in bile homeostasis.
- Hepatic arterioles also feed into the sinusoids and contribute to oxygen gradient across zones
- The liver is also the largest repository of the reticuloendothelial system.

SYNTHETIC FUNCTIONS

- Hepatocytes are metabolically active, polarized cells found in plate-like orientations in the acinus.
- Liver is crucial to production and release of a variety of circulating factors critical to coagulation

Carbohydrate Metabolism

- The liver is a critical storage site of glycogen and is essential to the maintenance of systemic glucose
- Also metabolizes lactate, and Cori cycle is important in maintaining peripheral glucose availability

Lipid Metabolism

- The liver is an important modulator of lipid metabolism, performing a critical role in the synthesis of lipoproteins, triglycerides, gluconeogenesis from fatty acids, and cholesterol metabolism.

Bilirubin Metabolism

- The excretion of bilirubin, a product of heme metabolism from erythrocytes, occurs in bile.
- Bilirubin circulates bound to albumin in the blood.
- Benign disorders of bilirubin metabolism include Dubin-Johnson and Rotor's syndrome, which produce conjugated (direct) hyperbilirubinemia.
- Unconjugated hyperbilirubinemia is seen in Crigler-Najjar type II and Gilbert's syndromes.
- Crigler-Najjar type I causes neonatal kernicterus and invariably is fatal

Bile and the Enterohepatic Circulation

- Bile is a mixed micelle composed of bile acids and pigments, phospholipids and cholesterol, proteins, and electrolytes
- Function: small intestinal absorption of fats and vitamins
- Production of bile by hepatocytes is active process that occurs at the level of the canalicular membrane
- The bile ductules and ducts actively change the water content of bile, and the volume of bile secreted in an adult ranges from 500 to 1000 mL/24 h.
- Distal ileum reabsorbs bile salts - resection of the ileum leads to malabsorption and steatorrhea.

Bile and the Enterohepatic Circulation

- **Cholic acids and chenodeoxycholic** acids are important primary bile acids.
- Secondary bile acids include **deoxycholic and lithocholic acids**, formed by intestinal bacteria.
- Enterohepatic circulation -95% of bile acids actively recirculated
- Bile acids are critical to the solubilization of intestinal lipids
- Bile acids form salt micelles that are critical for the absorption of intestinal lipids; likewise proteins within the intestinal mucosa combine with lipids to form lipoproteins.
- A complex series of molecular signals and enzymatic reactions occurs to regulate bile acid production.

INTERPRETATION OF LIVER TESTS

- Liver tests are broken down into tests of liver function, parenchymal injury, and biliary obstruction
- Function: Albumin and PT (all clotting factors but VIII)
- Parenchyma: AST and ALT
- Biliary obstruction: Alk Phos, GGT, Bi (>>direct)

Radiologic Evaluation of the Liver

Ultrasound

- Transcutaneous ultrasound is frequently the first radiologic evaluation performed on the liver
- Ultrasound is test for identifying biliary tract stones and intrahepatic biliary ductal dilation.
- In studies from the United States and Europe, ultrasonography has been shown to be superior to serum alpha-fetoprotein (AFP) measurement to detect early HCC in patients from chronic viral hepatitis
- IOUS can be performed laparoscopically or during laparotomy
- Placement of the probe directly on the surface of the liver enhances discrimination and sensitivity.
- IOUS is necessary for intraoperative image-guided procedures, biopsy, radiofrequency ablation (RFA)

Radiologic Evaluation of the Liver

Computed Tomography Scan

- Modern CT scans are helical and are highly sensitive at spatial discrimination and quantization
- CT remains the preferred method for evaluating the remainder of the abdomen

Magnetic Resonance Imaging

- MRI technology also is rapidly advancing
- MRI is somewhat less sensitive at spatial discrimination of lesions, but provides additional tumor characterization benefits that are not available with CT scanning
- MRI scans are slightly less accurate than helical CT in detecting the extent of colorectal liver metastases, but are more sensitive for detecting early HCC and in distinguishing HCC

Nuclear Medicine Studies

Positron Emission Tomography

- Positron emission tomography (PET) is a whole-body, multiaxial technology that has been used to detect a variety of cancers including melanoma, breast cancer, and colorectal

Nuclear Medicine Studies.

- Scans using radioactive octreotide, a somatostatin analogue, can be used in the evaluation and treatment of patients with neuroendocrine tumors
- Cells possess receptors to somatostatin, and study can be used to document the extent of tumor burden.
- ^{99}Tc -labeled red blood cell scans are useful in identifying atypical hemangiomas; this study relies on the pooling of radiolabeled red blood cells within the vascular hemangioma.

Angiography

- Angiography is becoming less important in the evaluation of liver tumors, as CT and MRI technology allows for the definition of vascular anatomy and characterization

Diagnostic Laparoscopy

- The last step in liver imaging to be considered is diagnostic laparoscopy.
- The goal of the preoperative evaluation in hepatic neoplasms is to detect surgically treatable disease
- Avoiding morbidity and longer hospitalization in patients who are not candidates for curative resection

LIVER FAILURE

- Liver failure can be divided into two general categories: *acute* and *chronic*.
- Twenty-five thousand people die each year from cirrhosis, making it the eighth leading cause of death from disease in the United States.
- *Cirrhosis* is a histologic term that describes generalized hepatic fibrosis and nodular regeneration
- Grossly, cirrhosis can be described as micronodular, macronodular, or mixed.
- CT findings of cirrhosis can be subtle, but include right lobe atrophy, ascites, caudate lobe hypertrophy, recanalization of umbilical vein, enlargement of the portal vein caliber and splenomegaly

Risks of General Surgical Procedures in Portal Hypertension

- Child classification - risk of portocaval venous shunt
- Laparoscopy = reduced rate of complications
- Laparoscopic chole is safe in Child class A and B
- In elective procedures, preoperative control of ascites, electrolyte abnormalities, and coagulopathy are critical
- Prevention of postoperative ascites begins with restriction of sodium-containing intravenous fluids
- Ascites accumulates, continued fluid restriction, diuretic therapy, bedrest, and intermittent paracentesis
- Chronic peritoneal catheter drainage is avoided - risk of contamination

Child – Turcotte – Pugh Classification

Marker	1	2	3
Ascites	Nil	Slight	Mod + >>>
Enceph	Nil	Mod	Severe
Bi	< 2.0	2 -3	> 3.0
Albumin	> 3.5	2.8 – 3.5	< 2.8
PT	13	17	> 18

Child – Turcotte – Pugh Classification

Score	Class	Mort %
5 – 6	A	5
7 – 9	B	15
10 – 15	C	50

Portal Hypertension

- Portal hypertension may be classified as presinusoidal, sinusoidal, or post-sinusoidal
- Sinusoidal causes are the most common in the Western Hemisphere due to alcoholic cirrhosis
- First imaging test should be a transcutaneous liver ultrasound with Doppler blood flow assessment.

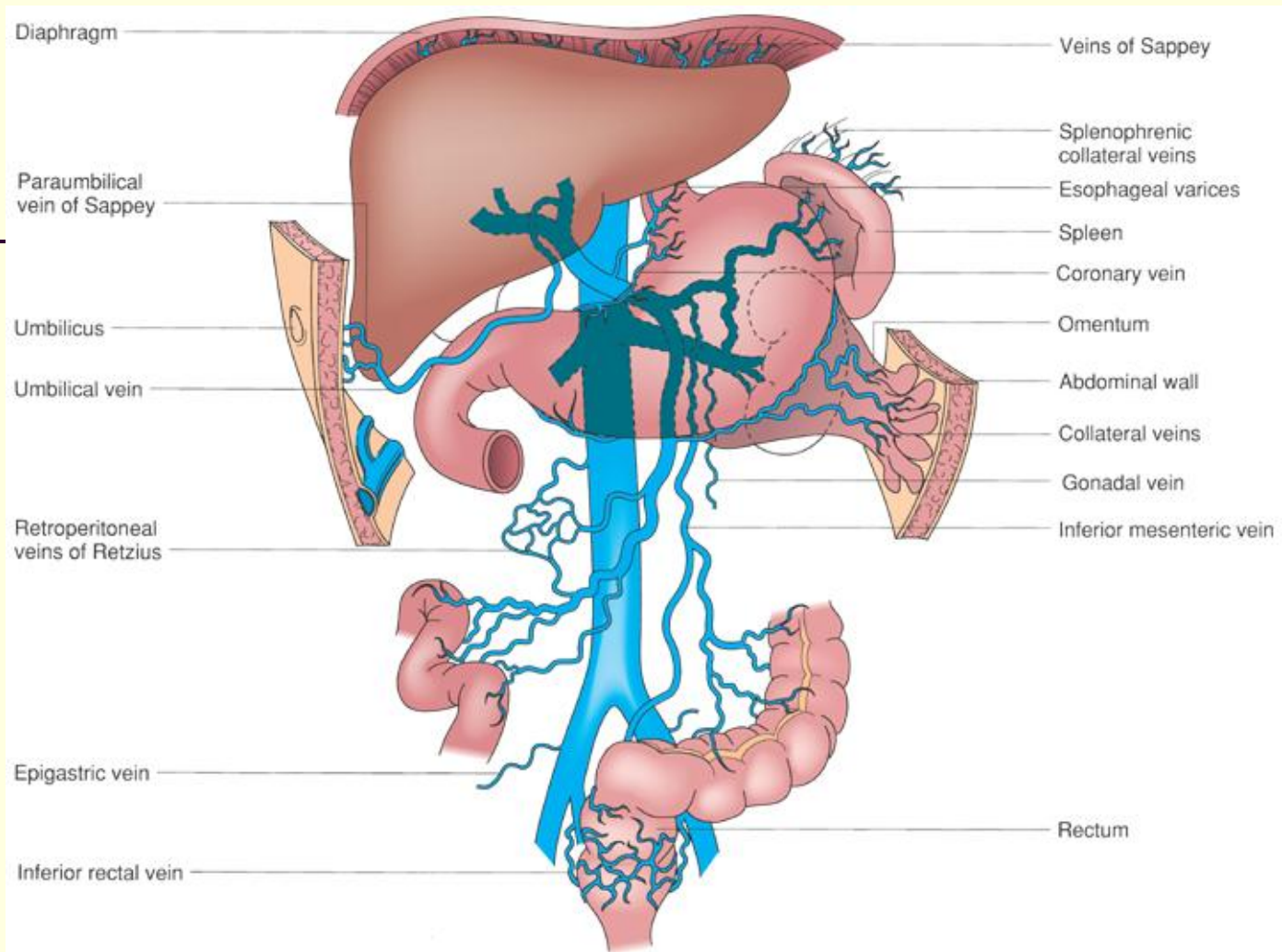


FIGURE 60.5 Potential venous collaterals that develop with portal hypertension. The veins of Sappey drain portal blood through the bare areas of the diaphragm and through paraumbilical vein collaterals to the umbilicus. The veins of Retzius form in the retroperitoneum and shunt portal blood from the bowel and other organs to the vena cava.

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Budd-Chiari Syndrome

- Budd-Chiari syndrome, which is a rare cause of postsinusoidal liver failure and cirrhosis, can occur as a spectrum of presentations that range from asymptomatic disease to fulminant liver failure.
- Hepatic Vein web, thrombosis, tricuspid regurgitation, CHF

Portal Vein Thrombosis

- Children
- Same therapy for acute problems
- Surgical shunting is long term Rx

Acute Bleeding

- Portal hypertension may require surgical intervention after upper gastrointestinal (GI) bleeding.
- Esophageal varices are the most common cause of massive bleeding
- Volume, packed red blood cells and replacement of clotting factors must be employed aggressively.
- VASOPRESSIN >>OCTREOTIDE
- Hepatic encephalopathy from absorption of the intestinal blood and azotemia from blood replacement, should be anticipated.
- Emergency TIPS is successful in treating acute bleeding, preventing rebleeding in approximately 80%
- The selection of a surgical shunt in the emergency setting requires consideration of the surgeon's experience and the patient's future candidacy for liver transplantation.
- Surgical shunts are associated with long-term survival rates of more than 70% in Child class A and B

Endoscopy

- Diagnostic and therapeutic
- Multiple methods – banding, injecting/sclerotherapy
- Other causes also may be present
- Varices may extend into stomach
- Rebleeding – 30% 6 weeks, 70% one year

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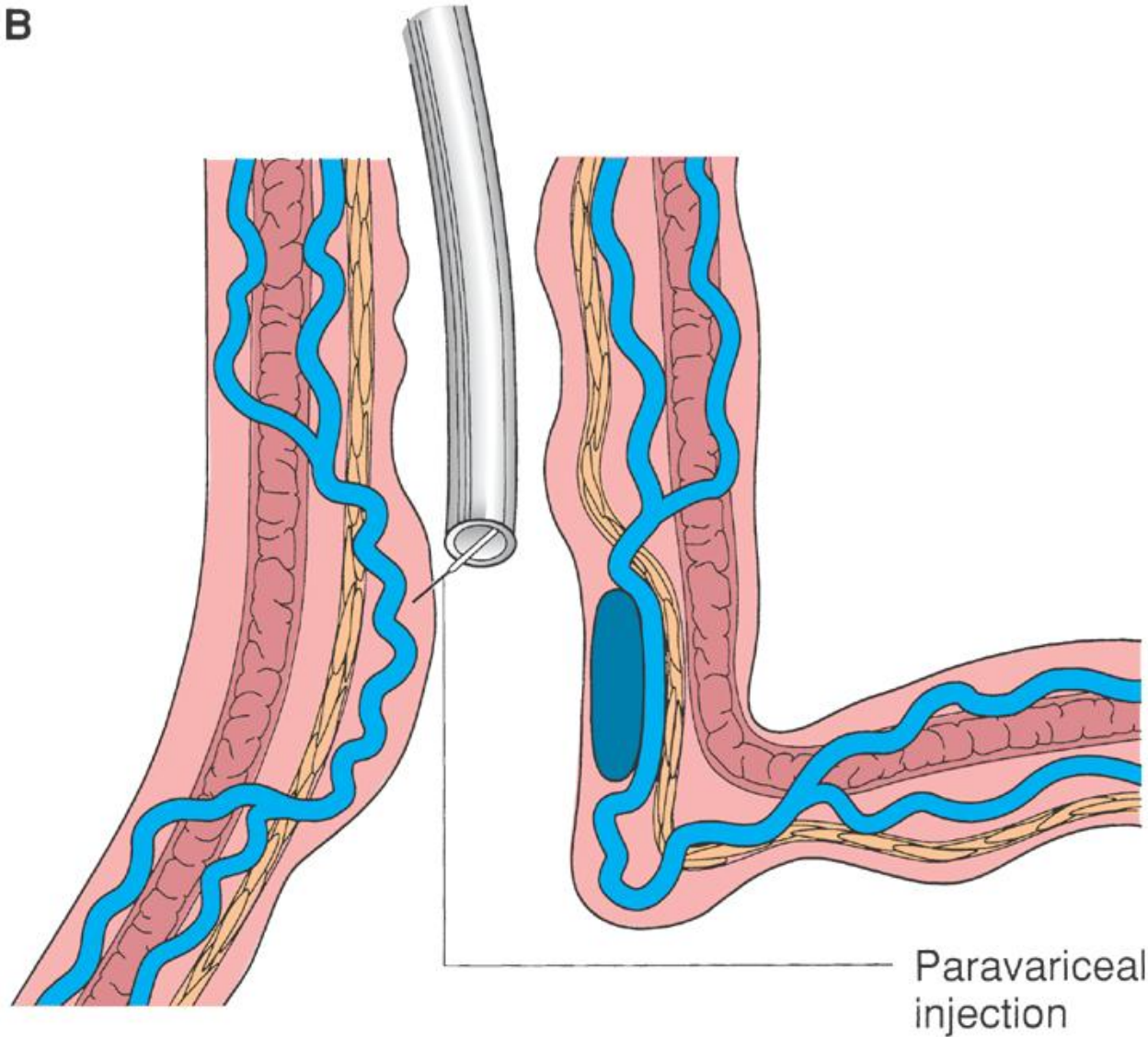


FIGURE 60.6B Techniques of intravariceal (A) and paravariceal (B) injection of esophageal varices.

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Prevention of Rebleeding

- After acute control of bleeding is achieved, long-term prevention of rebleeding must be made.
- Beta Blockade is key factor
- Abstinence

Portosystemic Shunts

- **Transjugular Intrahepatic Portosystemic Shunt.**
- The TIPS has revolutionized the management of the complications of portal hypertension

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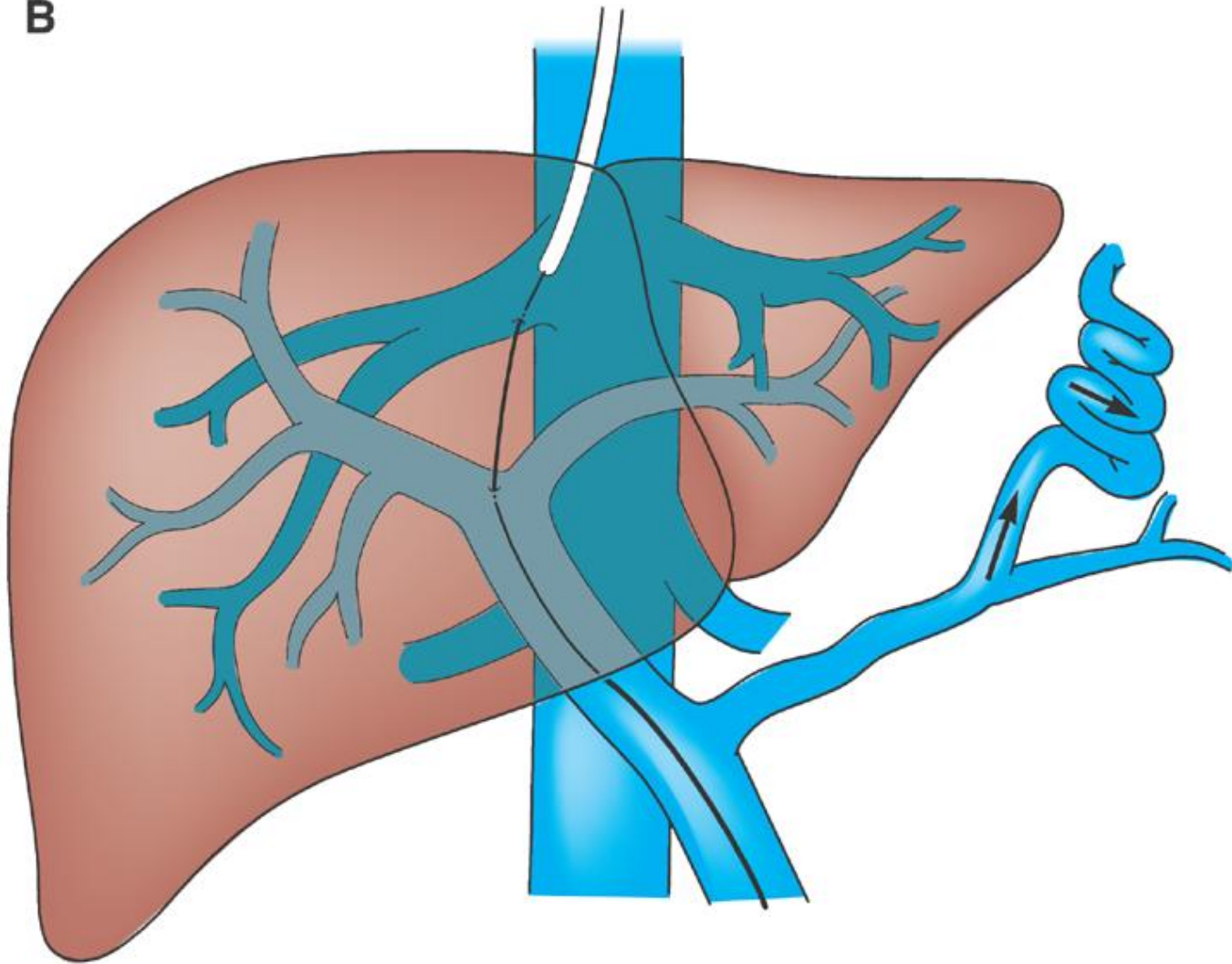


FIGURE 60.9B Schematic representation of the steps used to create a transjugular intrahepatic portosystemic shunt. (From Zemel G, Katzen BT, Becker GJ, et al. Percutaneous transjugular portosystemic shunt. *JAMA* 1991;266:390, with permission.)

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Surgical Shunts

- The advent of liver transplantation and TIPS has markedly reduced the need for surgical shunts in the management of portal hypertension and its complications of bleeding and ascites.
- Surgical shunts can be divided into two general categories: selective and nonselective
- Nonselective shunts are associated with a high risk of encephalopathy, especially in patients with marginal liver function.
- The DSRS is selective and has been shown to be most effective in nonalcoholic patients with preserved liver function who require a shunt for the elective treatment of refractory bleeding.
- In patients with complete intrahepatic portal vein thrombosis, an end-to-side portocaval shunt is the easiest to perform and the most effective shunt.

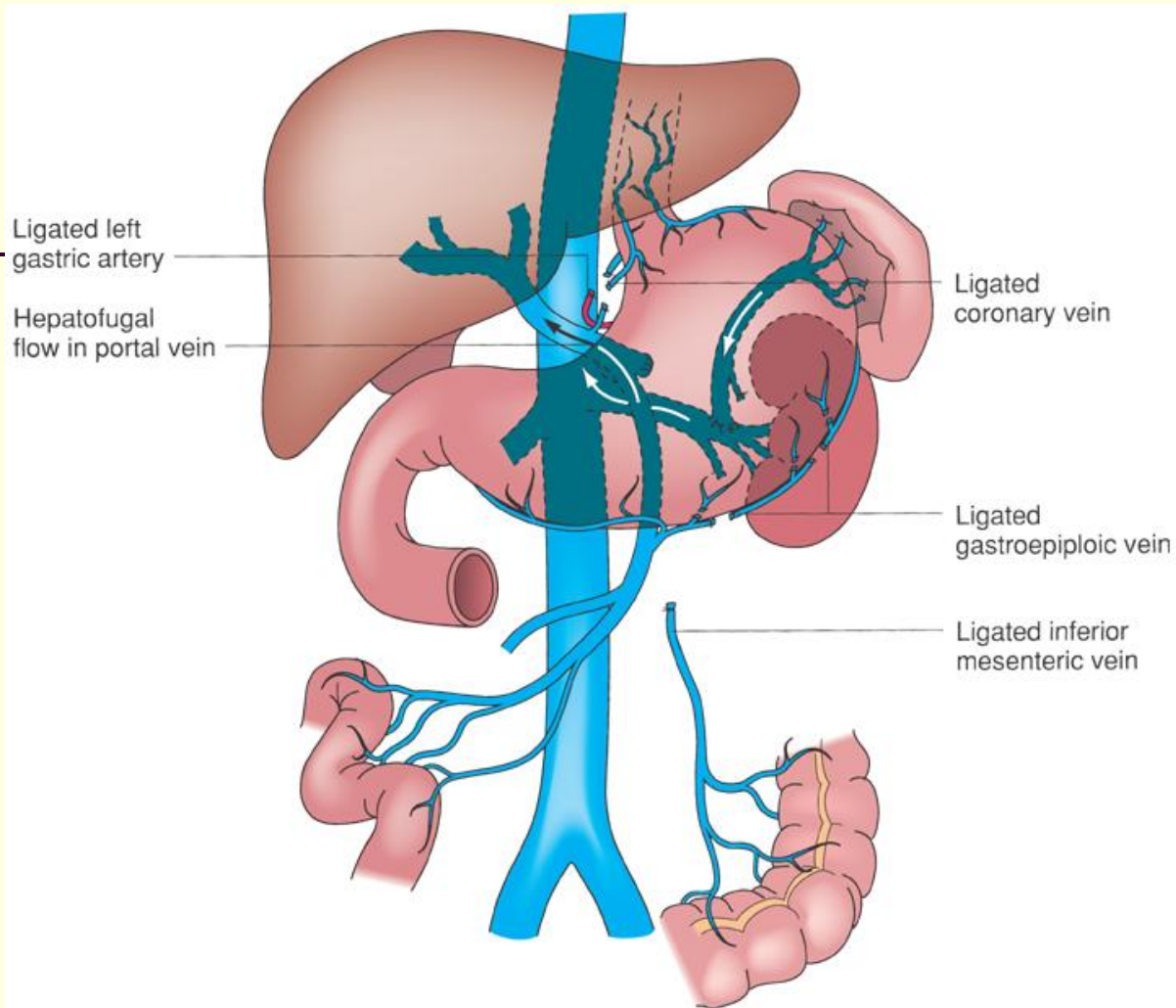


FIGURE 60.14 Distal splenorenal Warren shunt. The splenic vein is divided near its junction with the superior mesenteric vein. The distal end of the splenic vein is anastomosed to the renal vein. Varices are selectively decompressed through the stomach and short gastric veins into the splenic vein and then into the vena cava through the renal vein. Portal hypertension is maintained in the portal and superior mesenteric veins to provide enough pressure to drive portal blood through the diseased liver.

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Other Operations

- Patients with extrahepatic portal vein thrombosis and refractory bleeding are candidates for esophagogastric devascularization (Sugiura procedure)

Ascites

- Ascites is a common complication of portal hypertension and cirrhosis.
- Ascites forms as a result of a complicated interaction between portal hypertension, increased lymph production, and inadequate or inappropriate renal fluid and electrolyte responses.
- Dietary sodium restriction to less than 100 mmol/day is recommended.
- The diuretics furosemide and spironolactone are the mainstays of medical therapy.
- Medically refractory ascites is defined by the failure to correct ascites after 2 weeks of maximal diuretic therapy, especially when the urine sodium is less than 50 mmol/L.
- Treatment options include serial large-volume paracenteses with or without albumin replacement, TIPS, peritoneovenous shunting, or liver transplantation.
- Peritoneovenous shunting has become less popular in the management of chronic ascites because of a high rate of perioperative complications including disseminated DIC and thrombosis.

Encephalopathy

- Chronic encephalopathy in cirrhosis subtle and sometimes can manifest as sleep disturbances
- Acute or chronic encephalopathy will frequently have a nonhepatic etiology that should be treated.
- Treatment is directed at reducing the intestinal ammonia and bacterial load.
- Lactulose is an effective cathartic agent used to reduce intestinal ammonia and bacterial levels.

ACUTE LIVER FAILURE

- Acute liver failure (ALF) denotes a spectrum of highly morbid conditions that result from a massive loss of hepatocyte function without pre-existing liver disease or portal hypertension.
- Fulminant hepatic failure (FHF) is defined as hepatic encephalopathy occurring within 8 weeks
- Viral hepatitis, acetaminophen overdose, and other drug toxicities are the most common causes of FHF
- Approximately 20% of patients with FHF will survive and go on to have normal liver

ACUTE LIVER FAILURE

- Cerebral edema and intracranial hypertension are the complications of FHF most likely to result in adverse outcome and death
- Patients whose ICP rises above 20 mm Hg or whose cerebral perfusion pressure drops below 60 mm Hg will have a high risk of irreversible brain injury and are unlikely to benefit from transplantation
- The pathogenesis of cerebral edema in FHF is controversial, but is likely related to a combination of impaired blood flow, metabolic derangements, and increased cerebral nervous system permeability.
- Liver transplantation is therapy of choice and can improve mortality from 15% to 60%.
- Although 4 to 6% of all liver transplants in the United States are now performed for FHF, one third of patients listed as candidates for liver transplantation die before a donor organ becomes available.

CYSTIC DISEASES OF THE LIVER

- Noninfectious cystic lesions in the liver are common throughout all decades of life.
- The vast majority of hepatic cysts are asymptomatic and are found incidentally.

LIVER INFECTIONS

- The liver parenchyma is constantly exposed to a low level of enteric bacteria through the portal blood
- Liver abscess can be ascribed to two categories: pyogenic or parasitic.

Pyogenic Liver Abscesses

- Most common etiologies of pyogenic liver abscesses include biliary tract manipulation, diverticular disease, inflammatory bowel disease, and systemic infections such as bacterial endocarditis
- Patients with contrast material injected proximal to undrained strictures are at high risk.
- The clinical presentation of patients with pyogenic liver abscesses is rarely subtle.
- Patients present with right upper quadrant abdominal pain, fever, and occasionally jaundice.
- Ultrasound examination will demonstrate a cystic mass in the liver, often with multiple complex septations or inhomogeneous fluid characteristics.
- In patients with solitary abscesses, aspiration alone
- In patients with intra-abdominal sources leading to hepatic abscesses, Gram-negative aerobes, Gram-positive aerobes, and anaerobes are the predominant organisms found in liver abscesses.
- Antimicrobial therapy should be empiric, based on the etiology of the primary infection from the culture results following aspiration of the abscess.
- Rarely, in patients with recalcitrant lesions, formal liver resection may be necessary.

Parasitic Liver Abscesses

- Hydatid Disease
- Cystic hydatid disease is caused by the larval/cyst stage of *Echinococcus granulosus*
- Hydatid cysts can be uncomplicated and asymptomatic.
- Treatment of hydatid disease involves the use of oral anthelmintics such as albendazole.
- Alveolar echinococcosis occurs in the Northern Hemisphere, produces a more generalized granulomatous reaction, and can present in a manner similar to a malignancy.
- Resection is the treatment of choice.
- Amebiasis
- *Entamoeba histolytica* enters humans in cyst form but transforms into a trophozoite in the colon.
- It enters into the colonic mucosa and invades the portal venous system, infecting the liver.
- In patients who live in or who have recently visited an endemic area and who present with right upper quadrant tenderness and hepatomegaly, an ultrasound showing an abscess should be considered

Congenital Cysts

- Congenital cysts include simple hepatic cysts, most common benign lesions found in the liver.
- The surgical management of simple cysts centers on wide cyst fenestration
- Procedures are performed laparoscopically, if technically feasible.
- The recurrence rate after wide cyst fenestration is usually less than 5%.
- Cystic fluid analysis by cytology and tumor markers not indicated unless concern for neoplasia.
- Symptomatic simple cyst rarely requires complete resection, enucleation or as a formal liver resection.

Polycystic Liver Disease

- Polycystic disease occurs as an autosomal dominant disease presenting in adulthood.
- An autosomal recessive process associated with hepatic fibrosis also occurs in rare instances
- A wide spectrum of clinical and anatomic presentations is seen in polycystic liver disease (PCLD)
- The most common complication specific to surgery for PCLD is ascites
- Patients who develop progressive liver dysfunction from PCLD should be considered for orthotopic or living related donor liver transplantation.

Neoplastic Cysts

- Neoplastic cysts are more common in women and in those individuals older than 40 years of age.
- These lesions are symptomatic, characteristic appearance on ultrasound and other axial imaging studies
- Neoplastic cysts tend to have papillary excrescences and may have multiple loculations within the cyst
- Percutaneous aspiration is rarely indicated, but if performed will typically yield mucinous fluid.
- The surgical management of neoplastic cysts further relies on the initial differentiation between biliary cystadenoma and biliary cystadenocarcinoma
- Biliary cystadenocarcinoma is uncommon and is associated with marked thickening of the cyst wall and vascular enhancement on axial imaging studies.
- Biliary cystadenomas can be either enucleated or resected as dictated by the anatomy.

Other Cysts

- Occasionally, cystic lesions can occur in patients who have suffered liver trauma.
- The general appearance is that of a simple hepatic cyst, and management should be conservative.

BENIGN SOLID LIVER TUMORS

- Benign solid liver tumors are increasingly identified with more common use of axial imaging studies.
- Differentiation of benign tumors from malignancies including metastatic lesions is achieved based on the clinical scenario and interpretation of radiologic images. Therefore biopsy is rarely indicated.

Hepatic Adenoma

- Hepatic adenomas are the most significant benign liver tumors that surgeons encounter.
- Hepatocellular adenomas are significant in that they can rupture and as many as 25% of these lesions
- Radiographically, it is difficult to distinguish hepatic adenomas from focal nodular hyperplasia
- Typically, adenomas will be "cold" and FNH "hot" owing to the presence of nonparenchymal cells in the latter. Unfortunately, the accuracy of this radioisotope liver scan is only approximately 80%.
- The management of patients with hepatic adenomas is evolving.
- Cessation of OCPs in patients with lesions less than 4 cm in diameter is prudent.

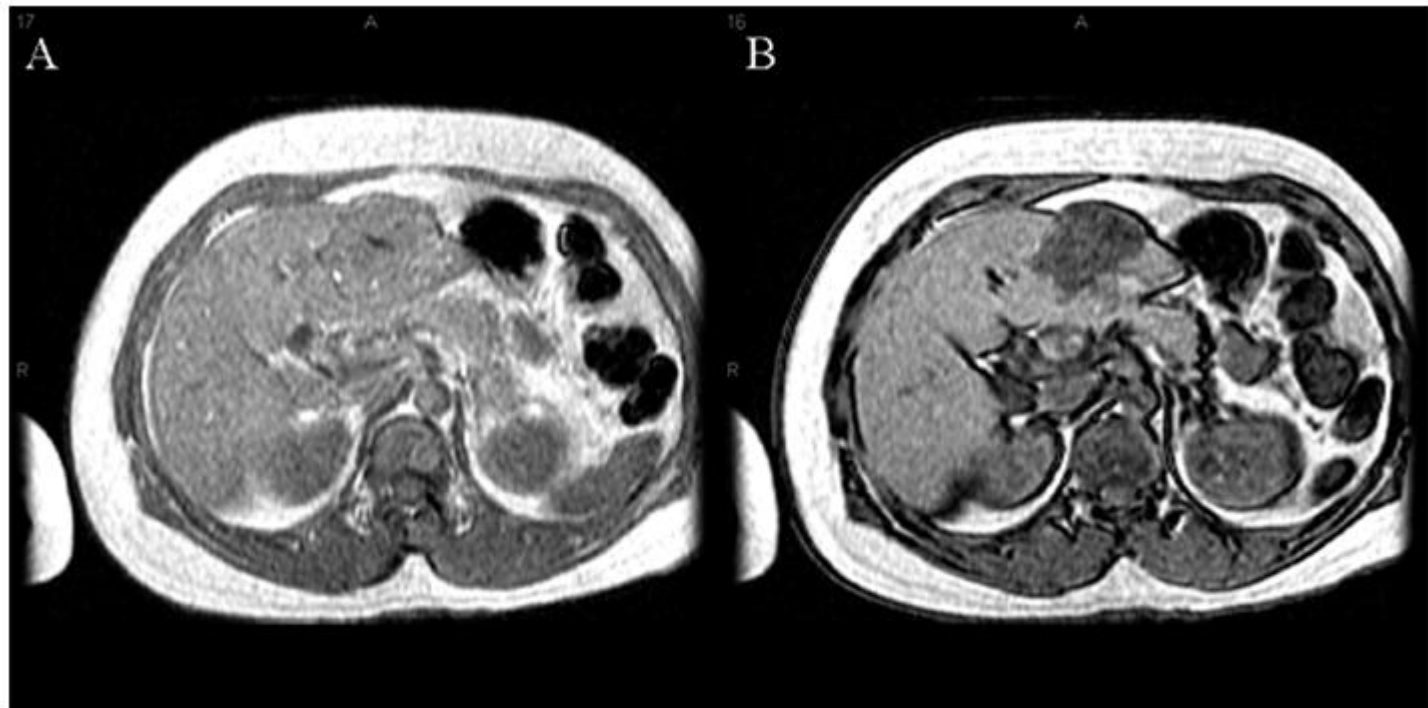


FIGURE 61.6B (A) Three-phase computed tomography scan of a hepatic adenoma. *Left*: arterial phase; *center*: portal phase; *right*: venous phase. (A) In-phase (*left*) and out-of-phase (*right*) magnetic resonance image of the same hepatic adenoma. As a result of the high fat content of the lesion, the signal cancels out on the out-of-phase image. The lesion, therefore, appears to be nonenhancing.

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Focal Nodular Hyperplasia

- In contrast to hepatic adenomas, focal nodular hyperplasia typically is not associated with symptoms and does not pose any risks of rupture or malignant degeneration
- These lesions intensely enhance on the arterial vascular phase of axial imaging studies
- Characteristically, up to two thirds of lesions will demonstrate a central scar.
- FNH is rarely symptomatic. Therefore other etiologies for symptoms should be explored.
- Resection of the lesion with a thin margin of normal liver parenchyma is curative, but formal segmental resection should be considered, as such procedures are associated with lower morbidity.

Hemangiomas

- Hemangiomas, also known as cavernous hemangiomas, are common benign liver lesions generally discovered incidentally on axial imaging studies
- Resection can be recommended if symptoms can be clearly ascribed to a large hemangioma.
- Hemangiomas can be resected by enucleation or more standard formal liver resection.
- Enucleation of hemangiomas follows the line of compressed liver tissue

Bile Duct Hamartomas

- Bile duct hamartomas are the most common liver lesions seen at laparotomy.
- Biopsy is indicated for grossly equivocal lesions.

EVALUATION OF FUNCTIONAL HEPATIC RESERVE

- Patients with normal hepatic parenchyma and serum liver tests can tolerate resection
- The average amount of liver parenchyma resected during a right trisegmentectomy is 85%, a right lobectomy 65%, a left lobectomy 35%, and segmental or wedge resections involve a loss of 3 to 15%.
- Patients with cirrhosis who develop HCC should undergo assessment of functional hepatic reserve.
- Most commonly used test to assess functional hepatic reserve is indocyanine green (ICG) clearance.
- ICG is an anionic dye bound by plasma lipoproteins which is rapidly cleared by the liver and excreted
- Administering intravenous dose of lidocaine to determine the rate of hepatic microsomal metabolism of lidocaine to monoethylglycinexylidide (MEGX) is another method of evaluating liver function
- ICG clearance can be useful in selecting patients to undergo partial hepatectomy who are at low risk of developing postoperative liver failure, despite the presence of a fatty or cirrhotic liver.

MALIGNANT LIVER TUMORS

- **Surgical Treatment**
- Couinaud's description of the segmental liver anatomy based on portal venous inflow and hepatic venous outflow, and the identification of eight hepatic segments for safe, anatomic hepatic resection
- Surgical resection of HCC, colorectal cancer hepatic metastases, and liver-only metastases from other types of primary tumors can result in significant long-term survival benefit in 20 to 45% of patients

MALIGNANT LIVER TUMORS

- Primary
 - HCC
 - Neoplastic Cyst
 - Cholangiocarcinoma
- Complete Extirpation
 - Surgery
 - Transplant
- Metastatic
 - Colon
 - Lung
 - Breast
 - Ovary
 - Melanoma
 - Neuroendocrine
- Resection when possible
- Represents Stage 4 disease - palliation

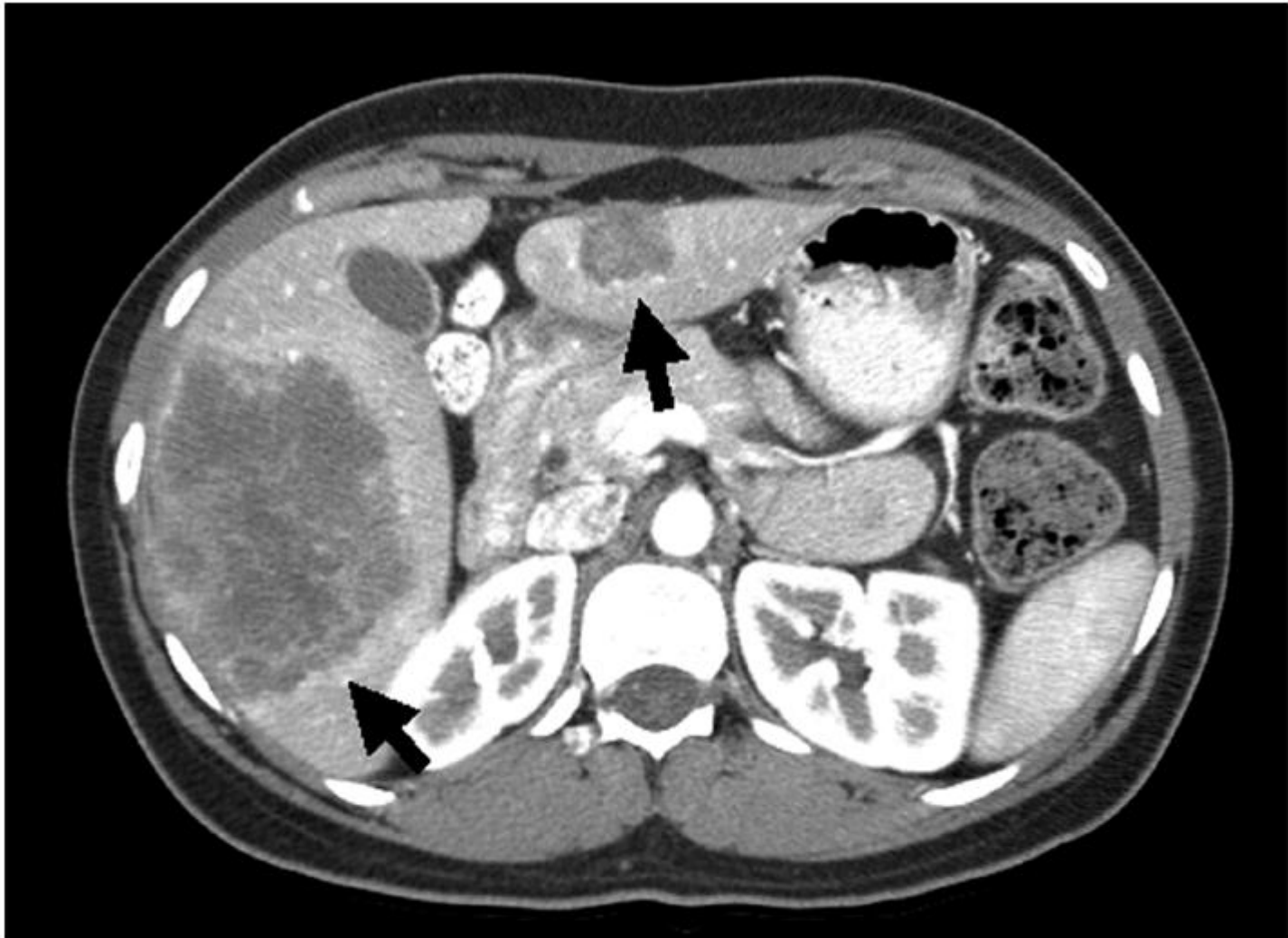


FIGURE 61.2 Arterial phase of a three-phase computed tomography scan of hepatic metastases from colorectal carcinoma. *Black arrows* mark the lesions.

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MALIGNANT LIVER TUMORS

- Indications for Resection
- Presence of four or more liver metastases from colorectal cancer became contraindication to resection, even when technically feasible with an adequate remaining volume of perfused hepatic parenchyma.
- Recent re-evaluations of the number of metastases that should be considered for resection have demonstrated that there is a potential survival benefit in patients with four or more metastases.
- The actuarial 10-year life expectancy of patients with four or more lesions was 29%, which was almost equivalent to the long-term survival of patients who underwent resection of a solitary metastasis.

MALIGNANT LIVER TUMORS

- Stapling Devices in Liver Resection
- Vascular staplers used in selected patients to reduce operative time and intraoperative blood loss
- Hepatic inflow and outflow control can be achieved with stapling devices.
- A major advantage of stapling techniques is intrahepatic ligation, division of vascular inflow to lobe.
- The low profile, flexible neck, and long handle of a vascular Endo-GIA stapler makes it ideal for outflow control with ligation and division of the hepatic veins.

-
- Laparoscopic Hepatic Resection
 - Laparoscopy has definite role in diagnosis and staging of patients with gastrointestinal malignancies.

MALIGNANT LIVER TUMORS

- Repeat Hepatectomy for Recurrent Malignant Tumors
- Long-term, disease-free survival rates for patients undergoing surgical resection of primary or metastatic liver tumors usually below 40% in most optimistic reports, and below 20% in others.
- Only 10 to 15% of patients who develop recurrent disease after liver resection for colorectal metastases will be considered as candidates for a second or third resection.

Portal Vein Embolization

- PVE was first reported as a potentially useful treatment to induce hepatic hypertrophy prior to liver resection in a small group of HCC patients in 1986
- These patients also were treated with hepatic arterial embolization of their primary liver tumor, but PVE was noted to induce hypertrophy rarely seen with hepatic arterial embolization alone.
- Surgical mortality from extended hepatic resections continues to be reduced as a result of improved patient selection and safer surgical and anesthetic techniques.

Indications for Portal Vein Embolization

- Patients with normal hepatic parenchyma, preservation of a perfused section of liver comprising 25% of the total hepatic volume is usually sufficient to prevent major postoperative complications.

Preoperative Volumetric Determination of the Future Liver Remnant

- Rapid-sequence, thin-section, helical CT is used to make direct measurements of total liver volume, volume of the liver to be resected, and volume of the future liver remnant
- The total liver volume also can be estimated based on the described association between body surface area (BSA) and the total liver volume, where total liver volume = $706.2 \times \text{BSA (in m}^2) + 2.4$.

Approach for Portal Vein Embolization

- A percutaneous transhepatic approach has become the standard technique for PVE.
- The principal advantage of this technique is that it allows direct access to the portal venous branches of the lobe and segments to be embolized via an ipsilateral approach.

Results After Portal Vein Embolization

- Preoperative PVE has been used to treat primary liver malignancies, including HCC and cholangiocarcinoma, and metastatic liver tumors, particularly colorectal cancer metastases.
- Perioperative mortality rates range from 0 to 7%, with no significantly higher mortality rate in cirrhotic compared to noncirrhotic patients.

Radiofrequency Ablation

- Background and Basics of Radiofrequency Tissue Ablation
- The use of radiofrequency (RF) energy to produce thermal tissue destruction has been the focus of increasing research and practice over the past several years.
- As the temperature within the tissue becomes elevated beyond 60°C, cells begin to die, resulting in a region of necrosis surrounding the electrode
- An RF needle electrode is advanced into the liver tumor to be treated via either a percutaneous, laparoscopic, or open (laparotomy) route.

Indications for Radiofrequency Ablation of Liver Tumors

- RFA performed only in patients with no preoperative or intraoperative evidence of extrahepatic disease, and only for tumor histologies with a reasonable probability of disease metastatic only to liver.
- does not replace standard hepatic resection in patients with resectable disease

Radiofrequency Ablation of Primary Liver Tumors

- The use of RFA to treat primary liver tumors was recently reported
- Primary liver tumors tend to be highly vascular, therefore a vascular heat sink phenomenon may contribute to the extended ablation times.
- Procedure-related complications were minimal in patients with HCC.
- Overall complication rate following RFA of HCC was low, which is particularly notable because there were 50 Child class A, 31 class B, and 29 class C cirrhotic patients treated.

Radiofrequency Ablation of Metastatic Liver Tumors

- Procedure-related complications were infrequent in patients with metastatic liver tumors.
- Thermal injury to adjacent organs or tissues, hepatic insufficiency, renal insufficiency, or coagulopathy following RFA of the hepatic metastases was not reported in any of the patients.
- Local recurrence or persistence of metastatic tumors at the site of the RFA occurred in approximately 7% of the patients, and over 80% of the local recurrences developed in tumors more than 5 cm
- Neuroendocrine tumors metastatic to the liver often produce symptoms secondary to excessive hormone production and release

Interstitial Laser Hyperthermic Ablation

- Direct thermal destruction of hepatic tumors using laser energy is known by several acronyms: LTA (laser thermal ablation), ILT (interstitial laser thermotherapy), ILP (interstitial laser photocoagulation), and LITT (laser-induced interstitial thermotherapy).

Background and Principles of Laser-Induced Interstitial Thermotherapy

- As described by thermal treatment modality, LITT requires placement of a laser fiber or fibers directly into the tumor or tissue to be treated. Thus LITT is a type of contact mode laser therapy.
- Irreversible cytotoxic effects develop in cells that are heated above 55 to 60°C.
- LITT produces local tissue heating when photons from low-intensity laser energy interact with molecular chromophores that are inherent to all mammalian cells.
- Laser light in LITT is scattered, reflected, and absorbed to varying degrees, depending on the wavelength of light, the applied laser energy, and the specific photoabsorptive properties of the tissue.
- The photoabsorptive characteristics of tissues can vary markedly from area to area within a tumor or normal tissue depending on tissue composition, vascularity, fibrosis, and necrosis.
- Natural chromophores have a strong dependence on wavelengths in the near infrared range for photochemical reactions to occur.
- This is fortunate because penetration depth increases with increasing wavelength of light.
- Penetration of tumor tissue is greater than in normal tissue by approximately 33% at the 1064-nm wavelength, but rapid coagulative necrosis reduces optical penetration by up to 25% in both normal and tumor tissues
- Similarly to RFA, transient hepatic inflow occlusion during LITT can be used to double the volume of thermal injury using single-fiber systems, and can produce up to a fivefold increase in the volume of thermal coagulation by using a four-fiber system
- Portal venous occlusion has been shown to be more important than hepatic arterial occlusion in producing this increase in the volume of thermal necrosis, suggesting that pretreatment transarterial hepatic arterial embolization associated with percutaneous LITT is less useful than laparoscopic or open surgical occlusion of both portal venous and hepatic arterial flow with a Pringle maneuver.

Results of Laser-Induced Interstitial Thermotherapy for Malignant Hepatic Tumors

- The majority of reports describing LITT for the treatment of liver malignancies describe a percutaneous approach for intratumoral placement of the laser fiber using ultrasonographic or MRI monitoring during therapy.
- The largest reported experience with LITT consists of 705 patients with 1981 metastatic liver tumors.
- The major limitation of single-fiber LITT is an inability to achieve large volumes of tumor necrosis. Another disadvantage is the need to perform multiple treatment sessions in most patients.

Microwave Coagulation Therapy for Hepatic Tumors

- Background and Principles of Microwave Coagulation Therapy
- Microwave coagulation was initially developed in the early 1980s to achieve hemostasis along the plane of transection during hepatic resection.¹⁶⁵ Microwave coagulation of tissue surfaces was slower than electrocautery units and produced deeper areas of tissue necrosis. While microwave coagulation has not been useful during hepatic resection, the extended area of tissue necrosis led to investigation of use of microwave coagulation therapy (MCT) to treat unresectable hepatic malignancies.
- The microwave generators developed for MCT produce microwaves with a frequency of 2450 MHz and a wavelength of 12 cm.
- The small areas of coagulation produced by MCT requires that the needle be advanced at 5- to 10-mm intervals throughout the area to be treated and surrounding parenchyma
- For tumors larger than 2 cm in diameter, multiple MCT needle placements are required to produce overlapping zones of coagulative necrosis in tumor and in a surrounding rim of hepatic parenchyma.
- Like RFA and LITT, MCT can be performed percutaneously using ultrasound or CT guidance for needle placement, or can be performed laparoscopically or during an open surgical procedure using intraoperative ultrasound guidance to place the MCT needle.

Results of Microwave Coagulation Therapy for Treatment of Malignant Hepatic Tumors

- The overwhelming majority of reports describing MCT to treat hepatic malignancies come from Japan, where this technique was first used in 1988.
- There is a striking paucity of data on local recurrence rates and complications following MCT to treat HCC or other malignant liver tumors.

Adjuvant Treatment of Liver Malignancies

- There is no accepted or clinically superior single combination of agents used as postresection adjuvant therapy for colorectal metastases or HCC.
- The 3- and 5-year survival rates in patients who did not receive adjuvant therapy were 35 and 12%, respectively, compared to 57 and 57%, respectively, for the 31 patients who received adjuvant regional chemotherapy.
- The surgical resection was not curative in 26% of patients.
- Individuals were treated with four different adjuvant chemotherapy regimens consisting of floxuridine (FUDR) alone, FUDR and folinic acid, or 5-FU and folinic acid.
- Chemotherapy-related side effects occurred with equal frequency in the two treatment arms, but the rate of diarrhea and abnormalities in serum liver tests was higher in patients in the combined regional plus systemic chemotherapy arm.
- Many of the patients in the combined regional and systemic therapy arm were unable to complete planned 6 months of adjuvant therapy because of chemotherapy-induced elevations in liver tests.
- Adjuvant therapy after resection of HCC also has been studied.
- There was a significant improvement in median disease-free survival in the treatment group (57.2 months) compared with the surgery alone group (13.6 months).
- The mean number of chemotherapy sessions required to achieve tumor reduction sufficient to allow resection was 10.6 over a 10-month period.
- Neoadjuvant and adjuvant therapy trials have indicated that an increased number of patients may be considered for resection with aggressive preoperative therapy
- Overall, the results from neoadjuvant therapy trials to downstage patients with primary or metastatic liver tumors in an attempt to convert unresectable to resectable disease indicates that only 10 to 20%