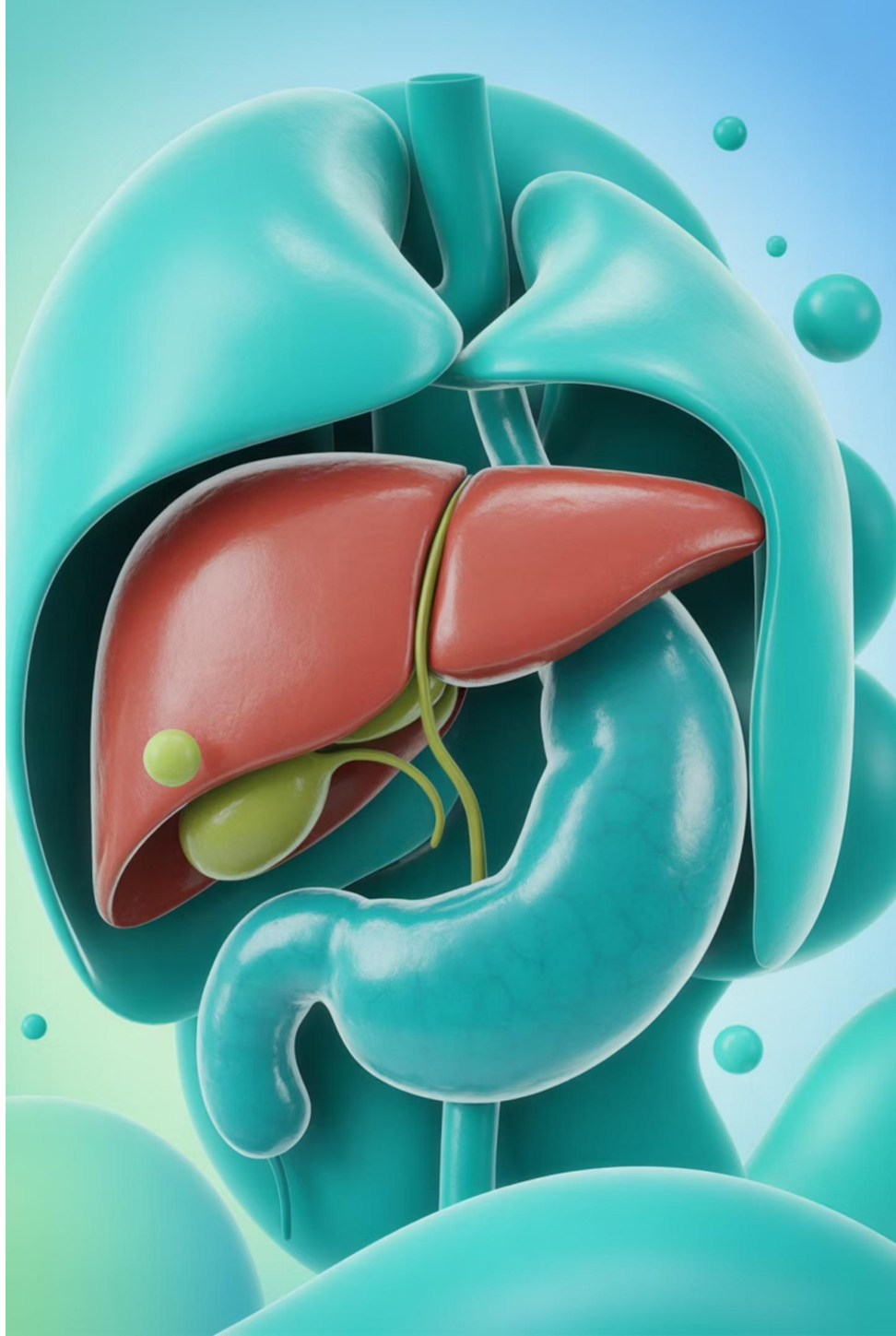
Gallbladder Anatomy and Pathophysiology

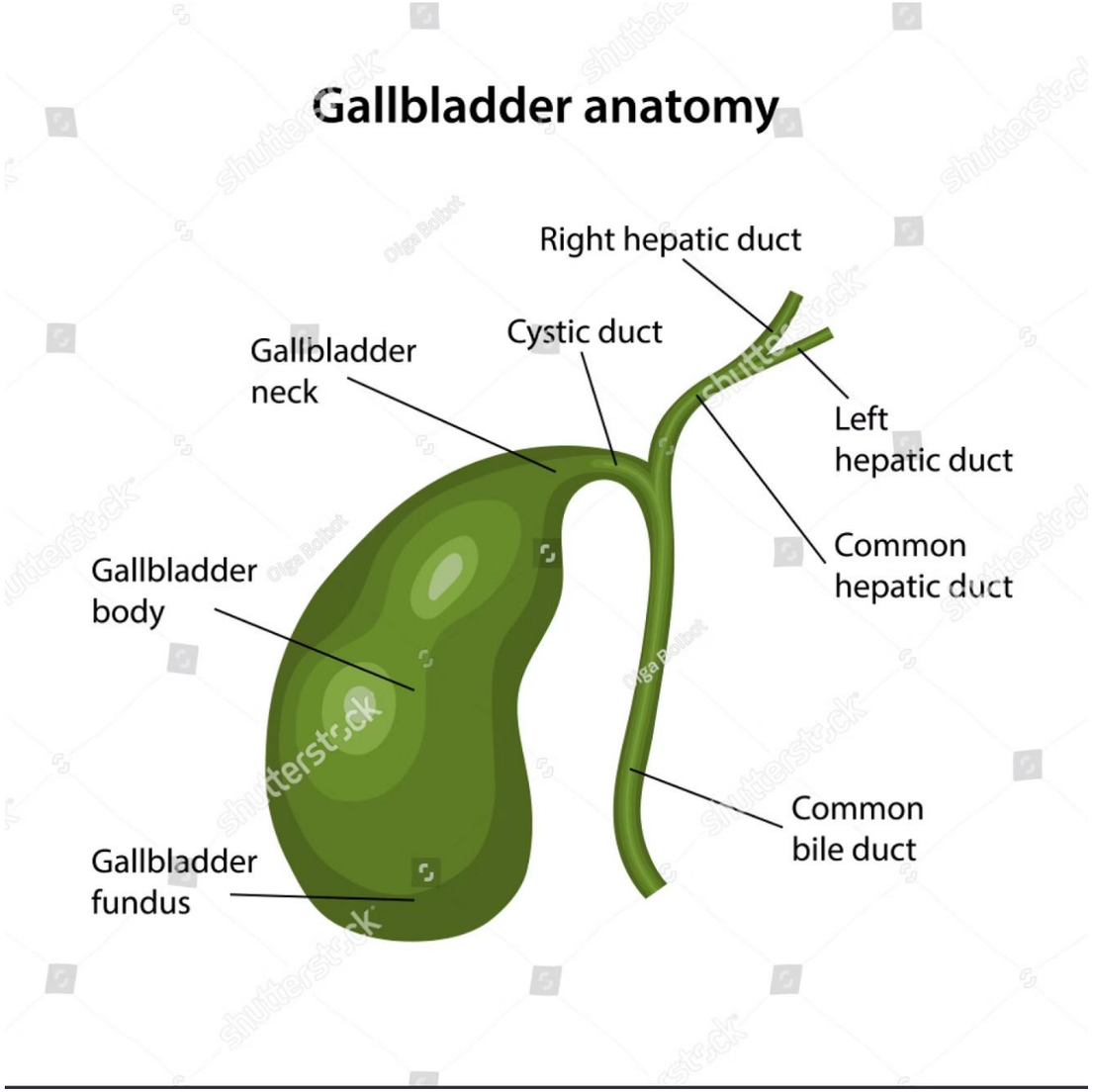


Gallbladder Anatomy: Structure and Position

The gallbladder (cholecyst), a pear-shaped organ 7-10 cm long, stores approximately 50 ml of bile for digestion.

Its dark green appearance is due to stored bile. Anatomically, it relates closely to the liver (superiorly) and the duodenum via the biliary tract.

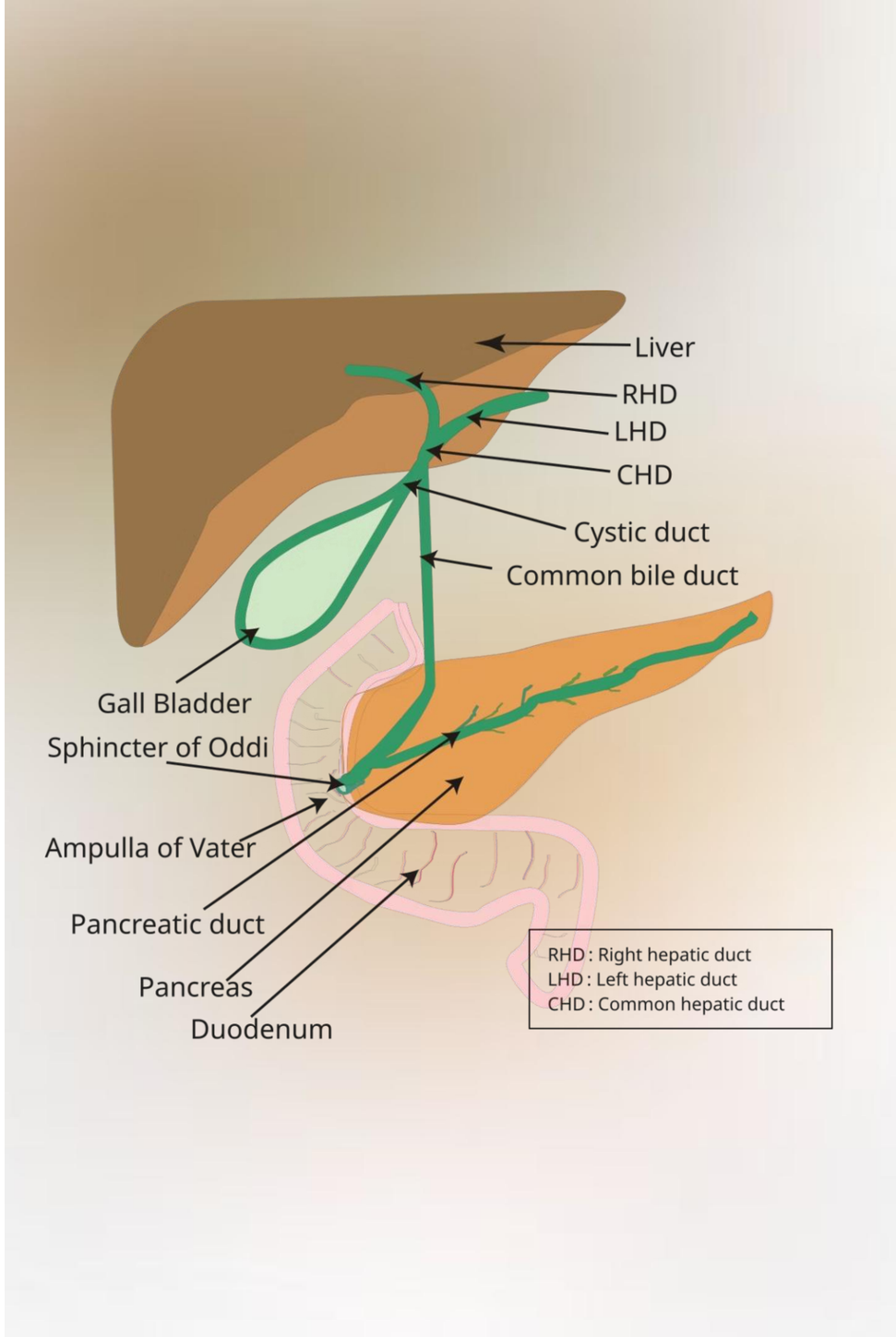
It lies in a fossa on the inferior right hepatic lobe, at the junction of right and left lobes, within the gallbladder bed.



Biliary Tract Connections

The biliary system connects hepatic bile production to intestinal delivery. The **cystic duct** from the gallbladder joins the **common hepatic duct** (draining bile from the liver) to form the **common bile duct**.

The **common bile duct** then descends, joining the **pancreatic duct** to form the hepatopancreatic ampulla (ampulla of Vater). This ampulla enters the duodenum via the major duodenal papilla, with bile release regulated by the sphincter of Oddi.



Vascular Supply and Innervation

Arterial Supply

Cystic artery - arises from right hepatic artery within Calot's triangle

Venous Drainage

Cystic vein - drains into right portal vein branch or gallbladder bed veins

Neural Control

Celiac ganglia and vagus nerve - provide sympathetic & parasympathetic innervation

Embryologic Origin

Foregut derivative - diverticulum from ventral primitive duodenum (week 4 gestation)

Physiological Function: Bile Storage and Concentration

1

Storage and Concentration

The gallbladder performs two critical functions: **storage and concentration of bile**. Between meals, hepatocytes produce bile, which is concentrated 5-20 fold by the gallbladder epithelium via water and electrolyte reabsorption.

2

Cholecystokinin (CCK) Release

When fatty food enters the duodenum, **cholecystokinin (CCK)** is released. CCK stimulates gallbladder contraction and relaxation of the sphincter of Oddi, propelling concentrated bile into the duodenum.

3

Bile's Essential Roles & Composition

Bile's essential roles include **emulsification of dietary fats** and **neutralization of gastric acid**. Normal bile composition is 70% bile salts, 22% phospholipids, 4% cholesterol, 3% proteins, and 0.3% bilirubin.

Anatomical Variations and Anomalies

Congenital Absence

Complete agenesis (0.075% population). Gallbladder and cystic duct may be absent, requiring careful assessment.

Morphological Variations

Common benign variants: Phrygian cap, hourglass, longitudinal septa. Rarely symptomatic, but can complicate radiology.

Duplication Anomalies

True duplication (0.026% cases) involves two separate gallbladders, each with its own cystic duct.

Ectopic Positions

Gallbladder can be intrahepatic, left hepatic, retrohepatic, suprahepatic, within falciform ligament, or anterior abdominal wall. Floating gallbladders risk torsion.

Cholelithiasis: Epidemiology and Impact

38.9%

Iraq Prevalence

Gallstone prevalence among suspected patients in Iraqi hospitals

38.3%

Post-bariatric Surgery Formation

Gallstone formation in Iraqi bariatric surgery patients

60-80%

Asymptomatic Cases

Gallstones clinically silent at presentation

Gallstone disease is highly prevalent in Iraq (38.9% in suspected patients). Post-bariatric surgery patients show 38.3% formation rates. Smaller stones pose higher complication risk due to duct migration. Early recognition is crucial as symptoms typically precede complications.

Cholesterol Stones: Pathogenesis

Cholesterol stones account for ~90% of gallstones in Western populations. The fundamental event in their formation is cholesterol supersaturation of bile, leading to the precipitation of cholesterol monohydrate crystals when bile salt and phospholipid ratios are inadequate.

Stone formation also requires **nucleation factors**, such as mucin glycoproteins, which promote crystal aggregation. Additionally, impaired gallbladder motility contributes by increasing crystal residence time and facilitating stone maturation.

Risk Factors: Cholesterol Stone Formation

Metabolic Factors

- **Obesity**: Increased cholesterol synthesis.
- **Rapid weight loss**: Cholesterol mobilization.
- **Diabetes mellitus**: Gallbladder hypomotility.
- **Hyperlipidemia**: Elevated biliary cholesterol.

Gender and Hormones

- **Female sex**: 2-3x higher prevalence.
- **Pregnancy**: Reduced gallbladder contractility.
- **Oral contraceptives**: Increased bile cholesterol saturation.
- **Hormone replacement**: Estrogen effect.

Genetic Factors

- **Ethnic variation**: Highest risk in Native Americans.
- **Family history**: Polygenic inheritance.
- **Cystic fibrosis**: Altered bile composition.

Gastrointestinal

- **Ileal disease/resection**: Impaired bile salt circulation.
- **TPN**: Gallbladder stasis.
- **Prolonged fasting**: Reduced gallbladder emptying.

Pigment Stones: Black vs. Brown

Black Pigment Stones

Composition: Calcium bilirubinate, calcium carbonate, and phosphate

Appearance: Hard, spiculated, jet-black

Location: Primarily in the gallbladder

Associated Conditions

- Chronic hemolytic anemias (e.g., sickle cell, spherocytosis)
- Cirrhosis
- Ileal disease
- Advanced age

Pathophysiology: Increased unconjugated bilirubin production exceeds hepatic conjugation capacity, precipitating as calcium bilirubinate.

Brown Pigment Stones

Composition: Calcium bilirubinate, fatty acids, cholesterol

Appearance: Soft, greasy, earthy brown, friable

Location: Bile ducts (intrahepatic or extrahepatic)

Associated Conditions

- Biliary stasis (strictures, obstruction)
- Bacterial infection (e.g., E. coli, Klebsiella)
- Parasitic infection (e.g., Ascaris, Opisthorchis)
- Endemic in Southeast Asia

Pathophysiology: Bacterial β-glucuronidase deconjugates bilirubin; bacterial phospholipases hydrolyze lecithin.

Spectrum of Gallstone Complications

Gallbladder

- Silent stones
- Biliary colic
- Acute cholecystitis
- Perforation & Empyema
- Gallbladder cancer (rare)

Bile Ducts

- Choledocholithiasis
- Obstructive jaundice
- Ascending cholangitis
- Biliary cirrhosis
- Hepatic abscess

Pancreas

- Acute gallstone pancreatitis
- Chronic pancreatitis

Intestine

- Cholecystoenteric fistula
- Gallstone ileus
- Bouveret syndrome

Acute Cholecystitis: Definition and Pathophysiology

Definition: Acute inflammatory condition of the gallbladder wall, typically precipitated by cystic duct obstruction.

Ninety percent of cases involve gallstones impacted in the cystic duct (calculous cholecystitis); 10% are acalculous.

Pathophysiologic Sequence

1. **Obstruction:** Stone obstructs cystic duct, preventing bile drainage.
2. **Chemical inflammation:** Bile concentration and lysolecithin cause mucosal damage.
3. **Distention:** Increased intraluminal pressure from secretions.
4. **Vascular compromise:** Reduced mucosal blood flow (ischemia) due to pressure.
5. **Secondary infection:** Bacterial proliferation (e.g., E. coli) in 50-75% (secondary).
6. **Progression:** Risk of gangrene, perforation, or empyema if untreated.

Clinical Presentation: History

1

Pain Characteristics

Pain: Constant, severe in epigastric or RUQ, often radiating to right scapula or back.

2

Temporal Pattern

Pain often starts after fatty meals, at night, and lasts longer than typical biliary colic.

3

Associated Symptoms

GI: Nausea, vomiting, anorexia, bloating, fatty food intolerance. **Systemic:** Low-grade fever, chills (suggesting complications). Pleuritic RUQ pain.

4

Patient Behavior

Patients lie still; movement worsens pain. May prefer sitting or leaning forward.

Clinical Pearl: Symptoms usually precede complications; asymptomatic gallstones rarely cause direct complications.

Physical Examination Findings

Vital Signs

Low-grade fever (38-38.5°C) and tachycardia are common. High fever (>39°C) or hypotension suggest severe complications (e.g., sepsis).

General Appearance

Distressed appearance; patients prefer to lie still. Elderly and diabetic patients may have minimal symptoms despite severe disease.

Abdominal Examination

RUQ/epigastric tenderness and voluntary guarding are typical. Positive Murphy's sign (97% sensitive). Jaundice, a palpable gallbladder, or peritoneal signs indicate complications (e.g., perforation).

Special Considerations

Elderly: Decreased Murphy's sensitivity, occult presentation.
Diabetic: Higher gangrene risk, minimal symptoms.
Immunocompromised: Acalculous cholecystitis, rapid progression.

Laboratory Investigations

Complete Blood Count

Leukocytosis (WBC >11,000/μL) is common. WBC >15,000/μL suggests gangrenous cholecystitis or perforation. A left shift indicates bacterial infection.

Liver Function Tests

Bilirubin & ALP: Normal or mildly elevated. Significant elevation (>4 mg/dL bilirubin) suggests choledocholithiasis or Mirizzi syndrome. **Transaminases:** Mild elevation common; marked elevation suggests choledocholithiasis or cholangitis.

Pancreatic Enzymes

Amylase/Lipase: May be mildly elevated, especially with gangrene. Higher elevations suggest gallstone pancreatitis.

Additional Studies

Blood cultures: Indicated if febrile. **Urinalysis:** Exclude renal issues. **Pregnancy test:** Mandatory for women of childbearing age before imaging.

Key Point: Normal labs do not exclude cholecystitis; clinical and imaging findings are paramount. Lab abnormalities may suggest complications or alternative diagnoses.

Imaging Studies: Ultrasound and Beyond

Ultrasound (First-line)

Sensitivity/Specificity: 90-95% sensitive, 78-80% specific for acute cholecystitis; nearly 98% sensitive/specific for gallstones.

Key Findings

- Gallstones, wall thickening (>3-4 mm), gallbladder distention (>4 cm)
- Pericholecystic fluid, positive Sonographic Murphy's sign
- Gas in wall (emphysematous cholecystitis)

Pros & Cons

- **Advantages:** Bedside, rapid, no radiation (safe in pregnancy), identifies complications.
- **Limitations:** Operator-dependent, challenging in obese patients or with bowel gas.

Additional Findings

CBD dilatation (>6 mm) suggests choledocholithiasis, while intrahepatic duct dilatation indicates proximal obstruction.

Advanced Imaging Modalities

Plain Radiography

Low utility for biliary pathology; mainly useful for differential diagnosis. Only 10-30% of stones are radiopaque. May show air in the gallbladder wall or porcelain gallbladder.

Computed Tomography

Used for uncertain diagnoses or suspected complications. Excellent for visualizing complications and surrounding structures, though it misses ~20% of stones. Involves radiation.

ERCP/MRCP

ERCP: Diagnostic/therapeutic for common bile duct stones. **MRCP:** Non-invasive visualization of biliary ducts, excellent for detecting choledocholithiasis without radiation.

Management Strategies

Initial Conservative Management

Succeeds in 90% of cases with NPO, IV fluids, broad-spectrum antibiotics, and analgesics. Gradually advance diet as inflammation subsides.

Timing of Cholecystectomy

Early cholecystectomy (within 72 hours) is recommended to reduce recurrence and hospital stay. Delayed for significant comorbidities.

Surgical Approach

Laparoscopic cholecystectomy is the gold standard (shorter recovery, less pain). Open for severe inflammation or unclear anatomy. Intraoperative cholangiography for suspected choledocholithiasis.

Salvage Procedures

Percutaneous cholecystostomy: Temporizes critically ill patients unfit for surgery by draining infected bile. Definitive cholecystectomy follows stabilization.

Absolute Indications for Abandoning Conservative Treatment: Uncertain diagnosis, increasing pain/tenderness (perforation/gangrene), sepsis with hemodynamic instability, peritoneal signs.

Gallbladder Carcinoma: A Rare but Serious Entity

Epidemiology

Rare in Western populations (<1% of cholecystectomy specimens); higher incidence in certain regions. Over 90% linked to gallstones.

Demographics

- **Age:** 7th-8th decade
- **Sex:** 5:1 female predominance
- **Risk factors:** Chronic cholecystitis, porcelain gallbladder, polyps >1 cm.

Pathology

Mainly **adenocarcinoma** (90%). Spreads via direct extension, lymphatic, and hematogenous routes.

Clinical Presentation

Two scenarios:

1. Advanced disease with hepatic mass/jaundice.
2. Incidental finding on cholecystectomy pathology.

Symptoms (when present): RUQ pain, weight loss, jaundice (late).

Treatment and Prognosis

Confined to mucosa (T1a): Simple cholecystectomy curative (>90% 5-year survival).

Beyond mucosa: Requires radical resection (extended cholecystectomy, liver wedge, lymphadenectomy).

Advanced disease: Chemoradiotherapy for palliation. Median survival for unresectable disease approximates 12 months.

Overall prognosis: Poor due to late presentation; 5-year survival (all stages): 5-15%.