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## 10.1 Classification

Bile duct tumors can be broadly classified into benign, premalignant and malignant tumors as per the histologic findings, and into intrahepatic and extrahepatic tumors based on their location [1]. Most of these tumors are malignant. Bile duct adenoma is the most common benign neoplasm of the bile ducts, though it is rare. Premalignant bile duct tumors include biliary intraepithelial neoplasia (BilIN) and intraductal papillary neoplasm of the bile duct (IPN-B). Cholangiocarcinoma (CC) is the commonest primary malignancy of the bile ducts [2]. It is predominantly adenocarcinoma (95% of cases), although other histologic types including squamous cell carcinoma, small cell carcinoma and sarcomas have been described.

CC can be classified as intrahepatic or peripheral, perihilar and distal depending on their location. The distal CC, if resectable, is treated by pancreaticoduodenectomy (described in next chapter). Perihilar CC, also called Klatskin tumor, accounts for 60% cases of extrahepatic CC [3]. It is a challenging situation, as it may require a formal hepatectomy with lymphadenectomy and reconstruction. We shall elaborate on these details in the sections below.

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## 10.2 Surgical Treatment

R0 resection of the tumor offers the only possibility for long term survival and has been regarded as the gold standard for the treatment of resectable disease.

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For Klatskin tumor, which forms the majority of cases, this may include extended hepatectomy, combined with complete extrahepatic bile duct resection and radical lymphadenectomy [4]. This aggressive surgical strategy has increased the rate of curative resection and long term survival for the patients harboring this disease [5]. There are many challenging technical complexities in this approach like inflow control, inclusion of caudate lobe and reconstruction with separate small caliber ducts. The feasibility and safety of laparoscopic techniques in liver resections have been reported, especially for anterior and lateral segments. However, the adoption of laparoscopy for biliary tumors has been restricted due to technical limitations and oncologic concerns [6].

Robotic surgery may help overcome certain limitations of laparoscopy and provide the minimally invasive advantage to these patients, who otherwise usually undergo extensive open surgery. The main challenges faced during these procedures are right lobe mobilization, hepatic hilum dissection, control of bleeding during parenchymal transection, and complex biliary reconstruction. The robotic platform provides many advantages which have been already well described. This helps the surgeon increase the precision of dissection while facilitating suturing in difficult situations. It also provides him with the ergonomic comfort in these long and challenging procedures so as to allow him to work to his full potential.

In all these advanced procedures, it is important to understand that with the use of a minimally invasive method, indications and patient selection for a procedure does not change. The fundamental principles of a safe R0 surgical resection and adequate lymphadenectomy should not be compromised. A low threshold for conversion to an open procedure should be kept if the goals of the operation cannot be accomplished safely by using minimally invasive technique.

### **10.2.1. Preoperative Assessment of Patient**

One has to assess these patients for their performance status and fitness for major surgery that may include a partial hepatectomy. Chronic liver disease or portal hypertension generally makes these patients bad candidates for surgery. If there is any evidence of cholangitis, it should be treated with adequate drainage and antibiotics before surgery [2].

The main goal of the surgery is R0 resection with free proximal and distal margins, resection of tumor bed (including caudate lobe and vascular elements) and adequate lymphadenectomy. A complete resection with histologically negative resection margins is a very important criterion for long term survival in cholangiocarcinoma.

The criteria for unresectable disease are [7]:

- major comorbidities precluding safe surgery;
- metastatic disease;

- invasion of main portal vein or hepatic artery proximal to their bifurcation;
- bilateral invasion of portal vein or hepatic artery branches;
- bilateral involvement of hepatic ducts up to secondary radicles; and
- unilateral duct and/or vessel involvement with contralateral liver lobe atrophy.

Some of these restrictions can be overcome by techniques like portal venous embolization, which induces contralateral liver hypertrophy to increase the future remnant liver volume.

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## 10.3 Procedure Overview

### 10.3.1 Patient Positioning and Docking

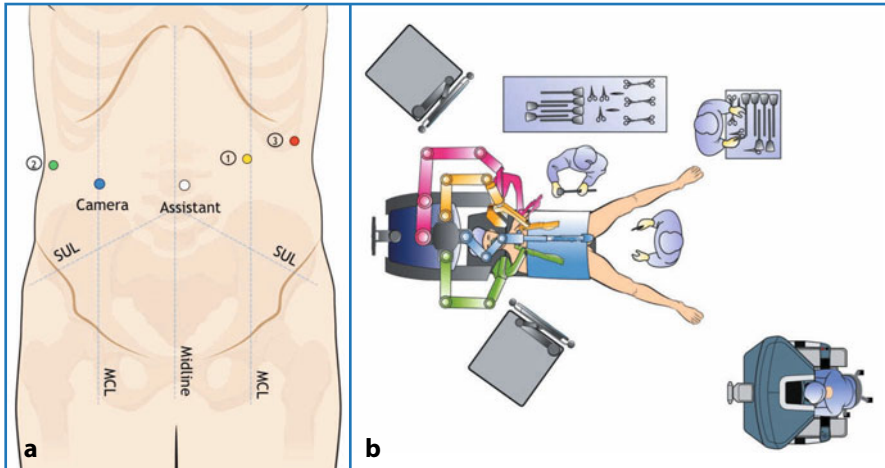
Under general anaesthesia, the patient is placed in the supine position with parted legs with approximately a 20° reverse-Trendelenburg tilt. The abdomen is cleaned and draped and an orogastric tube and urinary catheter are inserted. The assistant stands in between the legs. Pneumoperitoneum is achieved to 15 mmHg using a Veress needle at Palmer's point. A 10/12 mm trocar is placed in supraumbilical position (which is used as an assistant port in the operation). One optical and three da Vinci® trocars are placed as follows (Fig. 10.1a):

- optical (12 mm): in the right midclavicular line, approximately 10 cm from the assistant trocar, above the level of the umbilicus;
- R1: in the left midclavicular line approximately 10 cm away from the assistant trocar, above the level of umbilicus;
- R2: in right anterior axillary line, at least at 10 cm from the optical trocar;
- R3: in left anterior axillary line, used for retraction purpose.

The port placement needs to be adjusted based on the body habitus of the patient so as to prevent external arm collision and provide optimal exposure.

A diagnostic laparoscopy is done to look for any metastatic deposits or free fluid. If a suspicious deposit is seen, it is biopsied and sent for frozen examination to rule out metastatic disease. Any free fluid is sent for cytology to look for malignant cells. Intraoperative ultrasonography is performed to rule out any undetected metastatic deposits in the liver.

The da Vinci® patient cart is brought from the head of the patient, and the arms are docked to the placed ports. The third arm of the robot comes from the left side of the patient. To start the procedure, a monopolar hook is taken in R1, bipolar forceps in R2 and grasping forceps in R3. The assistant surgeon stands in between the legs for complementary maneuvers (i.e., suction, stapling, retraction, and laparoscopic ultrasonography). A sample OR setup for right extended hepatectomy for CC is depicted in Fig. 10.1b.



**Fig. 10.1** Robotic-assisted right extended hepatectomy. **a** Port position. *SUL*, spino-umbilical line; *MCL*, midclavicular line; 1, 2, 3 represent positions for robotic arm 1, 2 and 3 respectively. **b** OR setup. (© 2014 Intuitive Surgical, Inc.)

### 10.3.2 Bile Duct Resection

Hepatic flexure of the colon is mobilized medially and caudally and a partial Kocher maneuver is performed. Dissection is commenced at the hepatic hilum while it is retracted using R3. If the gallbladder is in place, it is taken down keeping the cystic duct attached to the common bile duct (CBD). Indocyanine green fluorescence aids in the detection of CBD and any aberrant biliary anatomy. The CBD is dissected and transected distally at the superior border of pancreas, and the distal stump is oversewn. The distal margin is sent for frozen section, which if positive, calls for a pancreaticoduodenectomy with or without liver resection, as per disease location, spread and performance status of the patient. Now, the proximal bile duct is lifted up and dissection is continued to separate the hepatic artery and portal vein from the bile duct. Starting at the superior border of the pancreatic head, a lymphadenectomy along the common hepatic artery is performed. The origin of gastroduodenal artery is exposed. Generally, lymph node dissection in hepatoduodenal ligament is adequate. The fat and lymph nodes are resected en bloc with the bile duct. At the hilum, right and left hepatic ducts are dissected and encircled with vessel loops to aid in traction. If one can get proximal to the tumor, bile ducts are divided and margins are sent for frozen section to confirm R0 resection.

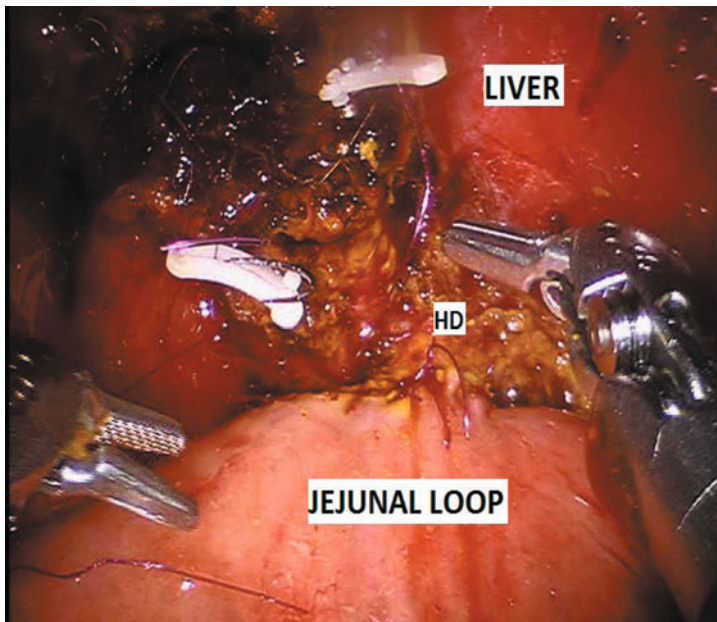
In case of Bismuth type III tumors, an extended right or left hepatectomy along with bile duct resection may be required for R0 resection. The detailed technique of these procedures is described below in separate sections.

Vascular resection and reconstruction may be required in case of portal venous or hepatic arterial involvement. This may be done only by experienced

surgeons and institutions with good perioperative results in such high risk procedures.

### 10.3.3 Reconstruction: Roux-en-Y Hepaticojejunostomy

For a Roux-en-Y hepaticojejunostomy, the attention is diverted to the submesocolic area in order to prepare the loop for reconstruction. A proximal jejunal loop is divided using a stapler, and a jejunojejunostomy is performed with a laparoscopic stapler to create a Roux loop. The distal loop is then brought into the right upper quadrant usually in a transmesocolic fashion. Here, an anastomosis between the bile duct and the loop is performed in end-to-side fashion, using 4-0, 5-0 or 6-0 PDS (Ethicon, Somerville NJ) depending on the diameter of the bile duct. A ductoplasty may be required if the bile duct diameter is small. We usually do a single layered anastomosis with half running layers of suture, one for the posterior and one for the anterior wall. Few interrupted stitches may be placed to reinforce the anastomosis. Sometimes, anterior layer has to be formed by interrupted stitches, in case of small diameter or thin walled ducts (Fig. 10.2). The possibility of doing microsurgical interrupted stitches is one of the main advantages of using robot. In order to decrease the tension of the anastomosis,



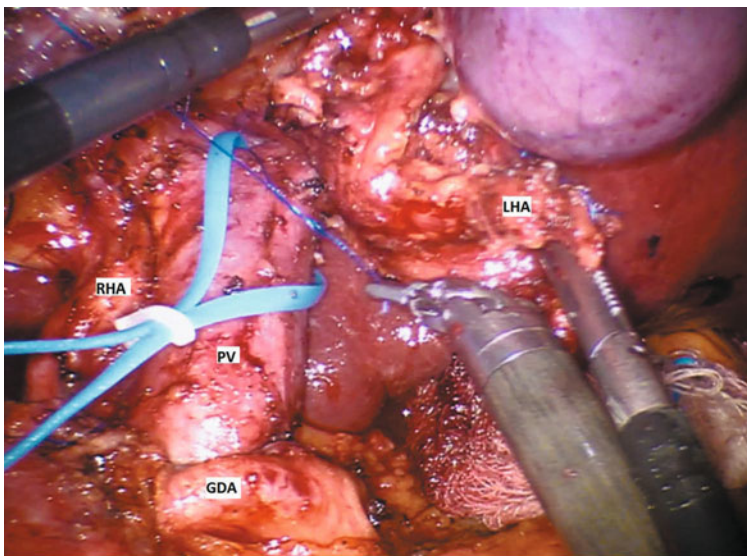
**Fig. 10.2** Interrupted stitches to perform the anterior layer of hepaticojejunostomy. The interrupted sutures are held in position by clips. Use of robotic platform provides the distinct advantage of ability to perform microsurgical interrupted stitches in a minimally invasive environment. HD, hepatic duct

two stitches of Prolene 3-0 (Ethicon, Somerville, NJ, USA) are placed to fix the jejunal loop to the hilum.

Use of fibrin glue may be considered at the end of the anastomosis. At the end of the procedure, a drain may be left near the biliary anastomosis.

### 10.3.4 Extended Left Hepatectomy with Caudate Lobe Resection

Ports are placed as already described. A thorough diagnostic laparoscopy is done along with ultrasonography of the liver to rule out metastatic disease. The patient cart is docked and the operation starts by removing the gall bladder, while keeping the cystic duct intact. Indocyanine green fluorescence is used to identify the biliary anatomy and look for any variations. The CBD is completely dissected, tied and transected. The distal margin of CBD is sent for frozen section and the stump is oversewn with PDS sutures. Lymphadenectomy is performed along the hepatoduodenal ligament. The left hepatic artery is dissected, and before transection with a stapler, confirmed by a clamping test which leads to a change in color of the liver parenchyma on the left side. The left branch of the portal vein is then dissected, ligated and divided (Fig. 10.3). Parenchymal transection is done along the line of ischemia usually using ultrasonic shears. Habib™ (a bipolar radiofrequency device) or cavitation ultrasonic surgical aspirator (CUSA) may be used for parenchymal transection. Anterior and pos-



**Fig. 10.3** Left branch of portal vein (PV) being ligated. The left hepatic artery (LHA) has been divided and lifted up. One can see the gastroduodenal artery (GDA) and right hepatic artery (RHA)

terior branches of right hepatic duct are dissected, transected and margins are sent for frozen section. The caudate lobe is dissected from the inferior vena cava. The parenchymal transection is completed and hemostasis confirmed. The reconstruction is done in a Roux-en-Y fashion. The Roux limb is created by stapled jejunojejunostomy (as described in Sect. 10.3.3) and it is brought cranially in a transmesocolic (sometimes retrogastric) fashion. Using 5-0 PDS, the two right ducts are connected to each other. An opening made in the Roux limb and a posterior layer of the anastomosis is performed using continuous suturing. An interrupted anterior layer is thrown and a few stitches are placed between liver and Roux limb so as to avoid undue tension on the anastomosis. Fibrin glue is used over the anastomosis and the raw surface of transected liver parenchyma. The specimen is retrieved in an Endobag usually through a Pfannensteil incision.

### **10.3.5 Extended Right Hepatectomy**

Initially, the hepatic flexure of the colon is mobilized, and a partial Kocher maneuver is performed. Starting at the superior border of the pancreatic head, a lymphadenectomy of the common hepatic artery is performed, using a monopolar hook and bipolar forceps, to expose the origin of the gastroduodenal artery. The inferior aspect of segment IV is retracted upward by using the third robotic arm, and the CBD is dissected and sectioned at the superior border of the pancreatic head. The distal stump of the CBD is sutured, and a frozen section is sent to rule out neoplastic invasion. The right hepatic artery is dissected and divided at its origin from the proper hepatic artery. The left hepatic duct is transected at the left umbilical fissure and a frozen section is sent at this level as well. Following this, the right portal vein is dissected and divided between ligatures. The right liver lobe is mobilized from its peritoneal attachments. This is done by sectioning the falciform ligament and the anterior half of the coronary ligament, until the anterior side of the inferior vena cava (IVC) and the right hepatic vein is reached. The hepatorenal ligament and the right triangular ligament are divided by using a monopolar hook. The third arm is used to retract the inferior aspect of the right liver lobe upward. In this way, the right side of the IVC is exposed. The accessory hepatic vein is suture ligated and the dissection proceeds until the inferior aspect of the right hepatic vein is reached. After sectioning the bridge of parenchyma between segments IV and III, the parenchymal transection is carried out along the right aspect of the falciform ligament, by harmonic scalpel, starting at the anterior border of the liver. The recurrent vessels from the umbilical fissure to segment IV, middle hepatic and right hepatic veins are divided using staplers. The reconstruction is done as per the already described method. The specimen is retrieved in an Endobag.

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## 10.4 Palliative Surgery

A vast majority of patients with cholangiocarcinoma have a surgically unresectable tumor at the time of diagnosis. The goal in these patients is palliation of symptoms using interventions with least morbidity and maximal efficacy [8, 9]. For distal CC, usually endoscopic stenting is the preferred modality, while for proximal CC, percutaneous methods with or without endoscopic interventions are helpful. In a limited number of situations, a surgical biliary and/or digestive bypass may be needed, but is associated with a high morbidity and mortality when done by open approach [10]. With the use of surgical robotics, we can provide minimally invasive advantage to these patients with a low morbidity [11].

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## 10.5 Liver Transplantation

Orthotopic liver transplantation, in combination with multimodality therapy, is rarely an option in advanced tumors like those invading the portal vein, bilateral hepatic ducts and atrophic liver lobes. However, there are only a few studies on liver transplantation as a modality for treatment of cholangiocarcinoma. Also, because of the shortage of organs and poor outcomes, the indications of transplant are very limited and it cannot be considered as a standard form of therapy. In a few cases when transplant needs to be done, use of robotic platform can be an option for living donor hepatectomy [12].

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## 10.6 Postoperative Outcomes

Surgery for bile duct tumors is associated with significant postoperative morbidity and mortality. The perioperative complications associated with the procedure are bile leak, hemorrhage, cholangitis, liver abscess, hepatic failure, organ space or superficial surgical site infections and respiratory complications.

Our experience included more than 150 cases of robotic hepaticojejunostomy for different indications, out of which 52.9% patients has had a previous hepatobiliary procedure, either open or laparoscopic. There was a 3.9% bile leak rate, 4% biliary stenosis rate and 3% cholangitis rate at 16.82±13.09 month follow-up. The variables which significantly increased the risk of complications after a minimally invasive bilioenteric anastomosis were iatrogenic bile duct injury and duct diameter ≤5 mm. These results are better placed than most of the studies with open and laparoscopic hepaticojejunostomy.

As per the literature, less than 50% of patients with cholangiocarcinoma are able to undergo a curative resection. The five-year survival rates are highly variable, ranging from 8 to more than 50%. The factors which predict a better outcome are negative margins on histopathology, no lymph nodal involvement, concomitant liver resection, well-differentiated tumors, papillary tumors and



lack of perineural invasion [13]. In general, the best outcomes are in patients who undergo R0 resection and this is the best predictor for five-year survival.

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