The gallbladder and bile ducts

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Anatomy

Normal anatomy

Gallbladder

The gallbladder is a pear-shaped organ which lies on the visceral inferior surface of the liver between segments IV and V of the liver. The first and second parts of the duodenum lie behind it and the transverse colon lies below. It is covered with peritoneum except where it is adherent to a depression in the liver surface known as the gallbladder fossa. The expanded lower end of the gallbladder, or fundus, may or may not project beyond the inferior border of the liver in the region of the right ninth costal cartilage and the body of the organ narrows to form the neck which terminates in the cystic duct. The dilated area proximal to the junction of the neck and cystic duct is known as Hartmann's pouch.

The cystic duct arises from the neck of the gallbladder and joins the common hepatic duct. It is typically of 1-3 mm diameter although may be much wider in some individuals. The mucosa is arranged in spiral folds known as the valve of Heister. It most frequently is 3-4 cms in length and joins the common hepatic duct at a slight angle.

The main blood supply to the gallbladder is provided by the cystic artery, which commonly arises from the right branch of the hepatic artery posterior to the common hepatic duct (figure 1). The cystic artery runs above and behind the cystic duct to reach the neck of the gall- bladder where it divides into an anterior and a posterior branch. The gallbladder also receives a variable blood supply from the liver through its bed. A major portion of the venous drainage passes directly to the liver through the gallbladder fossa but veins may be seen around the cystic artery and these drain directly into the portal vein.

The cystic lymph node lies adjacent to the cystic artery where it meets the gallbladder wall, and is therefore a useful landmark during cholecystectomy. Lymph from the gallbladder and bile ducts passes through the cystic node and into other hepatic nodes in the edge of the lesser omentum.

Bile ducts

The right and left hepatic bile ducts fuse at a variable distance below the liver to form the common hepatic duct. The area between the common hepatic duct which lies within the edge of the lesser omentum, the liver and the cystic duct, is called Calot's triangle. Its contents are the cystic artery and lymph node and its accurate identification and dissection are crucial to the safe performance of cholecystectomy. (n.b. Calot actually described the triangle lying between the cystic artery, cystic duct and hepatic duct but the above description is the one usually referred to and of more practical relevance).

The hepatic artery lies on the left of the common hepatic duct and the portal vein lies posteriorly. The cystic duct joins the common hepatic duct to form the common bile duct approximately 2cm above the duodenum. As it passes behind the first part of the duodenum and the head of the pancreas the bile duct loses its peritoneal covering, and it enters the duodenum through the posteromedial wall to join the main pancreatic duct within the ampulla of Vater, which then opens into the duodenum via a papilla in the second part of the duodenum approximately 10cm beyond the pylorus. Circular muscle fibres are present around the terminal portion of the bile and pancreatic ducts and their confluence at the ampulla. The combination of all these sphincteric mechanisms is known as the sphincter of Oddi.

The blood supply to the bile ducts is complex and branches are received from the gastroduodenal, hepatic and cystic arteries, as well as the coeliac and superior mesenteric vessels. Two vessels run along the lateral borders of the supraduodenal segment and 60% of their blood supply is provided from arteries below, mainly from the retroduodenal and retroportal vessels. The right hepatic artery provides most of the blood supply of the main bile duct from above and only 2% of the blood is derived from the common hepatic artery. This arrangement of the blood supply suggests that bile duct damage during surgery can be minimized by restricting dissection at the lateral margins of the common bile duct so as to avoid damaging the axial vessels. Flush ligation of the cystic duct on the common bile duct is also best avoided for the same reason. Anastomotic complications after transplant surgery may also be related to arterial damage.

The nerves to the extrahepatic bile ducts are derived from segments 7–9 of the thoracic sympathetic chain and from the parasympathetic vagi. Afferent nerves which include pain fibres from the biliary tract run in sympathetic nerves and pass through the coeliac plexus and the greater splanchnic nerves to reach the thoracic spinal cord via the white rami communicantes and dorsal ganglia. The preganglionic efferent nerves from the spinal cord relay with cell bodies in the coeliac plexus and the post-ganglionic fibres run with the hepatic artery to supply the biliary tract. A small contribution of pain afferents may travel within the right phrenic nerve and peritoneum below the right diaphragm. These fibres may account for the radiation of gallbladder pain to the right shoulder tip during attacks of gallstone colic. Vagal fibres supply the hilum of the liver and the bile ducts. Although vagal stimulation results in gallbladder contraction and relaxation of the sphincter of Oddi, the effects are overshadowed by the action of gastrointestinal hormones such as cholecystokinin.

Variations and anomalies of anatomy

Gallbladder

The gallbladder may rarely be absent or rudimentary, and when this occurs it may be associated with other congenital anomalies such as tracheo-oesophageal fistula or imperforate anus. Left-sided or intrahepatic gallbladders and double and triple gallbladders have also been reported. Discovery of duplications at operation, usually by operative cholangiography, should be followed by removal of both gallbladders. A second operation may be necessary later if only one organ is removed.

The gallbladder may be abnormal in structure, for example the body may be divided completely or partially by a septum. Complete division may result in two separate cavities fused at their necks to form a single cystic duct or they may drain by two separate ducts. Partial separation of the fundus from the body seen at surgery or during pre-operative imaging is known as a Phrygian cap, and is caused by a localised thickening of the gallbladder wall. It is of little significance and gallbladder function is usually normal.

Complete investment of the gallbladder with peritoneum can predispose to torsion around its associated mesentery, particularly when this is restricted to the neck of the organ so that the body and fundus remain free.

Bile ducts

Major variations in bile duct anatomy are common, and their frequency has been analysed in a large series of operative cholangiograms. The most important anatomical variations from an operative viewpoint are those pertaining to the cystic duct (figure 2). The most important, and potentially dangerous, variations involve different types of right subsegmental ducts and their drainage into the biliary tract via, or close to, the cystic duct (figure 3). A few examples of the commoner variations include:

1. A high insertion of the cystic duct into the region of the common bile duct bifurcation (3.1%).
2. An accessory hepatic duct, defined as a separate channel draining a segment of the right lobe of the liver into the common hepatic duct, cystic duct or gallbladder. The incidence is between 1 and 4% and it may be the only drainage from the relevant segment. An injury can easily occur to these ducts during cholecystectomy and may result in partial or total occlusion of a portion of the biliary tract as there is a lack of interductal communications within the liver.
3. The cystic duct entering the right hepatic duct. This is an uncommon variation (0.2%), but increases the risk of transection or ligation of the right duct during surgery.
4. The right and left hepatic ducts may join the common hepatic duct in a variable manner, and occasionally this junction may be truly intrahepatic. The right duct occasionally fuses with the cystic duct.
5. Duplication of the cystic ducts is very rare.

Intraoperative cholangiography is used for the recognition of these anomalies. Accessory ducts may be tied off if small, but larger ducts should be preserved and implanted into a Roux loop if necessary. Bile peritonitis or fistula may be a consequence of the unrecognized division of such a duct. Anomalies of the common bile duct itself are very rare but ectopic drainage of accessory ducts into the stomach has been described on five occasions, including an original report by Vesalius in 1543. The anomaly has been associated with symptomatic biliary gastritis.

Occasionally during cholecystectomy an accessory duct (or ducts) is encountered in the gallbladder bed – a duct of Luschka. When missed these ducts may present as bile leaks in the post operaive period. Once thought to be intrahepatic ducts draining directly into the gallbladder, anatomical studies and the common finding of two transacted ducts confirms that they are segmental or subsegmental ducts lying superficially in the gallbladder bed. They should be clipped or sutured to prevent leakage.

Hepatic and cystic arteries

Major anomalies of vessel origin are particularly important during hepatectomy and pancreatectomy. The left hepatic artery arises from the left gastric, splenic or superior mesenteric in 3–6% of the population and may be especially at risk during gastrectomy and laparoscopic fundoplication. The right hepatic artery arises from the superior mesenteric artery in 10–20% and an accessory right hepatic artery arising from the superior mesenteric is found in 5% of patients.

The right hepatic artery is particularly at risk during cholecystectomy if it takes a tortuous course close to the cystic duct and neck of the gallbladder, as the cystic artery may be very short in this variation. Anatomical variations of the cystic artery itself are common, and it may arise from the left, common or accessory hepatic arteries and pass anterior or posterior to the main bile duct. More than one cystic artery is present in some patients. The cystic artery not uncommonly runs in front of the common bile duct, which increases its risk of damage to the bile duct during cystic artery dissection and ligation.

Management of gallstone disease

Medical treatment of gallstones

An alternative treatment to cholecystectomy for gallstone disease has long been sought. Treatments are centred on agents that dissolve cholesterol back into the bile. These are either directly injected into the gallbladder such as Methyl-Tert-Butyl Ether (MTBE), or given by oral administration which are subsequently excreted into the bile and concentrated in the gallbladder such as Ursodeoxycholic acid (UDCA). These agents are only capable of dissolving cholesterol stones and are of no use in treating calcified or pigment stones. Extracorporeal lithotripsy has been used to shatter cholesterol stones and increase the surface area for dissolution, but can only be used when there are less than four stones that are greater than 10 mm diameter. Reliable identification of cholesterol stones is difficult and depends upon cholecystography, whilst CT remains the most reliable way of identifying calcification within stones. Patients must also have a functioning gallbladder and patent cystic duct in order to clear the debris. Only around 10-20% of patients with gallstones fit the criteria for dissolution therapy.

Controlled trials of patients with few stones, less than 20 mm diameter, with functioning gallbladders, receiving doses of ursodeoxycholic acid of 8-10 mg.kg for 6-24 months have achieved dissolution rates of around 40% (Roda 1982). Recurrent stones occur in 50-100% of patients when treatment is stopped. Ursodeoxycholic acid is expensive and a significant proportion of patients suffer with diarrhoea. Direct instillation of Methyl-Tert-Butyl Ether in appropriately selected patients achieves dissolution in 80-90% (van Sonnenberg 1988, Thistle 1989) with recurrent stone formation in 40-70% over 5-year follow up (Hellstern 1998). Complications include nausea, vomiting, bradycardia and hypotension; leakage and peritonitis, gallbladder injury, duodenal erosions and ulceration.

The development of laparoscopic cholecystectomy has led to abandonment of these procedures in all but the most phobic patients or physicians.

Cholecystectomy

Karl Langenbuch first described cholecystectomy in 1882. One hundred years later the procedure was revolutionized by the development of the laparoscopic approach. By 1992 over 80% of the 600,000 cholecystectomies performed in the USA were carried out laparoscopically (NIH consensus 1992). In the UK some 50,000 cholecystectomies are performed per annum. There has been a rise in the incidence of cholecystectomy since the introduction of the laparoscopic technique although it is not clear whether this is from a lowering of the threshold for offering surgery or that patients are more willing to undergo a minimally invasive approach.

The indications for cholecystectomy remain unchanged; documented cholelithiasis with symptoms attributable to the presence of gallstones or a diseased gallbladder.

Laparoscopic Cholecystectomy

The first laparoscopic assisted cholecystectomy was performed by Muhe in Boblinghen, Germany in 1985. Following the development of the solid state image sensor in 1985 it was possible for the first time to transmit the pictures from the laparoscope to a television monitor to enable assistants to hold the camera and participate in the operation. The first laparoscopic cholecystectomy as we would recognize it today was performed by Phillip Mouret in Lyons in 1987 and shortly after in 1988 by McKernan and Saye in Georgia, and Reddick and Olsen in Nashville. The technique was introduced into the UK the following year.

Contraindications

The number of absolute and relative indications have diminished over the last ten years as equipment and skills have improved. Absolute contraindications are: an inability to tolerate general anaesthesia, refractory coagulopathy and suspicion of gallbladder cancer. Laparoscopy in patients with gall bladder cancers is associated with a 20% incidence of port site metastases. Relative contraindications are dictated primarily by the surgeon's philosophy and experience and include previous upper abdominal surgery with extensive adhesions, portal hypertension, and third trimester of pregnancy (Underwood 2000). Severe cardiopulmonary disease and morbid obesity initially deemed to be contraindications have been demonstrated to be associated with a lower morbidity when surgery is performed laparoscopically.

Advantages and disadvantages

The advantages of the laparoscopic over the traditional open technique are now well established and include: earlier return of bowel function, less postoperative pain, a lower incidence of incisional hernias and adhesions, improved cosmesis, a shorter hospital stay, an earlier return to full activity and a decrease in the overall cost (Bakrun 1992, Bass 1993, McMahon 1994, Soper 1991 & 1992). The procedure is now routinely carried out as a day case procedure in many centres.

The major disadvantage is cited as a higher risk of bile duct injury. The true incidence of major bile duct injury (defined as injury affecting >25% circumference of CBD) in the open cholecystectomy era was poorly documented but was in the order of 0.1-0.5% (Andren-Sandberg 1985, Banting 1994, Garden 1991). Initial results from small series of laparoscopic cholecystectomies demonstrated an increase in these rates (Steele 1995, Dunn 1994) but subsequent large multicentre and single centre prospective studies show that bile duct injury rates are similar to the open era; Soper 0.2% (1200 pts) (Underwood 2000); Cushieri <0.01% of (1236 pts) (Cushieeri 1991); Croce 0.3% in 6865 pts (Croce 1994). A number of studies have shown that the incidence of bile duct injuries is proportional to the surgeons experience with the technique (Moore 1995). When bile duct injuries do occur with laparoscopic cholecystectomy they are frequently more proximal and more extensive than with open cholecystectomy (i.e. complete transection or excision of the bile duct).

The operative technique of laparoscopic cholecystectomy

Preparation

Patients are fasted for four hours prior to surgery. Anti-embolic prophylaxis is used (full length compression stockings; prophylactic dose low molecular weight heparin; calf compression boots). A general anaesthetic is administered with full muscle relaxation. A nasogastric tube is not routinely required. Routine antibiotic prophylaxis has been shown to be unnecessary but should be used in patients with biliary tract infection or when there is intraoperative bile spillage.

Setup and port placement

A pneumoperitoneum is established. The authors' preferred technique is an open longitudinal cut down below the umbilicus permitting insertion of a blunt 10mm trocar. A Verres needle can be used but there is increasing evidence to suggest that the incidence of bowel (0.083% v 0.048%) and vascular (0.075% v 0) injuries is higher with the Verres needle (Bonjer 1997) and furthermore there are no apparent disadvantages of the open technique. A 10mm laparoscope is inserted through the umbilical port. Two 5mm ports are then inserted under direct vision below the costal margin at the levels of the anterior axillary line and the midclavicular line. A second 10mm port is inserted in the midline approximately 5 cm away from the xiphisternum. The aim is to be able to work comfortably on the medial and lateral aspects of Calot's triangle. Reverse Trendelenberg position and lateral tilt are not routinely required but may be helpful in obese patients.

Dissection of Calot's triangle

The gallbladder fundus is grasped with an atraumatic grasper through the lateral most port and pushed cephalad. The assistant holds this instrument and the camera. The surgeon stands on the patients left side with the monitor on the patients' right side. The surgeon grasps the lower part of Hartmanns pouch and applies lateral and caudal traction to open out Calot's triangle (figure 4). The peritoneum investing Calots triangle is opened staying close to the gallbladder at all times. This can be done with a combination of blunt dissection and short accurate bursts of the diathermy hook. Blunt dissection alone can result in oozing and bleeding from small vessels; overzealous use of the diathermy may result in damage to the bile duct. The gallbladder is flipped medially and the process repeated on the lateral aspect of the gallbladder. In this way exposure of the cystic duct and artery is achieved with the development of a "window" posterior to the cystic artery.

Intraoperative cholangiography

This may be performed routinely or on an occasional basis when a bile duct stone is suspected or there is uncertainty over the biliary anatomy. All surgeons performing laparoscopic cholecystectomy should be capable of performing the procedure and patient should be routinely set up on a radio lucent table with facilities available to perform the procedure in the event of a problematical dissection.

A metal clip is applied to the cystic duct just below its origin from the gallbladder. The cystic duct is opened with scissors and any small stones within the duct "milked" back and removed. A 14fr abbocath cannula is inserted into the abdomen under the costal margin in the mid clavicular area and a 4Fr umbilical feeding tube (flushed with saline to remove bubbles) inserted through this and into the cystic duct. A metal clip is used to hold it in place. An image intensifier is used to obtain contrast images using dilute non-ionic contrast media with care to ensure that no bubbles are within the lumen of the catheter. Use of the image intensifier avoids the problems of misplacement of the machine/x-ray plate, saves time, uses less radiation exposure and enables real time imaging giving much more information than plain film imaging. Four points should be established: the entry point of the cholangiogram catheter (marked by the metal clip) must be through the cystic duct and not the common hepatic duct; there must be cephalad and caudal flow along the main bile duct with opacification of right (anterior and posterior branches) and left ducts (figure 5); the presence or absence of stones within the bile ducts; contrast should flow into the duodenum.

The debate over whether all patients should have intraoperative cholangiogram has continued through the open and laparoscopic era based largely around whether routine cholangiography prevents bile duct injury. There is evidence to support and refute both arguments, and most surgeons adopt a middle ground accepting a low threshold for performing cholangiography in patients with an intermediate or high risk of having common bile duct stones, or when there is any uncertainty in the biliary anatomy. A routine cholangiogram itself does not prevent all bile duct injuries, but performing one should allow early recognition of injury and prevent conversion of an inadvertent choledochotomy into a more major excision of the bile duct.

Evaluation of the common bile duct by laparoscopic ultrasound (LUS) in experienced hands is more sensitive than cholangiography for detecting bile duct stones and can be performed more rapidly (Steigman). It is however less good at defining ductal anomalies and the two methods of duct imaging are likely to develop differing roles as LUS usage becomes more widespread (Wu 1998b).

Removal of the gallbladder

Two or three clips are applied to the cystic duct and artery well away from the portal structures. The vessels are then divided (not diathermied which may cause necrosis and allow clip slippage). The gallbladder is then removed using the diathermy hook or scissors staying close to the gallbladder itself. Care should be taken to neither enter the liver (with resultant bleeding or injury to superficial biliary structures) nor the gallbladder with bile spillage and possible stone leakage into the abdomen. With the gallbladder remaining attached by a small portion near the fundus a check is made with gentle suction and irrigation if necessary to ensure the clips are still intact, and no bleeding points or bile leaks are present. Finally the remaining few attachments of the gallbladder are divided. The camera is moved to the upper port and a large grasper passed through the umbilical port and applied across the neck of the gallbladder. A tissue-spreading device is slid around the grasper to stretch the umbilical port as the gallbladder is withdrawn through the abdominal wall. The linea alba is closed with absorbable sutures and the skin incisions closed with glue, steristrips or sutures.

As with all operations there are many variations on the exact technique, but the one described has proved safe and reliable.

Dealing with operative difficulties

Obesity

There is now good evidence that obese patients have better results with laparoscopic than with open cholecystectomy both in terms of ease of access within the abdomen and reduced post-operative respiratory problems. Extra long ports are only rarely needed but ports may need to be inserted more cephalad particularly the camera port which is best sited above the umbilicus in morbidly obese patients. A 30^o laparoscope improves views in Calots triangle. Insertion of a fifth port in the left upper quadrant and use of an atraumatic retractor to push down the omentum, colon and duodenum and gives safe access to the cytisc artery and duct.

Bleeding

Bleeding form the cystic artery should be controlled with the grasper in the left hand allowing suction with the right hand and subsequent identification of the bleeding point prior to careful application of a clip. Grasping or pressure together with diathermy, without identification of the bleeding point vessel is dangerous and runs the risk of damage to the bile duct, or its blood supply causing a delayed bile leak or stricture. Blind firing of multifeed clip appliers should also be avoided**.** A small swab inserted through the 10 mm port can be used to control bleeding whilst the sucker is used to identify the artery before it is grasped with atraumatic forceps. Failure to achieve rapid control of bleeding necessitates immediate conversion to open procedure with insertion of a pack and direct pressure until adequate wound retraction can be achieved to safely locate the bleeding point.

Gallstone spillage

Inadvertent opening of the gallbladder should be controlled by moving the assistant’s grasper to close the defect where possible. Clips are rarely successful in containing the leak. If stones cannot be contained a bag should be inserted and the gallbladder emptied to prevent further stone spillage and loss. Most retained stones will cause no harm (Memon 1999), but efforts should be made to retrieve dropped stones where possible as a small proportion may cause intra-abdominal abscesses.

Difficulty grasping gallbladder

A mucocoele or empyema can be decompressed by inserting a Verres needle or cannula connected to the suction tubing followed by grasping the drainage point with the assistant’s grasper to prevent intra-abdominal leakage. Very thick walled gallbladders or others packed with stones may necessitate replacing the lateral port with a 10 mm port to insert an endobabcock or similar wide jawed instrument.

Difficult dissection – acute cholecystitis

The dissection should always be started on the gallbladder wall. Use of a harmonic scalpel allows safe dissection of dense adhesions by reducing oozing and allowing division of vessels without the risk of inadvertently displacing clips. If no progress can be made in Calot’s triangle a retrograde dissection must be considered or subtotal Cholecystectomy performed by opening the gallbladder removing the stones in a pre-placed bag and closing Hartman’s pouch with an endoloop or purse string suture. Conversion to open Cholecystectomy is the safest option in inexperienced hands.

Wide/thick walled cystic duct

The duct must be confirmed to be the cystic duct by cholangiogram before it is divided. Endoloops should be used to close the duct rather than clips which are likely to come off as the inflammation resolves.

Difficulty extracting gallbladder

The gallbladder should be opened and bile aspirated. Desjardins stone forceps are used to carefully remove any stones without perforating gallbladder. Large stones may be crushed with Kocher forceps within the gallbladder then extracted. Otherwise the wound can be extended by inserting an artery clip between gallbladder and linea alba to allow a reversed knife blade to extend the midline incision. When multiple stones are present it is wise to put the gallbladder into a bag to prevent spillage during extraction.

Cholecystostomy

This is a useful method of treating severe acute gallbladder disease in the gravely ill and may be carried out percutaneously using ultrasound guidance. At operation it may be useful when the anatomy is obscured by severe inflammatory disease particularly when less experienced surgeons are called upon to operate in an emergency.

The gallbladder is usually under tension and should be aspirated before an incision is made in the fundus. Infected bile and stones are removed but stones impacted in the cystic duct may be impossible to dislodge at this stage. The gallbladder is closed around a large Foleycatheter which is brought out through a separate skin incision and allows ongoing drainage of bile and pus. The Foley catheter should be left in situ for 4-6 weeks to ensure adherence to the abdominal wall prior to its removal.

In the long term there is a 75% incidence of recurrent stone formation following cholecystostomy [111] and patients should undergo definitive cholecystectomy once their overall condition has improved.

Management of Choledocholithiasis

The management of common bile duct stones has become increasingly complex with the variety of diagnostic and therapeutic measures now available. Few randomized trials are available and the solution for many patients is at present largely dictated by the available equipment and expertise in any particular unit.

Techniques for CBD stone removal

Endoscopic stone management

ERCP allows access to the bile duct without general anaesthesia. Access to the papilla can be achieved in 90-95% of patients but may be impossible with large periampullary diverticulae or after Polya gastrectomy. Following the demonstration of stones within the bile ducts the cannula is exchanged over a guidewire for a sphincterotome. A sphincterotomy is performed using diathermy to allow extraction of stones less than 3mm in diameter. Stones can them be extracted using a dormia basket or balloon catheter. Larger stones can be broken with a mechanical lithotripter. In the presence of suppurative cholangitis, or occasionally when multiple or large stones are present, a plastic stent is inserted to prevent stone impaction and allow drainage of bile or pus. Various techniques are available for dealing with the occasional large stone which is too big for mechanical lithotripsy including contact electrohydraulic lithotripsy (Hixon 1992) and extracorporeal shockwave lithotripsy (Ponchon 1990). This allows removal of 98% of stones without surgery (Schumacher 1998). There are a number of situations in which ERCP remains the best option for removal of common bile duct stones: These include acute cholangitis, acute gallstone pancreatitis in the presence of biliary obstruction; stones causing obstructive jaundice; post-cholecystectomy common bile duct stones; and bile duct stones in elderly patients considered unfit for cholecystectomy.

Open choledocholithotomy and choledochoscopy

The standard approach to the common bile duct is from the supraduodenal route. Intraoperative cholangiography is obtained via the cystic duct noting the number and site of stones, diameter of the main bile duct, position of entry of the cystic duct and ease of flow of contrast into the duodenum. The gallbladder is removed and the duodenum mobilized (Kochers manoever) to allow palpation of the lower common bile duct and facilitate choledochoscopy. The choledochotomy should be performed in the lower part of the common bile duct to preserve as much duct as possible should a further procedure be necessary. The duct is opened vertically between fine stay sutures. The cystic duct may overlay the bile duct and be opened in error. Exploration of the duct should be as atraumatic as possible. Palpation of the lower duct between the fingers of the left hand can often milk stones back into the choledochotomy. A flexible choledochoscope and dormia baskets or Fogarty balloon catheters allow removal of stones under direct vision with minimal trauma. Avoiding passage of the choledochoscope or instruments into the duodenum reduces the risk of post-operative pancreatitis. The scope should then be passed up in to the intra hepatic ducts to look for further stones. Continuous irrigation through the choledochoscope flushes small stones out through the choledochotomy. The duct can be primarily closed with fine absorbable sutures if there has been minimal trauma, few stones were present, all identified stones on the cholangiogram have been removed, and there is no evidence of cholangitis. In the presence of multiple stones, cholangitis or a large duct a T-tube should be placed through the choledochotomy site. The limbs of the tube should be cut short to prevent passage into the duodenum as this avoids duodenal reflux into the bile or pancreatic ducts and segmental obstruction of the smaller intrahepatic ducts. Fine interrupted absorbable sutures are used to close the choledochotomy to achieve a watertight seal on testing. A drain should always be left following a choledochotomy for a period of 24-48 hours and can be removed if no bile is present.

Stones can be removed blindly with palpation, Desjardin forceps and a Fogarty balloon catheter if no choledochoscope is available but care should be taken to avoid damaging the bile duct wall creating a late stricture or creating false passages. A T-tube should be inserted and a completion cholangiogram taken to confirm removal of all stones and good flow of contrast into the duodenum. It can be very difficult to remove all the air from the biliary system and differentiation between air bubbles and stones is often difficult.

Laparoscopic CBD stone removal

Stones identified on the intraoperative cholangiogram at laparoscopy can be removed either via the cystic duct or through a choledochotomy. The transcystic route can only be used for removal of stones of comparable diameter to the cystic duct itself. These may be removed by fluoroscopic dormia basket extraction or more commonly by introduction of an ultrathin choledochoscope (3.0 – 3.5mm diameter) with dormia basket extraction. It is not usually possible to pass the choledochoscope proximal to the entry point of the cystic duct because of its angled entry into the common hepatic duct. Occlusion of the common bile duct with a balloon and flushing after an intravenous injection of glucagons or buscopan to open the sphincter of Oddi can sometimes be successful in flushing small stones through the duodenal papilla. The main advantage is relative simplicity without the need to open the bile duct. It is however limited to a small group of patients and excludes those with small cystic ducts, tortuous spiral valves within the cystic duct, multiple or large stones and stones in the proximal ducts

In patients not suitable for transcystic stone removal a choledochotomy is made in the distal bile duct of a size just bigger than the largest stone. A flexible choledochoscope is introduced through the midaxillary or epigastric port into the bile duct and the stones are removed with a dormia basket or balloon catheter. When multiple stones are present it is useful to place a bag beneath the porta hepatis to ensure stones are not lost. From an ergonomic viewpoint the procedure is undoubtedly easier to perform with the surgeon standing between the patients legs, the so called “French position” for laparoscopic cholecystectomy. Insertion of a fifth port in the middle of the left upper quadrant also improves the position for suturing. As in open surgery the choledochotomy may be closed primarily or over a T-tube and a drain left for 24-48 hours. Stone extraction rates of 70-95% are achievable using the laparoscopic approach (Rhodes 1998, Cushieri 1996, Petelin 1993). Failure is usually because of impaction of the stone in the lower common bile duct necessitating conversion to an open procedure.

Management of Mirrizi Syndrome

Mirrizi syndrome is usually associated with the presence of dense fibrosis in Calot’s triangle. Opening the gallbladder at the fundus with removal of stones allows identification or absence of a connection with the bile duct. Type I Mirrizi syndrome is managed by a subtotal cholecystectomy avoiding dissection of the bile duct. A drain should always be left in case a subsequent small bile leak occurs. Type II Mirrizi which is associated with the presence of a cholecyst-choledochal fistula is best managed by a choledochojejunostomy. Primary closure of the clinically inflamed bile duct or closure over a T-tube should be avoided as this inevitably results in bile leaks or later stenosis (Baer 1990).

A decision making algorythm for patients with possible common bile duct stones.

There are now several different pre-operative diagnostic techniques and intra operative techniques for imaging and treating common bile duct stones. At present there is little data to support one or other approach and it is therefore important to develop a strategy for the preoperative and operative management of patients with gallstones dependant upon the local availability of techniques and skills.

Most clinicians attempt to stratify their patients in some way according to the probability of bile duct stones being present. Patients with normal liver function tests, non-dilated bile ducts on ultrasound and no history of jaundice will have a <1.5% (Somnay 2000) chance of having a common bile duct stone. This group can undergo laparoscopic cholecystectomy without the need for further preoperative imaging or intraoperative cholangiography.

Patients at high risk of bile duct stones can be identified pre-operatively - presentation with jaundice/ bilirubin >20 mmol (2g/dl); CBD >10mm and/or CBD stone seen on ultrasound; alkaline phosphatase 150mmol. If one or more of these criteria is present the incidence presence of ductal stones is 56% (Sonnay 2000). These criteria may be used to identify patients for pre-operative ERCP or for referral to a surgeon performing laparoscopic bile duct exploration. Two randomized trials have shown comparable duct clearance rates with either strategy but with shorter hospital stay in the single stage surgery arm (Cushieri 1996, Rhodes 1998).

Patients in the intermediate group with a mild derangement of liver function test or a history of acute pancreatitis (in which 90% pass their CBD stone) present more of a dilemma. The incidence of stones in this group is around 5% (Sonnay 2000). Pre-operative ERCP is no longer justified in this group without prior demonstration of stones since the risk of complications is similar to the rate of demonstration of bile duct stones. Pre-operative imaging with MRCP (Griffin 2003) or endoscopic ultrasound will demonstrate most stones but at a high financial cost as 95% of the procedures will be negative. A more pragmatic approach is to perform intraoperative cholangiography or laparoscopic ultrasound on this group to demonstrate stones at the time of surgery. Stones can then be removed laparoscopically or by open bile duct exploration. A third alternative particularly when the bile duct is small (and therefore at risk of structuring following choledochotomy) is to tie the cystic duct with an endo-loop, complete the cholecystectomy and arrange a post-operative ERCP. This strategy relies heavily on ERCP expertise, as failed ERCP requires referral on to a more experienced endoscopist or a second operative procedure. Intraoperative ERCP at the time of discovery of bile duct stones has also been performed by a few groups but is cumbersome and time consuming. The choice between the various strategies in this intermediate group of patients depends largely upon the quality of the surgical and endoscopic therapy available.

Bile duct injury

Classification of bile duct injuries

The most widely used and comprehensive classification is Strasberg's modification of the Bismuth classification (Strasberg 1995) (figure 6). Type A injuries occur following cystic duct clip slippage or division of an accessory subvesical duct of Luschka (figure 7). Type B and C injuries involve damage to an aberrant right sectoral duct with division and occlusion of biliary drainage (B) or division and leakage (type C). Type D injuries are partial division of the main bile duct. Type E injuries involve the main bile duct (E1 and E2), the common hepatic duct with maintenance of the biliary confluence (E3) or with loss of the confluence (E4). E5 lesions are complex injuries involving the right sectoral duct and common hepatic duct. These injuries may be transections, excisions or strictures.

Mechanisms of injury and prevention

Risk factors have been identified and include inexperience on the part of the laparoscopic surgeon, inadequate training, a difficult dissection in Calot's triangle, failure to recognize the correct anatomy and operations performed on patients who have had recent acute cholecystitis. The "classical" injury occurs where the operator mistakes the common bile duct for the cystic duct, with the result that the bile duct is clipped in two places and to achieve removal of the gallbladder a segment of the duct is resected as well. When the upper clip is correctly placed on the cystic duct the proximal bile duct will not be obstructed and a bile leak will be present ("variant classical" injury) (figure 8). These injuries and many of the partial transaction with clips applied to the common bile duct occur as a result of excessive traction on Hartmann's pouch or the gallbladder fundus. This allows tenting up of the common bile duct and misidentification. It is notable that young slim women with small common bile ducts feature heavily in the injured bile duct group.

Safe surgery requires clear visualization of the anatomy which itself demands proper exposure. Avoiding these injuries requires use of caudal and lateral traction on Hartmann's pouch and always dissecting as close to the gallbladder wall as possible. No structure should be clipped or divided unless its identity is certain and an intraoperative cholangiogram should be performed if any uncertainty exists. Conversion to open surgery should not be seen as a failure and should be performed if doubts persist.

A second group of injuries occurs as a consequence of abnormal anatomy where a low-entry right sectoral hepatic duct is mistaken for the cystic duct and clipped or divided. Segmental ducts (ducts of Luschka) can be damaged by dissection drifting away from the gallbladder wall during dissection of Calot's triangle or inadvertent dissection into the liver parenchyma during removal of the gallbladder.

Ischaemic injury to the main bile ducts or clip placement across a main bile duct often occurs after haemorrhage in Calot's triangle (Davidoff 1992, Rossi 1992). Over dissection of the bile duct and damage to the coaxial vessels may be another factor in ischaemic injuries. At laparoscopy even a small amount of blood obscures the field and hinders dissection. Precise control of haemorrhage is required and injudicious application of diathermy and clips avoided. Early conversion to open surgery should be considered in the presence of bleeding around the porta hepatis.

Presentation and management of bile duct injuries

A proportion of injuries are recognized at surgery. Advice should be obtained from an experienced hepatobiliary surgeon and major biliary reconstruction in this charged setting should not be undertaken by surgeons unfamiliar with high biliary anastamosis. Large bore drainage tubes placed in the right upper quadrant and transfer to a tertiary referral unit for definitive surgery may be more appropriate. The importance of repairing the injury at the first attempt cannot be over emphasized. Around two thirds of patients have undergone a failed repair by the original surgeon before referral for definitive surgery (Chapman 1995, Stewart 1995). Each failed repair is inevitably accompanied by a further loss of bile duct length requiring a higher anastamosis. In skilled hands immediate reconstruction has good results. End-to-end anastamosis and choledochoduodenostomy have a high stricture rate and are not appropriate repairs in this setting (Rossi 1994). Partial division of the bile duct (type D injury) may be closed primarily if the bile duct is sufficiently large and there is minimal diathermy injury. This is rare and usually there is more extensive injury requiring insertion of a T-tube. Subsequent stricturing may occur but this often causes ductal dilatation making reconstruction easier. Injuries affecting more than half the circumference of the bile duct require hepatico-jejunostomy.

The majority of patients present within the first 2 weeks of surgery with a combination of pain, sepsis and jaundice and a failure to progress in their recovery. Blood investigations show abnormalities in the liver function tests, most notably a rise in bilirubin and an elevated white cell count in the presence of sepsis. An ultrasound scan or CT scan shows a fluid collection with non-dilated ducts if a bile leak is present, or may show dilated ducts with a complete bile duct obstruction. Fluid collections should have a percutanoeus drain inserted to confirm bile leakage and establish drainage. Further management depends upon the presence or absence of sepsis and the level and extent of injury. In a septic patient drainage of intra abdominal collections and establishment of adequate biliary drainage is the first priority.

In the absence of sepsis further investigation of the extent of the bile duct injury should be obtained. MRCP has the advantage of being able to visualize above and below any obstructing lesion. ERCP will delineate the lower level of an obstructive lesion (figure 9), diagnoses and sometimes treats type B and C injuries, and is the standard treatment for type A and D injuries. Some of the type D injuries may require later surgery if stricturing develops.

Type E injuries are more difficult to manage. Establishment of the level of injury may be facilitated by MRCP, radionuclide scanning or percutaneous transhepatic cholangiography. The latter can be used to establish external drainage of an obstructed system. At surgery diathermy damage to the duct may indicate that the injury is more extensive than identified preoperatively. Division of the right hepatic artery is found in around 20% of patients. Surgical repair of the bile duct is by proximal hepatico jejunostomy onto healthy ductal tissue. Successful outcome defined as requiring no further intervention following specialist repair in units reporting more than 40 cases ranges from 76 – 95% with follow up of 6-9 years (Chapman 1995, McDonald 1995, Tocchi 1996).