Chapter 4
Intraoperative Cholangiography

Matthew B. Bloom and Edward H. Phillips

Introduction

Prior to the advent of biliary imaging in the late 1800s, bile duct exploration was based on direct operative palpation of the bile duct. This approach led to unnecessary duct exploration in roughly half of the cases. Missed and retained common duct stones were the greatest cause of morbidity and mortality in biliary disease. The introduction of operative cholangiography by Mirizzi in 1937 [1] represented a major technological advance. It reduced both the rate of negative bile duct exploration and the incidence of retained bile duct stones after exploration.

With the advent of endoscopic retrograde cholangiopancreatography/endoscopic sphincterotomy (ERCP/ES) in 1974, surgeons began to place less reliance on operative cholangiography, as the static cholangiography available at that time was both time-consuming and not very accurate. By the time of the adoption of laparoscopy in the 1990s, many surgeons were not trained to perform cholangiography, nor did they possess the skills necessary to perform laparoscopic duct explorations. As a direct result, there was a surge in number of ERCPs that were obtained preoperatively, and the majority were negative. The stones that were identified were removed by endoscopic means. So in this post-laparoscopic era, why should we perform a cholangiogram?

The performance of an intraoperative cholangiogram (IOC) permits the real-time identification of common duct stones, which may be immediately addressed during cholecystectomy or immediately after surgery. If a properly performed cholangiogram is negative, unnecessary tests can be avoided postoperatively if patients continue to have symptoms or develop new ones. In addition, the identification of unusual anatomy and/or the prompt recognition of erroneously placed clips, ductal

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injuries, and/or transections can be identified and corrected at the time of the original operation, which results in better outcomes [2–5].

Performing IOC does not need to be a lengthy, frustrating, or difficult procedure. Portable digital fluoroscopes are readily available in operating rooms (ORs) capable of supporting cholangiography. When performed routinely, IOC is seamlessly incorporated into the flow of the operation. The equipment is on the table ready to go, and both the operating room staff know how to help and the radiology techs are better trained. Additionally, the radiologists will have more experience in reading and interpreting the images. If a strict selective approach is adopted, the surgeon and staff may not have developed the skills to perform a cholangiogram when a difficult case is encountered.

Rationale and Benefits of Routine Use

Whether or not cholangiography should be performed routinely or "when necessary" has been debated for years. Improvements in technology, especially mobile fluoroscopy machines, have made the procedure faster and safer to perform and permit a more accurate assessment of the bile ducts.

The rationale for performing cholangiography is that it affords:

1. A roadmap of the anatomy of the biliary tree prior to transection/division of the cystic duct
2. The intraoperative identification of bile duct injury
3. Demonstration of the presence of biliary stones that can then be flushed into the duodenum or removed at the time of cholecystectomy
4. Greater experience in performing and interpreting cholangiograms and performing laparoscopic common bile duct explorations in teaching programs, which is critical to producing well-trained surgeons

Large population-based studies have demonstrated that routine cholangiography is associated with lower rates of bile duct injuries [6–9], while others have suggested that its routine use is unnecessary and results in extra costs and additional procedures [10, 11]. A meta-analysis of 40 studies revealed that with the routine use of IOC, the incidence of intraoperative common bile duct (CBD) injuries was 0.21% versus 0.43% with its selective use. Furthermore, the rate of immediate diagnosis of these injuries at the time of the primary operation was 87% vs 45% [12]. The large recent Swedish Inpatient Registry study [6] of 152,776 patients demonstrated that those surgeons who performed cholangiography had lower rates of bile duct injury. Whether this represents greater awareness of anatomy or skill in common duct exploration is unknown. More recently, in a study of 856 consecutive patients compared before and after the adoption of routine cholangiography, the rate of major bile duct injury fell from 1.9% to 0% ($p = 0.004$, $n = 435$ routine IOC vs $n = 421$ selective IOC) [13].

Still, there is controversy as to whether a cholangiogram can provide adequate information to prevent injuries, such as visualizing the cystic duct insertion on the right hepatic duct or identifying a cystic duct that spirals across the common bile duct. A clear road map of a specific patient's anatomy can demonstrate one of the several variations in ductal configurations (Fig. 4.1). Only 17% of cystic ducts drain directly into the common bile duct at a 90° angle. The overwhelming majority drain posteriorly, spirally, or parallel to the common duct, or they drain directly into the right hepatic duct [14, 15]. As the single most important factor responsible for the creation of bile duct injuries is the misinterpretation of the patient's anatomy, accurate anatomic knowledge prior to further dissection or clip placement can avoid injury (Fig. 4.2) [16, 17].

In the case of a bile duct injury identified during surgery, the ability to treat the injury during the primary procedure reduces the greater morbidity associated with its late recognition and treatment [18]. A clip placed across the common duct, for example, can be immediately removed. Partial transection may be treated with the placement of a biliary stent across the injured area and primary closure. A more complete transection injury may require immediate or delayed hepaticojejunostomy reconstruction by a surgeon with this specific expertise. If not immediately available at the time of the primary operation, drainage, ligation, or tube drainage and referral to the care of a surgical team with expertise in repair of complex biliary injuries are recommended. The delayed recognition of bile duct injuries is associated with a mortality rate of 11% and risks severe morbidity that for some is lifelong and may

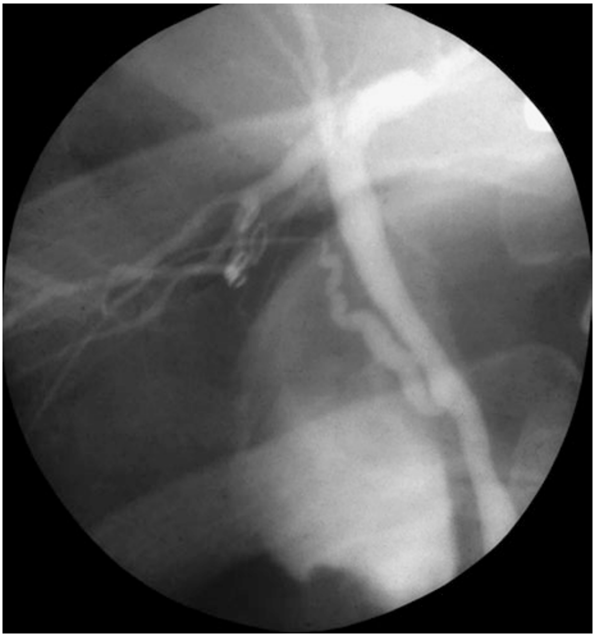

Fig. 4.1 A normal variant of cystic duct configuration that runs parallel to the common bile duct

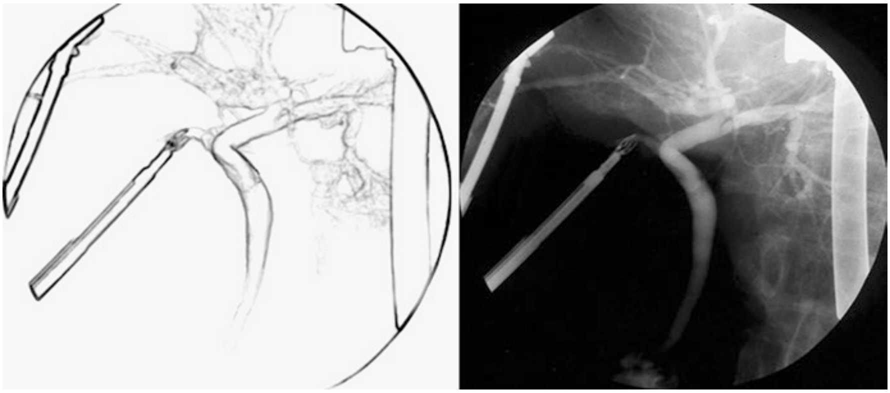

Fig. 4.2 Providing normal lateral retraction when there is a short cystic duct can tent the common bile duct laterally, making it easy to inadvertently clip or transect

require multiple corrective operations and/or procedures such as balloon dilation and stenting [19].

While several authors have noted the increased immediate cost associated with performing "unnecessary" cholangiograms, it has been estimated that performing routine IOC would prevent 2.5 deaths for every 10,000 patients at a cost of $390,000 per life saved. From a purely financial perspective, this more than makes up for the additional cost of the procedure, making it more financially attractive to perform than not [20]. This cost analysis did not include the potential for even greater economic savings to be realized if fewer postoperative magnetic resonance cholangiopancreatographies (MRCPs)/ERCPs are ordered because intraoperative cholangiography has been performed for the workup of the 5–25% of patients who continue to experience pain symptoms postoperatively [21].

The discovery of biliary stones during the cholangiogram allows for their treatment at the time of surgery or more accurately guides postoperative therapy [13]. Approximately 2–12% of patients will have unsuspected choledocholithiasis found on a routine IOC, which would be missed with thoughtful selective cholangiography [10, 22–24]. Small stones may be flushed with warm saline, often with the additional use of glucagon. The majority of the remainder may be removed through laparoscopic ductal exploration: either via transcystic or choledochotomy. Unsuspected duct stones tend to be smaller and fewer than in a symptomatic patient and are the perfect cases to hone one's laparoscopic duct exploration skills. Again, by identifying these stones and treating them at the time of operation, the patient is spared an additional ERCP/ES procedure. ERCP/ES carries a 3–6% risk of pancreatitis and a 1% risk of bleeding, perforation, or stricture and requires additional follow-up and possibly still more procedures for the placement and subsequent removal of biliary stents and/or treatment of duodenoscope-based carbapenem-resistant *Enterobacteriaceae* transmission. Reduced hospital length of stay and cost savings are achieved when stones are treated in a single procedure during cholecystectomy, compared to preoperative or postoperative ERCP/ES [25, 26].

The performance of IOC is facilitated by a support staff who are familiar with the setup of the equipment and the procedural steps and a surgical team with experience and confidence in interpreting the fluoroscopic images. Both are only achieved through the repetition that is achieved with a protocol of routine cholangiography. The experience gained from multiple cases will be called upon during difficult ones. When cholangiography is only occasionally performed, the skills needed by the entire team for the critical and challenging cases may not be developed. With repetition, a cholangiogram can be completed quickly, with no disruption of the flow of the operation. The performance of routine cholangiography also sets the stage for the acquisition of more difficult laparoscopic skills such as ductal exploration or placement of a biliary stent [27, 28]. This is particularly relevant in teaching institutions [29].

Technique

An intraoperative cholangiogram can be performed quickly and reliably when all the members of the OR staff are familiar both with the equipment required and the proper setup of materials. Having a dedicated instrument tray that includes a laminated photograph of the required equipment makes reprocessing, prepackaging, and assembly more reliable (Fig. 4.3a, b). A list of recommended equipment is provided (Table 4.1).

Back Table Prepare a 50/50 mixture of saline and contrast material such as Omnipaque (Novaplus) or the iso-osmolar Visipaque (Novaplus), and fill two 30 ml syringes with mixture. Connect a three-way stopcock to the extension tubing (the ideal length is 96 in.), one of the filled 30 ml syringes and to a third syringe filled with saline, and label them. Connect the other end of the extension tubing to the cholangiocatheter. It is of utmost importance that care is taken not to introduce air bubbles into the system. It is easier to take your time and avoid introduction of air bubbles than getting rid of them. Flush the tubing with the saline syringe while tapping the tubing with a hemostat to remove any trapped air bubbles, and set it aside.

Ductotomy Once the cystic duct has been identified, place a clip across the proximal cystic duct-gallbladder junction. Make a partial anterior ductotomy distal to the clip, taking care not to transect the duct entirely. Ideally, bile will start to flow out of the ductotomy, but if not, small stones and debris should be milked proximally into the incision and removed. To flush debris and stones out of the cystic ductotomy, carefully place a grasper from the patient's left side, down toward the duodenum, gently apply medial pressure, and sweep upward along the porta hepatis and the common bile duct. If this does not ultimately produce bile, the cystic duct can be gently squeezed in a distal to proximal direction using a blunt grasper to milk contents toward the opening. This maneuver should be followed by gently sweeping the common duct/porta hepatis again.

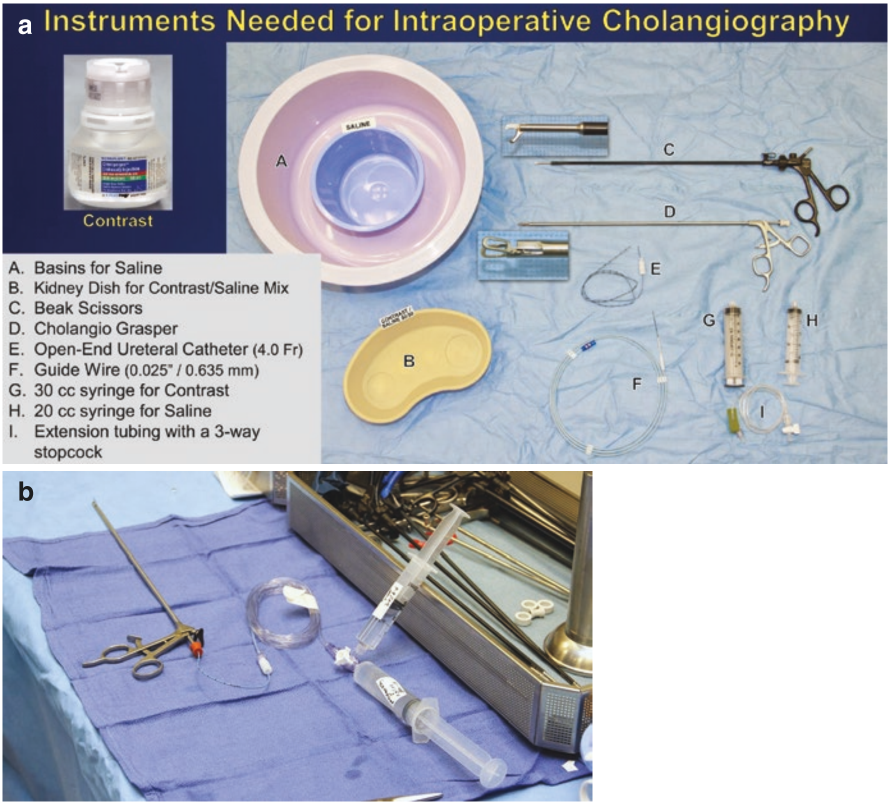

Fig. 4.3 (**a**) The equipment for performing a cholangiogram, and (**b**) its setup on the back table

Table 4.1 Recommended equipment for intraoperative cholangiogram

Recommended materials
Contrast media, such as Omnipaque (Novaplus) or iso-osmolar Visipaque (Novaplus)
Glucagon 1 mg IV; wait for 3 min, OK to repeat
Saline mixed 50/50 with contrast material
1 × 20 ml syringe, 2 × 30 ml syringes
Extension tubing, 96 in. length
Three-way stopcock
Catheter (e.g., 4Fr ureteral catheter, balloon-tip catheter, or Taut cholangiocatheter)
Clamp device (e.g., cholangioclamp, Kumar device)
Endo scissors

Selection of Cholangiogram Catheter A variety of cholangiocatheters may be used, but the 4Fr end-hole ureteral catheter works well and is very inexpensive. If a ureteral catheter is employed, the cystic duct will need to be secured around it, either by clamping with a cholangiography fixation forceps/clamp or with a simple clip applied across the cystic duct. Other variations include the slightly barbed Taut catheter or balloon catheters, which secure themselves by insufflation against the cystic duct wall, or the Kumar clamp for injecting into the gallbladder itself.

Retraction upon the gallbladder/cystic duct varies depending on the site of introduction of the cholangiogram catheter. Placing it through the right upper quadrant port usually provides the best angle for insertion. Alternatively, the catheter may be introduced via the subxiphoid port. Another effective way to introduce a cholangiogram catheter without using an additional working port is to insert a #14 gauge angiocatheter through the abdominal wall in the right upper quadrant. For right upper quadrant insertion, the gallbladder/cystic duct junction should be retracted laterally to present the duct under gentle tension. The incision in the cystic duct should take into account where the duct will ultimately be ligated and the location of the valves. Sharp hooked scissors or micro-scissors are preferred. The optimal angle of entry of the catheter into the duct will be approximately 130°. The act of inserting the catheter into the duct with a grasper is made easier by the availability of additional working ports or the use of an angiocatheter that allows for a two-handed technique.

The injection of saline should be possible without leaking or extreme resistance. If it is not, the catheter should be reinserted. If a cholangiography fixation forceps has been used, its handle should be propped up against a pile of folded sterile towels and the handle clamped in a secure position to avoid any further traction on the duct. The tubing should be clamped securely to the surgical drapes to avoid inadvertent traction. A sterile half drape should be placed over the operative field, or a clear plastic sterile mobile C-arm cover should be used. The sterile drape is less expensive: The area over the patient's xiphoid process can be marked with a twist in the cover drape to aid the placement of the C-arm and reduce the number of images needed to locate the duct. If the cholangiogram catheter is approximately one-third the distance from the top of the image and half of the vertebral bodies are visible on the right side of the image in a vertical fashion, the C-arm is in good position to view the early filling phase of the distal duct where most of the stones are found.

Injection While placing the cholangiocatheter in the cystic duct, saline should be slowly dripped through the catheter so that air or CO_2 is not instilled in the duct. Once the catheter is secured in the cystic duct, the saline syringe should be carefully replaced with a second 30 ml contrast-filled syringe so as to not introduce any bubbles into the three-way stopcock and cholangiogram tubing. After securing the cholangiogram clamp or catheter and the sterile drape or cover placed, the C-arm should be brought into the operative field from the patient's right side, if possible. The table should be brought back to a neutral position and then rolled 10–15° away from the top of the C-arm if it is on the patient's right side. This rotates the patient's vertebrae

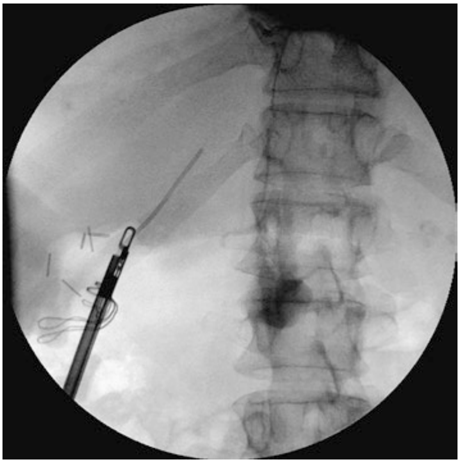

Fig. 4.4 The first static image with very little contrast injected

out of the plane of the image, so that the biliary tree is not superimposed over the bony structures, making interpretation of the images easier. Once OR personnel are appropriately shielded and at a safe distance from the C-arm, a localizing image over the area of the twist in the drape is obtained. Additional images may be required to direct and orient the C-arm image so that a view of the cystic duct, common bile duct, and duodenum is in the field.

At first, only a few milliliters of contrast material should be injected under live fluoroscopy, and video or a static image should be captured (Fig. 4.4). Injecting too much contrast too early may obscure any filling defects from small stones. Under live fluoroscopy, additional contrast is injected, which should fill the common duct distally, and flow freely into the duodenum. Once again, delivering too much contrast too soon can obscure the filling defects from stones. The C-arm can magnify areas of interest to allow for easier interpretation. After dye is observed in the duodenum, the C-arm should be repositioned for viewing the intrahepatic region. Both the left and right hepatic ducts must be visualized (Fig. 4.5). This is aided by placing the patient in a Trendelenburg position to promote retrograde filling. A final still image, without magnification, is taken of the entire biliary tree and duodenum to conclude the cholangiogram (Fig. 4.6). A checklist of critical findings such as contrast in the duodenum and intrahepatic bile ducts can be helpful.

Completion If a common duct stone has been identified, an exploration of the common duct can be performed at this time (Fig. 4.7). Small stones and debris identified at the ampulla can often be flushed into the duodenum by injecting contrast or saline under pressure. This procedure is aided by asking the anesthesiologist to inject glucagon 1 mg intravenously, which promotes the relaxation of the smooth muscle of the sphincter of Oddi. Wait 3 min for this effect to take place. This glucagon injection may be repeated once. Other techniques such as antegrade balloon dilation of the ampullae followed by flushing, common duct exploration by transcystic wire basket retrieval under fluoroscopic guidance, biliary endoscopy via the

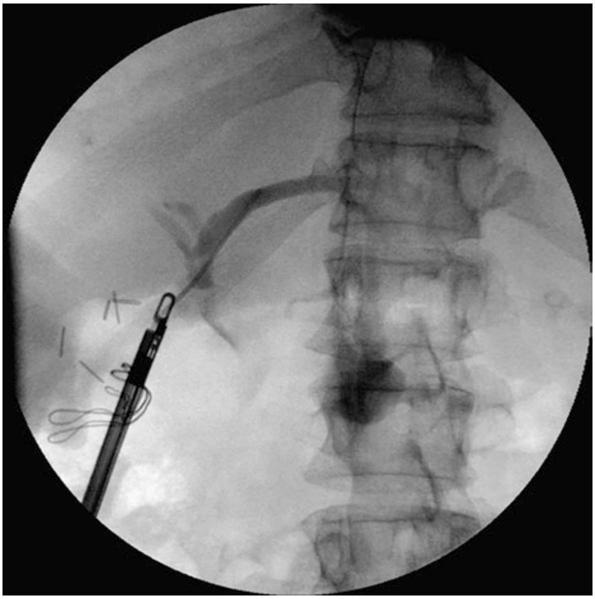

Fig. 4.5 Early filling of the hepatic ducts with contrast

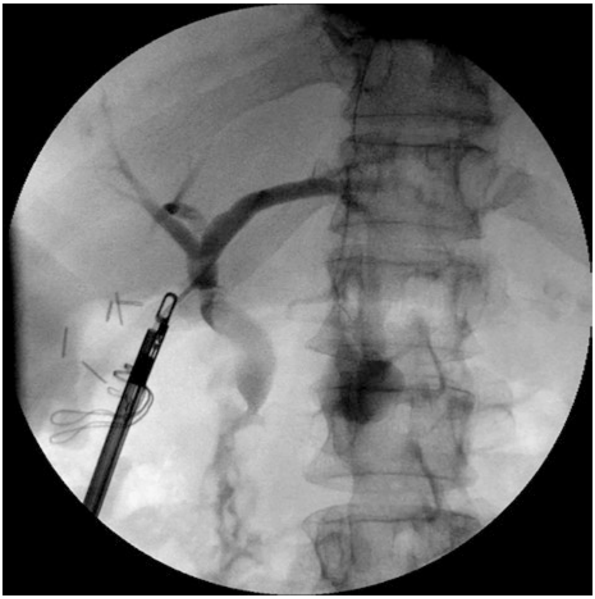

Fig. 4.6 The completion cholangiogram shows that both sets of intrahepatic ducts are visualized, and contrast is seen to flow into the duodenum

cystic duct, or choledochotomy can be performed (see subsequent chapters). If the cholangiogram was unremarkable, the catheter is removed under direct laparoscopic visualization, and the cystic duct can be clipped or ligated distal to the cystotomy. If the cholangiogram was abnormal due to a bile leak or an obstructing clip, this is the time to recognize a possible iatrogenic error and address it (Fig. 4.8).

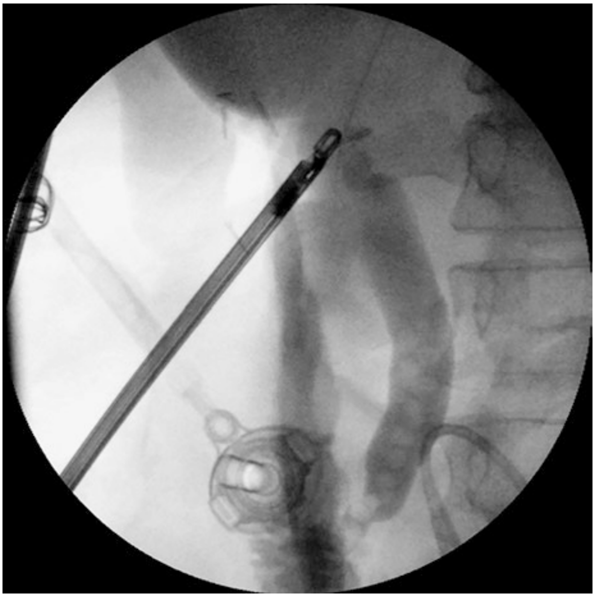

Fig. 4.7 Multiple stones are observed in the distal common bile duct

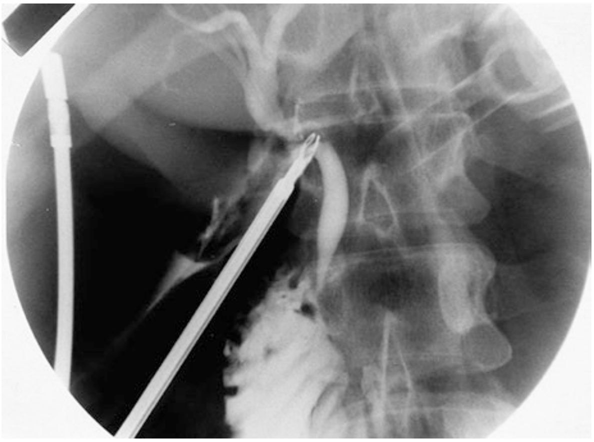

Fig. 4.8 Extravasation of contrast is seen and must be immediately managed

Intraoperative Cholangiogram Interpretation: Pearls and Pitfalls

While the proper performance of a cholangiogram is necessary, its correct interpretation is essential. Even when a cholangiogram has been obtained, its misinterpretation may result in causing or missing a major ductal injury.

Difficulties in placing the catheter into the cystic duct:

1. *Valves*: One must ensure to instrument the true lumen of the duct, and not a false passage or valve fold. The internal valves of Heister of the cystic duct may

prevent the passage of a cholangiocatheter. These valves may be opened by carefully inserting micro-scissors into the ductotomy in a closed fashion and pushing them gently through the obstructing valve. When a valve is encountered, it may be sharply incised with micro-scissors, or one may choose to relocate the ductotomy to the distal side of the valve. Be aware that if the micro-scissors are opened too wide to dilate or disrupt the valve, they can lacerate the wall of the cystic duct.

2. *Size of the duct*: If the duct is small, usually a more distal dissection will find a larger diameter cystic duct. If that is not the case, performing a cholecystogram is usually a safer option.
3. *Stones and debris within the cystic duct*: These can usually be teased out through the ductotomy with a gentle sweeping motion of the closed blunt grasper along the porta hepatis and common and cystic duct. The cystic duct (and stones within) may be gently crushed by the jaws of an atraumatic blunt grasper and its stones milked out as well. It is not ideal to push the stone into the common duct with the cholangiogram catheter (or have it fall into the common duct post cholecystectomy), so returning clear bile with the reflux maneuver is important. Even if the cystic duct cannot be safely identified, a cholecysto-cholangiogram can still be performed via the gallbladder (Fig. 4.9). This technique is commonly used in the infant or pediatric population where small size makes cannulation of the cystic duct more difficult [30]. Localizing clips can be placed in the area overlying where the cystic duct/common duct is thought to be. Then, the gallbladder is pierced with a needle. Bile is aspirated and in its place contrast is injected as in a routine cholangiogram.
4. *Inability to identify the cystic duct, porta hepatis, or critical view of safety*: Another alternative is to divide the gallbladder transversely midway up on the

Fig. 4.9 A cholecysto-cholangiogram is performed by injecting contrast into the gallbladder when identification of the cystic duct is difficult

body of the gallbladder, being careful to control the spillage of gallbladder contents by placing a sponge in Morrison's pouch and a specimen bag adjacent to the liver. Once the gallbladder is divided and contents removed, inspection from within the lumen of the opened gallbladder can identify the cystic duct origin, and a cholangiocatheter can be inserted from within the gallbladder. Lastly, a 25-gauge needle can be inserted into what is thought to be the common duct. If the bile is aspirated, cholangiogram can be performed. If blood is aspirated, the needle should be withdrawn and pressure applied until bleeding stops.

Cholangiogram interpretation:

1. *Inability to visualize the proximal bile ducts on cholangiography*: The most common error of this type is the interpretation of the lower biliary tree as normal without the opacification of the hepatic ducts. This may occur if the common bile duct has been instrumented or a clip has been placed so that contrast cannot flow into the hepatic ducts. When only the lower portion of the ducts are visualized, the catheter may be repositioned, erroneously placed clips may be removed, or the patient placed in a Trendelenburg declination and/or intravenous morphine can be administered to increase sphincter of Oddi tone, in an effort to demonstrate cranial flow. Additionally, a blunt grasper can be used with gentle lateral to medial pressure on the distal common bile duct/porta hepatis while contrast is injected. The grasper is then removed and an X-ray taken. Also, intravenous (IV) Demerol can be administered to raise the sphincter pressure if the duct is emptying too quickly to fill the upper ducts. If the hepatic ducts still cannot be visualized, corrective surgical action should be considered immediately.
2. *Inability to visualize the duodenum on cholangiography*: The first step should be asking the anesthesiologist to inject 1 mg of glucagon IV, which promotes the relaxation of the smooth muscle of the sphincter of Oddi. Wait for 3 min for this effect and attempt the cholangiogram again. Another 1 mg of IV glucagon may be repeated once. Sometimes, contrast does not enter the duodenum because the contrast cannot be injected with appropriate force. Assure that the tubing, catheter, or cystic duct is not kinked. If OK, exchange the contrast-filled 30 ml syringe with a 20 or 10 ml syringe, which allows greater force to be applied. If there is still no contrast exiting the bile duct, transcystic choledochoscopy can be employed. Judgment is needed if the common duct is small. Allowing a small stone to pass spontaneously may be the safer choice, but the patient needs close follow-up.
3. *Air bubbles* vs *stones*: Bubbles that are introduced into the biliary tree may mimic the appearance of stones. These bubbles can usually be differentiated by the parallel motion observed when rapidly injecting and withdrawing the syringe. Additionally, placing the patient in a reverse Trendelenburg position should cause the bubbles to float proximally toward the liver, whereas calculi would not. Also, air bubbles tend to move in the duct more rapidly during flushing than stones, and air bubbles deform as they enter the smaller intrahepatic ducts. Avoidance is the easier approach. The attention of the operating staff must be directed to ensuring that any air bubbles that are seen in the syringes and the tubing are flushed out with saline prior to the equipment being handed to the surgeon, but the surgeon should personally inspect the tubing and syringes prior to use.

Intraoperative Near-Infrared Fluorescent Cholangiography

Fluorescence cholangiography is a recently developed technique for imaging the extrahepatic biliary tree without the need for ductotomy. It employs an indocyanine green (ICG) fluorophore, which absorbs near-infrared irradiation between 790 and 805 nm and re-emits it at an excitation wavelength of 835 nm. ICG is typically administered as a single intravenous dose approximately 1 h prior to the start of surgery. It then binds to plasma proteins and remains within the intravascular space until it is metabolized by the liver and excreted into the biliary system 15–20 min after administration [31].

Near-infrared fluorescent cholangiography (NIRFC) has been suggested as an alternative technique to IOC for the safe and easy intraoperative recognition of biliary anatomy and avoidance of ductal injury. It provides a real-time assessment of extrahepatic biliary anatomy and can be done rapidly without the use of ionizing radiation [32]. One cost analysis has suggested that its use results in significant cost savings per case, it is quicker to perform, and the surgical team enjoys an increased ease of use, when compared to standard cholangiography [33].

However, there are several important limitations to NIRFC that may impact its overall usefulness. Despite excellent results in non-inflamed cases, the performance of NIRFC decreases in the presence of inflammation, due in part to the limited depth of tissue penetration of near-IR light of 5–10 mm [32, 34]. In symptomatic cholelithiasis without acute inflammation, rates of visualization have been reported to be 93% for the cystic duct, 88% for the common hepatic duct, and 91% for the common bile duct prior to dissection of Calot's triangle [35], but in a second study, this dropped to 91.6%, 75%, and 79.1% in the presence of acute cholecystitis [36].

A second drawback of this new technology is that it will not provide visualization of most common bile duct stones because the fluorescent light cannot be detected from within the intrapancreatic portion of the CBD [36]. It is also difficult to distinguish small stones. For these reasons, the role of NIRFC in the management of patients with choledocholithiasis remains to be demonstrated.

Conclusion

The intraoperative cholangiogram provides important information concerning the precise anatomy of the biliary tree. This knowledge minimizes the risk of bile duct injury. The cholangiogram also helps the surgeon recognize any bile duct injuries at the time of operation, and this prompt recognition decreases morbidity and mortality. Also, by identifying common duct stones and treating them at the time of surgery, rather than as a separate procedure, the patient is spared additional days in the hospital, additional procedures, and the potential for additional complications.

The routine performance of IOC by a team familiar with the procedure is a quick and painless process. The knowledge and skills developed by regular performance of the procedure will help the surgeon make the best choices during difficult cases and are the first step in developing more advanced laparoscopic biliary surgical skills. At the least, perform routine cholangiography until both your and your team's skills have been perfected. Properly performing and interpreting cholangiograms can be an important step in the performance of a safe laparoscopic cholecystectomy, and these are important skills to be imparted to surgical trainees.

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