

REVIEW ARTICLE

Nonoperative imaging techniques in suspected biliary tract obstruction

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Abstract

Evaluation of suspected biliary tract obstruction is a common clinical problem. Clinical data such as history, physical examination, and laboratory tests can accurately identify up to 90% of patients whose jaundice is caused by extrahepatic obstruction. However, complete assessment of extrahepatic obstruction often requires the use of various imaging modalities to confirm the presence, level, and cause of obstruction, and to aid in treatment plan. In the present summary, the literature on competing technologies including endoscopic retrograde cholangiopancreatography (ERCP), percutaneous transhepatic cholangiopancreatography (PTC), endoscopic ultrasound (EUS), intraductal ultrasonography (IDUS), magnetic resonance cholangiopancreatography (MRCP), helical CT (hCT) and helical CT cholangiography (hCTC) with regards to diagnostic performance characteristics, technical success, safety, and cost-effectiveness is reviewed. Patients with obstructive jaundice secondary to choledocholithiasis or pancreaticobiliary malignancies are the primary focus of this review. Algorithms for the management of suspected obstructive jaundice are put forward based on current evidence. Published data suggest an increasing role for EUS and other noninvasive imaging techniques such as MRCP, and hCT following an initial transabdominal ultrasound in the assessment of patients with suspected biliary obstruction to select candidates for surgery or therapeutic ERCP. The management of patients with a suspected pancreaticobiliary condition ultimately is dependent on local expertise, availability, cost, and the multidisciplinary collaboration between radiologists, surgeons, and gastroenterologists.

Key Words: *jaundice, cholestasis, choledocholithiasis, common bile duct neoplasms, cholangiocarcinoma, cholangiopancreatography, cholangiography, endosonography, magnetic resonance angiography, magnetic resonance imaging, CT, spiral CT, ultrasonography, costs and cost analysis*

Introduction

Evaluation of obstructive jaundice is a common clinical problem. Often, the initial problem is to distinguish between intrahepatic and extrahepatic biliary obstruction. Choledocholithiasis and pancreaticobiliary malignancies (pancreatic head cancer, ampullary cancer, and cholangiocarcinoma) are the most common causes of extrahepatic obstruction. Less common causes include benign strictures, chronic pancreatitis, metastatic nodes to the porta hepatis, and primary sclerosing cholangitis. Many studies have shown that clinical data such as history, physical examination, and laboratory tests can accu-

rately identify up to 90% of patients whose jaundice is caused by extrahepatic obstruction [1–21]. However, complete assessment of extrahepatic obstruction often requires the use of various imaging modalities to confirm the presence, level, and cause of obstruction, and to aid in treatment planning. Current technologies include transabdominal ultrasound (US), endoscopic retrograde cholangiopancreatography (ERCP), transhepatic cholangiopancreatography (PTC), endoscopic ultrasound (EUS), magnetic resonance cholangiopancreatography (MRCP), helical CT (hCT), and helical CT cholangiography (hCTC). With the rapid advancement in imaging technology, there is

little consensus in the literature as to which imaging modality is most appropriate for a given clinical situation. This can lead to duplication of testing with the possibility of increasing costs and delaying diagnosis. Furthermore, newer modalities are often being incorporated into practice before accurate assessment of their cost-effectiveness has been completed.

The purpose of this article is to review competing technologies in the evaluation of suspected extrahepatic obstruction with regard to diagnostic performance characteristics, technical success, safety, and cost-effectiveness. Patients with obstructive jaundice secondary to common bile duct (CBD) stones or pancreaticobiliary malignancies are the primary focus of this review. The work-up of patients with suspected intrahepatic cholestasis will not be addressed. Algorithms for the management of suspected obstructive jaundice due to CBD stones and pancreaticobiliary malignancies are provided.

Methods

A systematic search was performed for relevant articles published in English language using MEDLINE and PUBMED from 1966 to December 2003. The search strategy included the key terms: *cholestasis, choledocholithiasis, pancreatic neoplasms, biliary tract neoplasms, cholangiocarcinoma, ampulla of vater, cholangiography, endoscopic, intravenous, laparoscopic, intra-operative, ultrasonography, magnetic resonance imaging, computed tomography, spiral computed tomography, surgery, complications, decision support techniques, costs and cost analysis, cost-benefit analysis, sensitivity and specificity, comparative study, and prospective studies*. Information was collected on test performance characteristics (sensitivity, specificity, negative and positive predictive values), with regards to identifying the presence, level, and cause of biliary obstruction. The technical success, safety and costs of the various imaging modalities were also examined

where appropriate. Where appropriate, although beyond the scope of this narrative review, pertinent issues relating to tissue diagnosis and therapy (since some of the techniques described may be both diagnostic and therapeutic) are briefly discussed. Finally, based on the results of the literature search, clinically relevant algorithms were constructed to highlight the possible roles of new technologies in the work-up of patients with suspected CBD stones or pancreaticobiliary malignancies.

Current imaging technologies

Direct versus indirect imaging

The various imaging modalities can be classified into either direct or indirect techniques [22]. The former are more invasive, and include ERCP and PTC. They carry a higher associated risk, but have the added ability to sample tissue and perform therapeutic maneuvers, such as biliary drainage with stenting or stone removal. The main concern with these techniques is the risk of pancreatitis and cholangitis as a result of opacification of an obstructed biliary tree that cannot be drained, with rare complications such as perforation, bleeding or bile leak [23–26]. Also, direct techniques are limited to the evaluation of the intrinsic biliary tract and cannot define the presence of extrinsic compression of the biliary tree by surrounding structures. Indirect techniques offer lower procedural risk and may allow staging of malignancies. New indirect modalities, such as MRCP (with solid organ MR), EUS, and hCTC (with hCT) offer improved imaging quality, while at the same time maintaining a low risk profile. EUS has some therapeutic potential in addition to the opportunity for biopsy and cytology, but because it requires conscious sedation, it is the most invasive of the indirect group of imaging technologies. Table I summarizes the advantages and disadvantages of the main techniques discussed.

Table I. Comparison of advantages and disadvantages of the main biliary imaging techniques.

Imaging modality	Indirect			Direct		
	US	hCTC*	MRCP†	EUS	ERCP	PTC
Portability	+++	–	–	++	+	–
Safety	+++	++	+++	++	+	+
Operator dependence	+++	+	++	+++	++	++
Low cost	+++	+	+	+	+	++
Staging of malignancy	+	+++	+++	+++	–	–
Tissue sampling	+	+	–	+++	+++	++
Therapy	–	–	–	+	+++	+++

US, transabdominal ultrasound; hCTC, helical CT cholangiography; MRCP, magnetic resonance cholangiopancreatography; EUS, endoscopic ultrasound; ERCP, endoscopic retrograde cholangiopancreatography; PTC, transhepatic cholangiopancreatography.

*hCTC includes cholangiography that requires intravenous contrast administration that is excreted into the biliary tract.

†Includes abdominal MR.

Transabdominal ultrasonography (US)

Transabdominal US (US) remains the initial imaging test of choice in the evaluation of suspected biliary obstruction because it is noninvasive, inexpensive, and readily available [9,27–34]. Dilated ducts are usually taken as indirect evidence of biliary obstruction [9,32,33,35–38]. The presence of normal ducts, however, does not exclude obstruction [9,32,33,35–38]. This is mainly because, in certain cases, biliary obstruction may not be accompanied by dilatation of the CBD. Conversely, the CBD increases in diameter in response to cholecystectomy and aging [39–45]. Despite these exceptions, ductal dilatation remains an excellent clue to biliary obstruction. Specifically, US has been shown to be highly accurate (78–98%) for detecting extrahepatic obstruction [9,27,32,33,36,46]. In conjunction with a concordant clinical evaluation, US allows an accurate differentiation between liver parenchymal disease and extrahepatic obstruction (sensitivity 65%, specificity 92%, PPV 92%, NPV 98%) [8,47]. However, US is less discriminating with respect to the level and cause of obstruction, with reported accuracies ranging between 27–95% and 23–88%, respectively [29–32,34,35,46,48–50]. Also, the test performance of US is variable in differentiating malignant from benign causes of obstruction with an overall accuracy ranging from 47% to 90% [29–31,34,35,46,48–51]. In the diagnosis of CBD stones, US exhibits poor test performance at detecting CBD stones with sensitivities in the range of 25–58% and specificities of 68–91% [27,36,46,48,52,53]. Variable results are also seen in the setting of pancreaticobiliary malignancies, with sensitivities ranging from 5% for ampullary to 67–81% for pancreaticobiliary malignancies [54–59]. These data demonstrate that the major limitation of US is in its inability to reliably diagnose the level and cause of obstruction. Other drawbacks of US are operator dependency and suboptimal imaging of retroperitoneal structures due to overlying bowel gas or obesity [60].

Endoscopic retrograde cholangio-pancreatography (ERCP)

Endoscopic retrograde cholangio-pancreatography (ERCP) is performed using a side-viewing duodenoscope, which allows an en face view of the ampulla. An instrument channel in the duodenoscope enables cannulation of the papilla and injection of contrast into the biliary and pancreatic ducts to obtain diagnostic images. Therapeutic interventions such as sphincterotomy, stone extraction, stricture dilatation, stent insertion, and tissue sampling can be performed at the same time.

ERCP has traditionally been considered the gold standard for imaging the biliary system, particularly if therapeutic intervention is planned. It can demon-

strate the cause of biliary obstruction, and helps in making a diagnosis based on the morphology of the biliary and pancreatic ducts. In the evaluation of CBD stones, Frey et al. [61] noted that ERCP had a sensitivity of 90%, a specificity of 98%, and an accuracy of 96%. Standard procedures, such as sphincterotomy (ES) and balloon or basket stone extraction, are successful in clearing CBD stones in 85–90% of cases [62–67]. For those patients in whom standard techniques are unsuccessful, mechanical lithotripsy will increase the success rate to more than 90% [68,69], while the insertion of a biliary stent is reserved for rare high-risk cases [70–72].

ERCP also plays an important role in the diagnosis and palliation of pancreaticobiliary tumors. Radiographic findings may be suggestive of malignancy, but a definitive diagnosis requires tissue sampling. Although many patients are managed without histological confirmation, confirmation allows accurate decision making with respect to patient management options, including surgery, endoscopic stenting, chemotherapy, or radiotherapy [73]. Common methods of endoscopic tissue sampling including brush cytology, endoscopic fine-needle aspiration (FNA), and forceps biopsy have relatively low to moderate sensitivity (20–60%) but almost 100% specificity [74–76]. Cancer detection rate may be increased by combining at least two sampling methods [74,77]. Tissue sampling sensitivity also varies according to the type of tumor. Brush cytology and forceps biopsy have a higher sensitivity for cholangiocarcinoma (44–100%) than for pancreatic cancer (30–65%) [73,74,77–84]. Forceps biopsy is the single best technique for the diagnosis of ampullary tumors, with a cancer detection rate of 77–88% [74]. More recently, a number of newer technologies have been proposed [76]. Palliation of malignant obstruction can be achieved by ERCP with biliary stent insertion (plastic or metal). Randomized controlled trials have shown endoscopic stent placement to be cost-effective compared with surgery, and to enhance quality of life [85–89].

ERCP combines the advantage of diagnosis of biliary obstruction with possible therapeutic intervention. Because of the ability to perform therapeutic maneuvers, ERCP has become the intervention of choice in the management of patients with CBD stones, and in the palliative treatment of patients with malignant biliary obstruction [90–92]. The drawbacks to ERCP include equipment cost, need for conscious sedation, and high operator dependency. Failure rate increases substantially for patients with altered anatomy such as Billroth II gastrectomy [93–96]. Limitations of ERCP include reduced sensitivity with small stones in a dilated bile duct, failure to visualize stones because of inadequate opacification of the biliary tree with contrast, and difficulty in differentiating stones from air bubbles [97,98]. These limitations may lead to increases in procedure time, unnecessary sphincterotomy, and

unnecessary instrumentation of the bile duct with balloon catheters and basket. Visualization of the biliary tree proximal to an obstructing lesion can be difficult, and contrast injection above the site of obstruction usually mandates biliary stent insertion because of the risk of cholangitis [92]. Also, the low yield of ERCP for cytology in malignant obstruction often results in additional procedures (EUS-FNA, CT-FNA, or operation) to make a tissue diagnosis of cancer [73,74,77–84,99]. Furthermore, staging information for pancreaticobiliary malignancies is very difficult to obtain by ERCP [100,101]. Large prospective series have found overall complication rates of 5–10% and mortality rates of 0.02–0.5% after diagnostic and therapeutic ERCP [23–26]. The most common complication is acute pancreatitis, occurring in 5% of cases, and being moderate to severe in about 1% [23–26,102]. Complication rates appear to have decreased more recently owing to a more careful selection of patients (at lower risk for complications), and perhaps, the increased use of guidewires for selective cannulation [103,104]. Because of its attendant risks, and the availability of safer noninvasive cholangiographic methods with comparable diagnostic abilities, ERCP is evolving into a predominantly therapeutic procedure [105].

Percutaneous transhepatic cholangiography (PTC)

PTC involves puncture of the liver with a 22-gauge needle under fluoroscopic guidance to enter the peripheral intrahepatic bile duct system above the common hepatic duct [106–108]. Contrast is then injected to opacify the biliary tree and to identify obstruction. The biliary tree can be successfully visualized in close to 100% of patients with dilated ducts, and in 60–80% of patients with nondilated ducts [106–108]. PTC is considered, along with ERCP, the gold standard by which all other imaging modalities of the biliary tree are evaluated. It is excellent at determining the level and cause of biliary obstruction, as well as distinguishing benign from malignant lesions, while being less costly than ERCP [109,110]. It can also be applied therapeutically for external drainage of obstructed ducts.

The overall rate for major complications is <5%, with a mortality rate of 0.1% [107,111]. Complications include bile leaks, bile peritonitis, hemobilia, sepsis, intraperitoneal hemorrhage, intrahepatic fistulas, gallbladder puncture, pneumothorax, subphrenic/subhepatic abscess, pseudoaneurysms, arteriovenous shunts, and allergic reactions to contrast material [106,112–114]. In a randomized controlled trial comparing ERCP to PTC in the management of patients with malignant biliary obstruction, ERCP was found to be superior to PTC because of a higher success rate, and lower complication rate and mortality [115]. Currently, indications for PTC are few; it is performed primarily in patients in whom ERCP has

failed or when altered anatomy (gastroenterostomy) precludes accessing the ampulla [116]. It has also been used as a therapeutic drainage procedure in patients with unresectable hilar tumors or hepatolithiasis [117–121].

Endoscopic ultrasonography (EUS)

EUS combines endoscopy and ultrasound to provide high-resolution images of the pancreaticobiliary system transgastrically or transduodenally using a water-filled balloon system for acoustic coupling [122,123]. Echoendoscopes have frequencies in the 7.5–12 MHz range, which gives a depth of penetration of 8–10 cm. Tissue sampling in the form of EUS-guided fine-needle aspirate (EUS-FNA) can also be performed.

EUS is very accurate in determining the cause of extrahepatic obstruction with a sensitivity of 97% and a specificity of 88% compared with the combined gold standard of ERCP, intraoperative cholangiography (IOC), and clinical-follow-up [124]. In particular, EUS is very accurate in diagnosing CBD stones, with a sensitivity of 95%, specificity of 98%, and an accuracy of 96% [17,22,57,122,123,125–131]. These results are far superior to US (sensitivity 63%) and CT (sensitivity 71%) [127], and are equivalent if not superior to those of ERCP or MRCP [132]. EUS is especially more accurate in detecting small stones or stones within small caliber CBDs [127,133]. EUS has also been shown to be excellent in distinguishing among different types of malignant obstruction [57,99,134–136]. The reported accuracies for EUS-FNA of pancreaticobiliary masses are over 80%, with results better for pancreatic masses than for biliary tumors [137–144]. Many prospective studies have shown EUS to be more sensitive (93–100%) than all other imaging modalities including CT (53–77%), US (50–67%), MRI (50–67%), and ERCP (90%) in the detection of pancreatic tumors [54–56,136,145–153]. The superiority of EUS becomes even more evident for tumors <3 cm [54,55,145,149,150,152]. This is clinically relevant as patients with small tumors are most likely to benefit from surgical resection. Once a pancreatic mass is identified, accurate staging is crucial to identify patients with locoregional disease that is amenable to surgical resection, and to prevent unnecessary surgical exploration. EUS is highly accurate in determining the T (69–94%) and N staging (54–80%) of pancreatic tumors [54,136,147,148,148,154]. It is more accurate (87–95%) than CT (41–75%) and angiography (75–79%) for detecting invasion of the portal vein, splenic vein, and confluence of the portal vein and superior mesenteric vein [55,155–160]. It is not as accurate, however, for detecting involvement of the superior mesenteric vein and major arterial vessels [156,159,160]. For the detection of ampullary tumors, many prospective studies have shown EUS (95–100%) to be equivalent to ERCP, but more

sensitive than CT (5–68%) and US (5–24%) [57,57,59,158,161–169]. Also, locoregional tumor staging was more accurately assessed by EUS (72–82% for T stage, 47–71% for N stage) than with any other imaging modalities [57,57,59,158,161–169]. The improved staging ability of EUS may allow selection of patients with ampullary tumors who can undergo local resection instead of pancreaticoduodenectomy [157,165]. With respect to cholangiocarcinoma, EUS has not been proven to offer more information than other imaging modalities.

There are many features that make EUS an attractive procedure. It is less invasive than ERCP [170], and is able to diagnose most causes of obstructive jaundice such as pancreaticobiliary malignancies and CBD stones [17,122,123,125–131] with the same or better accuracy than ERCP. This technology does not expose the patient to radiation or contrast material. EUS-FNA can also provide a tissue diagnosis and important staging information for pancreaticobiliary malignancies. The limitations of EUS include the high operator dependency with a steep learning curve, equipment cost, unit availability, the inability to provide an immediate therapeutic solution, the need for conscious sedation, and a 2% failure rate [126]. Visualization is limited to the nearest 8–10 cm depth from the probe, and imaging can be obscured by pneumobilia, stents, surgical clips, calcifying pancreatitis, or a duodenal diverticulum [171].

Intraductal ultrasonography (IDUS)

IDUS is a relatively new technology and is not available at most centers. IDUS of the bile duct is performed with a highly flexible, thin-caliber (~2 mm), non-optic US probe that can be passed through the working channel of a standard duodenoscope and introduced into the biliary and pancreatic ducts during ERCP. Acoustic coupling is optimized by filling both ducts with fluid. IDUS images at higher frequencies (12–30 MHz) than standard EUS and therefore provides higher resolution (0.07–0.18 mm), but the depth of penetration is consequently reduced (2–3 cm) [172]. Compared to standard EUS, IDUS provides a better evaluation of the proximal biliary system and surrounding structures such as the right hepatic artery, portal vein, and contents of the hepatoduodenal ligament [172–176]. Use of wire-guided IDUS probes allows biliary cannulation in nearly 100% of patients without sphincterotomy [177,178]. However, it may be necessary to dilate severely stenotic lesions to facilitate passage of the probe [177,178].

In the evaluation of biliary obstruction, IDUS as an adjunct to ERCP and tissue sampling has been shown to improve the ability to distinguish malignant from benign strictures with a high degree of accuracy (>90%) [173–176,178–190]. Furthermore, when

ERCP-guided bile duct biopsy fails to demonstrate malignancy, the presence of certain IDUS sonographic criteria such as a sessile tumor, tumor size >10 mm, and an interrupted wall structure can more favor a diagnosis of malignancy [184]. In a prospective study by Menzel et al., IDUS was more accurate than EUS for determination of the nature of bile duct strictures (89% vs 76%) and for T staging (78% vs 54%), particularly for tumors located at the bifurcation and mid-bile duct [185]. However, N staging with IDUS was inferior [185]. For the diagnosis and T staging of ampullary tumors, IDUS was found to be superior to EUS (100% and 88.9%, 59.3% and 56.3%, respectively) in a prospective study using histopathology as gold standard [191]. For the diagnosis of pancreatic cancer, preliminary studies suggest that IDUS may be useful in detecting carcinoma *in situ* and small tumors and in assessing parenchymal invasion and the intraductal spread of the tumor [150,192,193]. However, the tortuosity of the pancreatic duct often precludes passage of the probe to the proximal duct [194]. For the diagnosis of CBD stones, IDUS seems to be more accurate than ERCP in the detection of small stones within a dilated duct and can differentiate stones from air bubbles [195–198].

IDUS has several advantages over EUS of the bile duct, including higher resolution and the ability to image the proximal bile ducts. Complications are rare [176,194]. The drawbacks of IDUS include high equipment cost, fragility of the probe, low depth of penetration, and operator expertise. IDUS is of limited value in assessing lymph nodes, and cannot provide a histopathological diagnosis. Stent-related changes of the bile duct wall may reduce the diagnostic utility of IDUS [199–201]. More studies are therefore needed to clearly define the role, utility, and cost-effectiveness of IDUS in the evaluation of patients with selected pancreaticobiliary diseases. Depending on local availability, expertise, and competing technologies, IDUS may be considered in the work-up of patients with biliary obstruction. A combination approach, using information from IDUS, EUS, and ERCP may prove to be ideal.

Magnetic resonance cholangio-pancreatography (MRCP)

Magnetic resonance cholangio-pancreatography (MRCP) is performed with high resolution heavily T2-weighted sequences to enhance the signal of stationary fluids in the biliary and pancreatic ducts without the use of contrast material or ionizing radiation [202–205]. Multiple images are generated and reconstructed by a computer providing a three-dimensional image of the bile ducts. Current techniques permit imaging of the entire biliary tract in a single breath-hold of 20 s or less and provide high spatial resolution so that structures such as

fourth-order intrahepatic bile ducts are easily visualized in many cases [206–208].

A recent authoritative meta-analysis [209] of 67 published controlled trials showed that MRCP has excellent overall sensitivity (95%: 95% CI (75,99)) and specificity (97%: 95% CI (86,99)) for demonstrating the level and presence of biliary obstruction. However, MRCP is less sensitive for detecting stones (91%: 95% CI (73,97)) [209]. Moreover, the sensitivity for detecting stones seems to decrease according to stone size: 67–100% for stones >10 mm in size, 89–94% for stones measuring 6–10 mm, and 33–71% for bile duct stones <6 mm in size [210–213]. Therefore, there may still be a need for additional non-invasive or invasive imaging methods when choledocholithiasis is suspected. Also, MRCP is not reliable for differentiating malignant from benign obstruction (88%: 95% CI (70,96)) [209].

MRCP is very useful in the diagnosis of cholangiocarcinoma by identifying the exact location, extent, and severity of the obstruction [214–218]. Complete staging information of tumor size, bile duct involvement, and vascular invasion can be obtained when MRCP is combined with conventional MRI and MR angiography (MRA) [215]. In so doing, MRCP can evaluate the appropriateness of curative surgical resection versus palliative drainage procedures, and help determine whether PTC or ERCP constitutes the most appropriate therapeutic intervention [215,218,219]. For pancreatic cancer, a large prospective controlled study found MRCP to be as sensitive (84%) as ERCP in detecting pancreatic cancer associated with ductal dilatation [220]. However, the detection of pancreatic cancer by MRCP alone without ductal dilatation is difficult [221–225]. Ampullary lesions may be missed because of the poor performance of MRCP at or near the duodenal wall as a result of interference from intraluminal gas [226]. Also, MRCP does not provide adequate information on staging and resectability. The combinations of MRCP with conventional MRI and MRA may provide sufficient ductal, parenchymal, and vascular information for the diagnosis and resectability of pancreatic cancers [221–225].

The major advantage of MRCP is the noninvasive nature of the procedure. It does not require conscious sedation, intravenous contrast, or radiation exposure. Diagnostic images can be obtained in the vast majority of patients including those who have complex bilio-enteric anastomoses [227]. As well, MRCP can demonstrate the biliary tree above and below a complete obstruction [203]. In cholangiocarcinoma, the main advantage of MRCP is that it can noninvasively provide a three-dimensional understanding of the biliary tree, which can help in planning treatment [218]. The major disadvantages of MRCP compared with ERCP are lower spatial resolution, unit avail-

ability, lack of an immediate therapy that can be provided for duct obstruction, claustrophobia, and the inability to evaluate patients with pacemakers or ferromagnetic implants [228]. Causes of possible artifacts include pneumobilia, normal vessels, flow artifacts, and duodenal diverticulum [229–231]. A stone impacted at the ampulla may be missed [232]. As well, low insertion of the cystic duct may be mistaken for a dilated CBD [226], and clips in the abdomen from previous surgery may distort images [233].

Helical CT (hCT) and helical CT cholangiography (hCTC)

hCTC uses slip ring technology with oral or intravenous contrast to acquire volumetric data in a single breath-hold for high-quality three-dimensional reconstructions of the acquired image [2,4,203,234–240]. It has the ability to opacify up to third-order intrahepatic bile ducts, and evaluate extra-ductal structures in different phases (arterial, portal, parenchymal) [241,242].

The accuracy of conventional CT in determining the presence and level of obstruction has been 81–94% and 88–92%, respectively [9,29,46,242–245]. In the majority of cases, conventional CT can also determine the cause of obstruction with a high degree of accuracy (70–94%) [4,29,53,234,244]. There are only a few studies published on the use of hCTC [2–4,214,235]. In a prospective study involving 131 patients with suspected biliary obstruction, hCTC had an overall diagnostic accuracy of 93% in differentiating benign from malignant causes of biliary obstruction [214]. For the diagnosis of CBD stones, hCTC achieved a sensitivity of 87% (95% CI (84,90)), a specificity of 97% (95% CI (95,98)), and an overall accuracy of 95% (95% CI (94,97)) for the diagnosis of CBD stones compared to direct imaging such as ERCP or IOC [3,4,235,237–242,246]. For the diagnosis and determination of resectability of pancreatic cancer, a recent meta-analysis of 68 controlled trials showed that hCT has significantly higher accuracy (sensitivity 91% and specificity 81%) than conventional US (sensitivity 82% and specificity 75%), or MRI (sensitivity 84% and specificity 76%) [247]. For the diagnosis and locoregional staging of peri-ampullary tumors, many prospective studies have shown CT to be unreliable (detection rates of 22–29%) and less accurate than EUS [59,157,158,162,166,167,191]. With regards to the diagnosis of cholangiocarcinoma, hCT has been shown to display accuracies up to 100% in hepatic arterial dominant phase and 86% in portal vein dominant phase scans [248]. However, hCT is inaccurate for assessing resectability (60–86%), because of its limitations in detecting small peritoneal implants, small hepatic metastasis, lymph node

metastasis in normal sized nodes, and the intraductal extent of tumor [248–250].

The major advantages of hCTC over ERCP or EUS include its low level of invasiveness, operator independence, and low technical failure rate (1%), as well as, in contrast to ERCP, a three-dimensional understanding of the biliary tree. Although noninvasive, hCTC gives a relatively high dose of radiation to patients. The major drawback of hCTC is a risk of adverse reaction to the iodinated contrast agents (1%). Major reactions include hepatorenal toxicity, cardiopulmonary symptoms, hypotension, severe skin reactions, and anaphylaxis [113]. Minor reactions have been reported in up to 24% of patients [113]. These include urticaria, pruritus, and gastrointestinal symptoms. The overall mortality rate is 1 in 3000–5000 examinations [113]. Its main limitation is in patients with high-grade obstruction and impaired hepatic function with high serum bilirubin levels (>35 μmol/L) because contrast is not eliminated sufficiently into the biliary tree [237,238]. The artifacts produced by a patient’s movement or respiration might also limit the diagnostic value of this test.

Algorithmic approach to patients with suspected biliary obstruction

None of the aforementioned technologies are ideal, and each exhibits advantages and disadvantages. The optimal method of biliary imaging for the diagnosis and management of patients with biliary obstruction depends on the clinical situation. Although every patient is different, general guidelines, based on diagnostic test performance of the different imaging modalities, may be put forward in the form of management algorithms. It must be emphasized, however, that any final management decisions for a given patient must be based on the pre-test probability of a given condition (based on history, physical examination, and laboratory data), patient preferences, local availability of equipment, and expertise. We attempt below to provide broad guidelines in the work-up of patients with suspected biliary obstruction.

The initial imaging test in patients with suspected biliary obstruction should be a transabdominal ultrasound. It is inexpensive, easy to perform, readily available, and noninvasive. It has been shown to be excellent for determining the presence

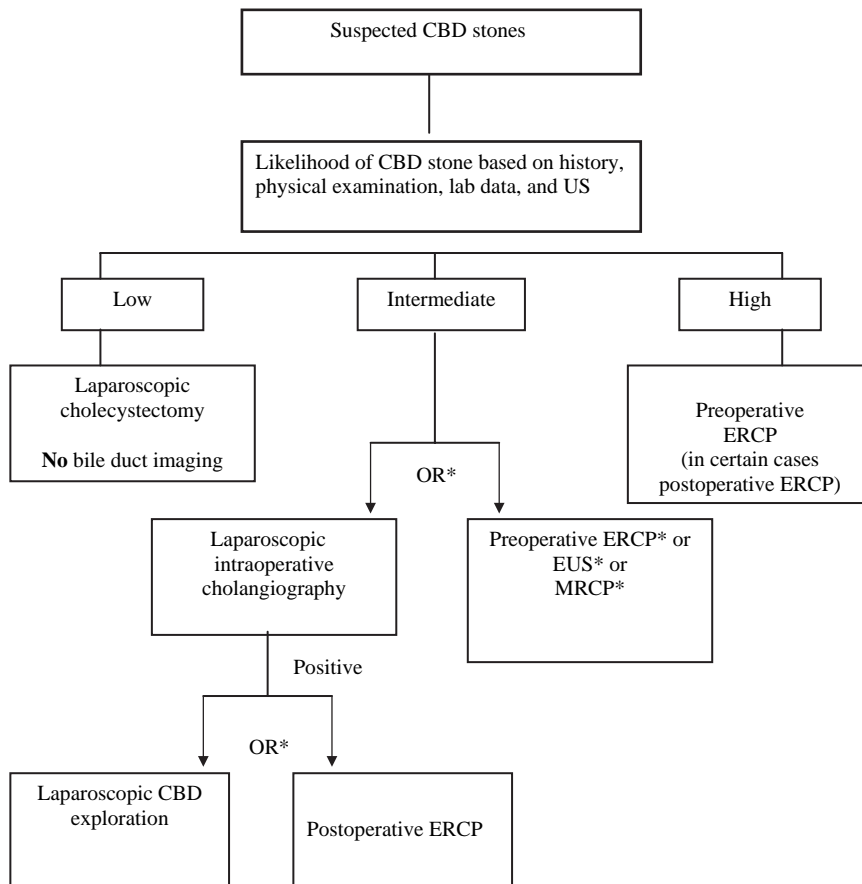


Figure 1. A proposed algorithm for the management of patients with suspected common bile duct (CBD) stones undergoing laparoscopic cholecystectomy. ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; MRCP, magnetic resonance cholangiopancreatography; US, transabdominal ultrasound. *Depending on costs, availability, and local expertise.

or absence of bile duct obstruction, although it is not as good for determining the level or the cause of the obstruction. Ultrasound results will help determine the next imaging study to perform, if any.

Biliary obstruction – suspected CBD stones

Proper selection of patients for further biliary imaging to exclude CBD stones is crucial in order to minimize patient morbidity and institutional costs. Many decision models have confirmed that an optimal approach to the management of these patients is dependent on the pre-test probability of having CBD stones, as well as local availability and expertise [1,10–21]. A full discussion of all predictive models is beyond the scope of this review. For patients at low risk of CBD stones,

laparoscopic cholecystectomy should be performed with no cholangiography. ERCP remains the preferred procedure (either preoperatively or postoperatively) for patients at high risk of CBD stones. For patients at intermediate risk of CBD stones, the optimal approach seems to be intraoperative cholangiogram followed, if positive, by laparoscopic CBD exploration or postoperative ERCP depending on local expertise. Alternatively, a strategy that involves preoperative ERCP, EUS, or MRCP may be considered for patients at intermediate risk, depending on local availability, expertise, and cost issues. A proposed algorithm for the management of patients with suspected CBD stones undergoing laparoscopic cholecystectomy is shown in Figure 1 [22]. In the postoperative setting, the optimal approach is again dependent on the pre-test probability of CBD stones.

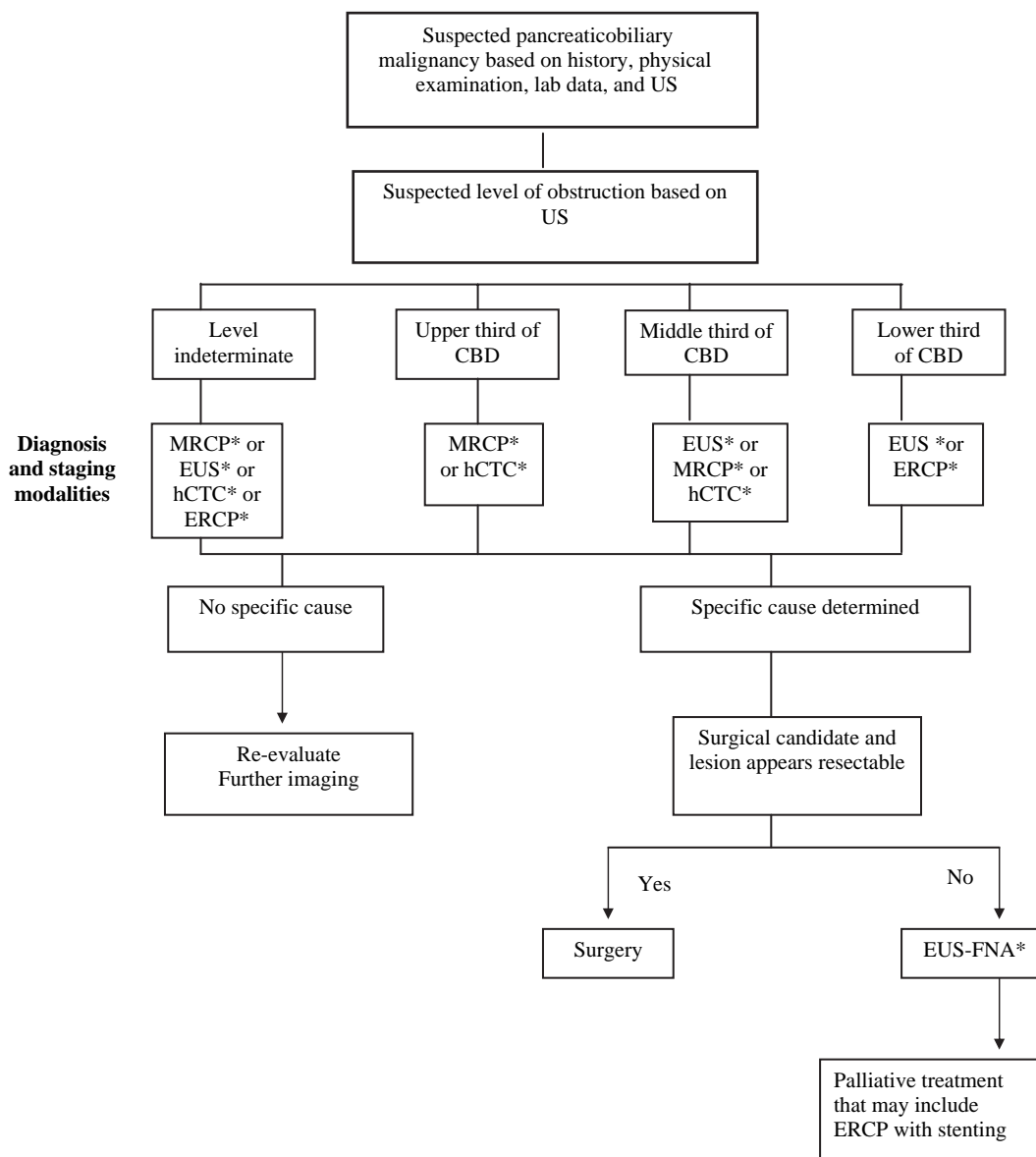


Figure 2. A proposed algorithm for the management of patients with suspected pancreaticobiliary malignancy. CBD, common bile duct; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; FNA, fine-needle aspiration; hCTC, helical CT cholangiography; MRCP, magnetic resonance cholangiopancreatography; US, ultrasound. *Depending on costs, availability, and local expertise.

PTC can be used as an alternative to surgery in patients with failed ERCP who require urgent biliary drainage, such as in undrained cholangitis. hCTC cannot be recommended in the routine work-up and management of patients with suspected CBD stones because of its risks and limited performance characteristics in patients with high grade obstruction.

Biliary obstruction – suspected pancreaticobiliary malignancy

If pancreaticobiliary malignancy is suspected on the basis of clinical and US findings, further imaging must be performed to obtain a diagnosis, stage the extent of the malignant process for resectability, and evaluate the need for possible palliative treatment. Identification of the level of obstruction is of great importance since the differential diagnosis and therapeutic implications are different for each level. A distal CBD obstruction may be amenable to an endoscopic or surgical drainage procedure whereas a more proximal one may require a more complex intrahepatic anastomosis or percutaneous drainage. The optimal approach to patients with malignant biliary obstruction must take into account the performance characteristics of the different imaging modalities, the level and cause of the obstruction, the risk of cholangitis when opacifying an obstructed biliary tree, and the potential for curative versus palliative therapy. Recent data suggest that noninvasive biliary imaging may greatly assist endoscopic drainage and diminish septic complications that occur when there is a failed attempt at unilateral or bilateral drainage [215,216,218,251,252]. A proposed algorithm for the management of patients with suspected pancreaticobiliary malignancy is shown in Figure 2, and presents many similarities to that recently proposed by the ASGE [253].

Decision models, cost-effectiveness and outcome studies

The literature with respect to cost-effectiveness of the new biliary imaging technologies is unfortunately limited. In a decision analysis, the use of MRCP to guide unilateral biliary stent placement in a patient with inoperable hilar obstruction reduces the overall cost of treatment by \$469 per patient [254]. However, the uncertainty of any survival advantage that bilateral biliary stent placement conferred over unilateral stent placement makes cost-effectiveness difficult to assess. Another decision analysis model found that EUS was the least costly method to evaluate possible CBD stones before laparoscopic cholecystectomy unless its accuracy dropped below 90% and the cost rose above 60–70% that of ERCP [255]. Other cost-effectiveness analyses also favor EUS-FNA in the diagnosis and staging of pancreatic cancer by minimizing the number of unnecessary surgical explorations, avoiding

the need for further diagnostic tests while influencing clinical decisions [256–259].

Real-life results, however, may be different from what could be anticipated on the basis of test performance characteristics or decision modeling. For example, coincident with the marked increase in the number of MRCPs performed for biliary obstruction at the Hopital Erasme in Brussels from 1995 to 1997, there was only a minor reduction in the total number of ERCPs (about one diagnostic or therapeutic ERCP less for every four additional MRCPs) [260]. Preliminary data from a prospective randomized trial [261] from our group comparing ERCP with MRCP, whose study population was mainly composed of patients with suspected choledocholithiasis, suggested a high rate of subsequent ERCPs in the MRCP arm (51%), with no differences between the groups in terms of rate of subsequent complications or overall duration of hospital stay. In a prospective study, performing EUS-FNA as the first endoscopic procedure in patients suspected to have biliary obstruction obviated the need for about 50% of ERCPs, helped direct subsequent therapeutic ERCP, and substantially reduced costs by \$3513 per patient [262]. Similarly, in a selected cohort of 44 patients with pancreatic cancer, EUS-FNA may have avoided unnecessary surgery in 27% and further diagnostic testing in 57% for a saving of \$3300 per patient [140]. More true outcome trials are therefore needed to better assess the impact on clinical decision-making or patient outcomes of these new diagnostic methods.

Conclusion

In summary, published data suggest an increasing role for EUS and other noninvasive imaging techniques such as MRCP and hCT following an initial US in the assessment of patients with suspected biliary obstruction to select candidates for surgery or therapeutic ERCP. Ultimately, the management of patients with a suspected pancreaticobiliary condition is dependent on local expertise, availability, cost, and collegial multidisciplinary collaboration between radiologists, surgeons, and gastroenterologists.

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