Validity of MDCT cholangiography in differentiating benign and malignant biliary obstruction

Ahmed M. Alsowey[1], Ahmed F. Salem[1] and Mohamed I. Amin[1,2]*

Abstract

Background: MDCT cholangiography can be utilized to identify variant biliary anatomy to guide preoperative planning of biliary surgery, and determine the cause and level of biliary obstruction. Early tumor detection and staging of biliary cancer are key factors for a possible cure by surgical resection. Between December 2019 and October 2020, 69 patients with clinically suspected biliary obstruction were enrolled in the study, subjected to clinical assessment (full history taking and clinical examination) and imaging assessment by MDCT cholangiography. Our findings were correlated to standard reference examinations including operative/ERCP/biopsy and histopathology findings.

Results: The most affected age was between 60 and 70 years old, and males were more affected. The commonest clinical presentation was yellowish discoloration of the skin and sclera followed by biliary colic. Right hypochondrial tenderness was the main clinical finding on clinical examination. Our patients were categorized according to the etiology of biliary obstruction into 7 groups: malignant stricture 52.2% (36 patients), calcular 24.6% (17 patients), iatrogenic 5.8% (4 patients), portahepatis lesions 5.8% (4 patients), benign stricture 4.3% (3 patients), inflammatory 4.3% (3 patients), and congenital 1.4% (1 patient). The malignant group shows dominant mass, moderate biliary obstruction, and arterial and venous enhancement. The overall sensitivity was 94% for malignancy.

Conclusion: MDCT cholangiography is non-invasive, fast, and highly sensitive and specific in the diagnosis of different causes and levels of biliary obstruction and is useful in the characterization of the lesion in cases of malignant obstruction and differentiating it from benign stricture. It can be used as an effective alternative to ERCP or PTC.

Keywords: Multidetector computed tomography, Biliary obstruction, Obstructive jaundice

Background

Obstructive jaundice is a common surgical problem that happens when there is a blockage to the passages of conjugated bilirubin from liver cells to the intestine. This can lead to life-threatening complications such as ascending cholangitis, malabsorption, and hepatorenal syndrome [1].

Causes of biliary obstruction can be divided into intrahepatic or extrahepatic causes and can be divided also according to its pathology into benign or malignant causes. Diseases of the biliary tract affect a large portion of the worldwide population, and the majority of cases are caused by cholelithiasis [2–6].

Ultrasound (US) is the initial imaging technique as a non-invasive cost-effective modality for evaluating the biliary obstruction but of lower sensitivity and specificity with limited value in the evaluation of the peripheral intrahepatic ductal lesions [7, 8].

Magnetic resonance cholangiopancreatography (MRCP) is considered the most reliable non-invasive technique that produces high-contrast and high-resolution images of

* Correspondence: aasser2012@gmail.com
[1]Faculty of Medicine, Zagazig University, Zagazig, Egypt
[2]Zagazig City, Egypt

the biliary tree and allows the evaluation of the solid organs. However, contraindications including patients with cardiac pacemakers, cerebral aneurysm clips, or claustrophobia added to that high cost and not readily available [9–11].

Direct cholangiography (percutaneous cholangiography (PTC) or endoscopic retrograde cholangiopancreatography (ERCP)) is considered the gold standard technique. They enable direct visualization of the biliary tree and at the same time propose the therapeutic intervention. The drawbacks include invasiveness and even life-threatening complications [12, 13].

Recently, in the last decade, multidetector computed tomography (MDCT) has led to the acquisition of true isotropic voxels that can be post-processed to yield images in any plane [14]. The combined use of multiplaner reformatting (MPR) and minimum intensity projection (MinIP) techniques significantly improves the visualization of the biliary ducts and their site of confluence compared with those obtained by axial CT. Moreover, MinIP technique enables us to depict the small biliary duct and the pancreatic duct more clearly [15–17].

MDCT cholangiography has a vital role as a post-processing technique that can be utilized to identify variant biliary anatomy to guide preoperative planning of biliary-related surgery [18] and determine the level and the cause of biliary obstruction; early tumor detection and staging of the biliary cancer are the key factors for a possible cure by surgical resection [19, 20].

MDCT cholangiography, as a non-invasive modality, committed to the biliary tract denotes a good substitute to MRCP. CT systems are particularly useful when magnetic resonance imaging (MRI) is contraindicated or unapproachable or when the value of MRCP images is suboptimal. The benefit of MDCT due to thinner (1 mm) sections, quick scanning, and the parallel escalation in the abilities of the workstations has permitted the development from section-based to volume-based systems [21–24]. MDCT cholangiography with VR images has some advantages over formerly mentioned imaging tools. The pre-contrast series is useful in those with an elevated bilirubin level or abnormal liver or renal functions. By using CPR/MPR, all intra-hepatic ducts can be viewed, a feature that is not possible at ERCP or PTC. Contrast series data set is used as well to reproduce angiography images to delineate tumoral vascular invasion [25].

The aim of this work was to evaluate the validity of MDCT cholangiography in differentiating benign and malignant biliary obstruction.

Methods
Study design and population
This was a prospective diagnostic study in concordance with the STARD guidelines conducted during the period

from December 2019 to October 2020 in the Radio-diagnosis Department, at our university hospitals. The data were collected from 69 patients (39 males and 30 females) with the majority of cases belonged to the 5th to 6th decade age which clinically presented with obstructive jaundice. Written consent was obtained from all patients included in our study (except for a young patient, the consent was obtained from her parents). The consent and exam protocols were approved by the international review board (IRB), faculty of medicine with reference number ZU-IRB#4539. More than one clinical presentation could be found in the same patient; the clinical presentations were jaundice (63 patients), biliary colic (52 patients), dark urine (45 patients), pale stool (32 patients), pruritus (24 patients), fatty dyspepsia (23 patients), vomiting (22 patients), fever (16 patients), cachexia (12 patients), and abdominal swelling (10 patients).

Patient inclusion criteria
The following are the inclusion criteria:

1. All cases with clinically suspected biliary obstruction and abdominal US revealing any degree of biliary obstruction
2. Elevated serum levels of indirect bilirubin or alkaline phosphatase enzyme

Patient exclusion criteria
The following are the exclusion criteria:

1. Case contraindications for contrast-enhanced computed tomography scanning, for example, thyroid disease, pheochromocytoma, and contrast hypersensitivity
2. Patients with raised renal functions not on dialysis
3. Pregnant females (mainly in the first trimester)
4. Morbid obesity (>150 kg), due to the couch weight limitation, besides those patients who get dyspenic when lying in a supine position, an obstacle that hinders the image quality

Scan protocol and parameters
All cases were scanned by 128™ detector rows scanner (Ingenuity core, v3.5.7.25001, Philips Healthcare Systems, The Netherlands). Scanning parameters were 350 mAs, 120 kVp, reconstruction interval of 5 mm, section collimation of 2.5–5 mm, and table speed of 7.5–10 mm per rotation within one breath-hold attainment of 8–10 s. Contrast administration is by automatic power injector (model mark V: medrad, Indianola, PA).

Patient preparation

Fasting for 6 h prior to scanning and vigorous oral hydration 2 h earlier to the examination are required. Water-soluble oral contrast was used only in those patients with suspected portahepatis lesions. Ten-centimeter contrast diluted in 1 L of water should be drinked by the patient during a period of 1 h prior to the exam with the last 250 mL drinked while sitting on the couch. An intravenous catheter was introduced at the arm vein for intravenous contrast administration. Creatinine clearance must be >30 mL/min, GFR >45 mL/min/1.73 m^2, or serum creatinine level <1.5 mg/dL.

Patient position

The patient lies supine, head first; the scanning begins from the lung bases down to the pelvic inlet during suspended complete expiration or complete inspiration.

CT scan protocol

Non-contrast phase It is used to make a baseline for deciding whether an identifiable lesion enhances and helps in identifying biliary stones or pancreatic calcification which may be concealed by contrast material.

Contrast-enhanced phases It comprises arterial, portovenous, and late phases. Administration of a non-ionic contrast agent (300 mg of iodine per milliliter) was done intravenously (2 mL/kg), through the intravenous catheter, at a rate of 3–5 mL/s for 30 s via a programmed powerful automatic injector, at that time, the helical acquisition began (8 s) after a threshold level of 140 HU was extended in the abdominal aorta then the arterial phase attained (20–30 s), after injection of contrast media. The porto-venous phase developed (50–60 s) after the injection of contrast media; finally, the delayed phase assimilated (5–10 min) after the injection of the contrast media.

Post-procedure care

The following are the post-procedure care: excess oral hydration and follow-up for 30 min for any reactions or side effects after contrast injection, such as inflammation, rash, itching, or trouble in breathing.

Image analysis
Post-processing technique

The 3D reestablishment with thin planar slicing (1 mm) and MPR was achieved in coronal and sagittal planes for well description of the biliary tract wall and intraluminal lesions. Such technical development permits thinner slices to be gained in shorter scan periods, with good patient agreement and lower motion artifacts.

Standard reference examinations

MDCT cholangiography findings were correlated with operative and endoscopic interference (17 calcular group patients), ERCP (12 patients of the remaining benign nature lesions and the negative case), PET/CT for portahepatis lesions (4 patients), and biopsy and histopathology in malignant masses (36 patients).

Statistical analysis

The data analysis was performed using SPSS 20 (Chicago SPSS, SPSS Inc., Chicago, IL). Qualitative data were expressed as number and percent. Quantitative data were displayed as mean and SD. Through the comparison of MDCT diagnosis with the last diagnosis acquired from standard reference inspections, the diagnostic precision of MDCT cholangiography in the assessment of the reasons for biliary obstruction will be accessed in terms of accuracy, specificity, sensitivity, PPV, and NPV.

Results

Our cross-sectional prospective study included 69 patients, 39 males and 30 females, with their ages ranging from 13:82 years; the mean age for males is 55.61 years ± 13.68 SD and for female is 54.23 years ± 18.01 SD, making the overall mean age of the total patients 55.01 years ± 15.6 SD.

The degree of biliary radical dilatation was assessed as follows: mild—localized to the central radicals; moderate—extending to the first- and second-order branches; and severe—involving the most peripheral branches as well. Biliary dilatation of mild degree was the most observed finding, and distal obstruction was the most observed level.

Regarding the nature of the cause of biliary obstruction, malignant causes (36 cases 52.2%) were more predominant than benign causes.

Our patients were categorized according to the cause of the biliary obstruction into malignant lesions in 36 patients (cholangiocarcinoma in 14 patients (20.3%), pancreatic carcinoma in 14 patients (Fig. 1) (20.3%), periampullary carcinoma in 3 patients, hepatic focal lesions in 3 patients, gall bladder carcinoma in 1 patient, and gastric carcinoma in 1 patient), calcular biliary obstruction (Fig. 2) in 17 patients 24.6% (due to the presence of common bile duct stone), iatrogenic lesions in 4 patients 5.8% (due to the presence of fluid collection and aerobilia in patient with a history of recent biliary surgery or intervention), portahepatis lesions in 4 patients 5.8% (due to the presence of enlarged portahepatis LNs; 2 cases proved to be lymphoma and two cases metastatic portahepatis LNs), benign stricture in 3 patients 4.3% (two cases due to recurrent cholangitis and one case attributed to sludge), inflammatory lesions in 3 patients 4.3% (due to the presence of signs of inflammation:
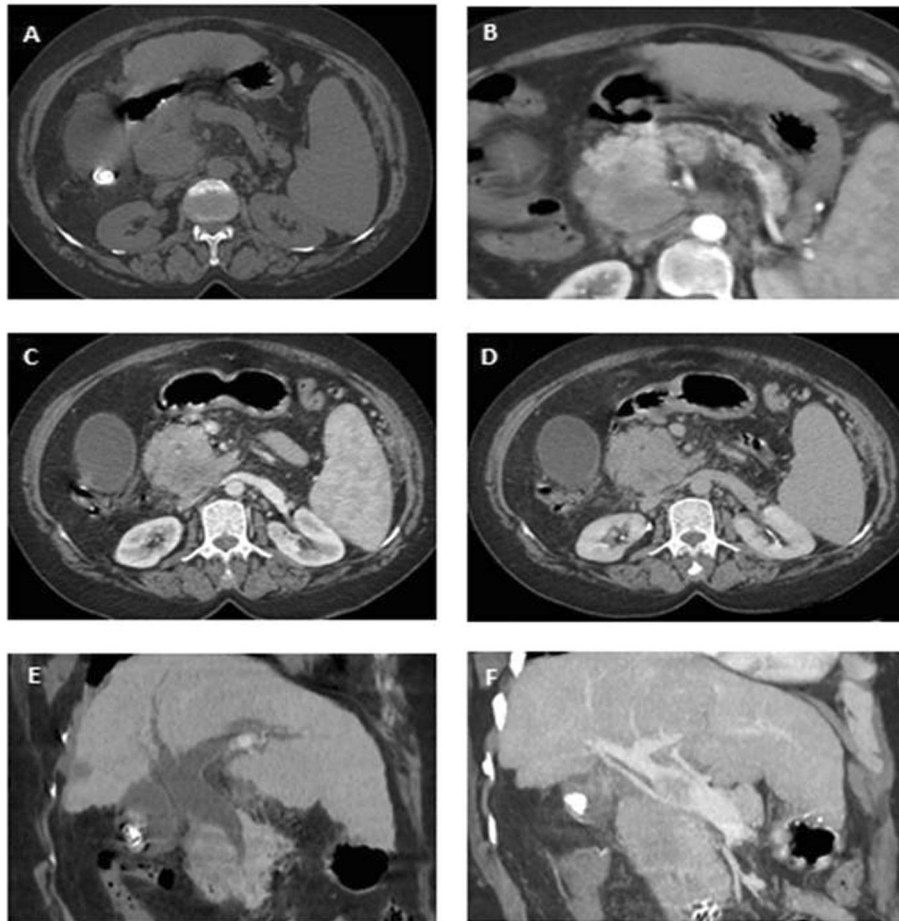
Fig. 1 Pancreatic head adenocarcinoma. Malignant obstructive jaundice due to pancreatic head adenocarcinoma (pathologically proved) with moderate intra- and extra-hepatic biliary dilatation and PV thrombosis. Male patient, 55 years old, presented with jaundice, abdominal pain, anorexia, and cachexia. **a** Axial non-contrast, **b** axial oblique reformatted post-contrast (arterial phase), **c** axial (portal phase), and **d** axial (delayed phase) images showing fairly defined pancreatic head mass that is poorly enhancing at the arterial and venous phases, being isodense at delayed phases. **e** Coronal oblique MinIPreformatted MDCT cholangiography image showing moderately dilated CBD till its distal end where the mass encroaches upon it. **f** Coronal oblique MIP reformatted MDCT cholangiography images showing partially thrombosed PV

enhancement in arterial phase, haziness or stranding of surrounding the fat planes, thickening of the common bile duct wall), congenital lesion in one patient 1.4% (presented as a cystic lesion that communicates to the bile duct and is discrete from the GB; classified according to modified Todani classified as type IA), (Fig. 3) and negative in 1 patient 1.4%; from our results, the most frequent group was malignant stricture, and the least frequent group was congenital (Table 1).

Table 1 shows the differences between the MDCT cholangiography and the gold standard method regarding the malignant stricture findings that can be summarized as follows: cholangiocarcinoma in 14 (20.3%) cases by MDCT (Fig. 4) compared to 15 cases (21.7%) by gold standard, pancreatic carcinoma in 14 cases in both

(20.3%), periampullary carcinoma in 3 (4.3%) in both, hepatic focal lesions in 3 cases (4.3%) by MDCT compared to 2 cases (2.9%) by gold standard cases, and GB and gastric carcinoma (Fig. 5) in one case at each of them (2.9%). Other causes of biliary obstruction show no differences between both methods except for portahepatis lesions (Fig. 6), with fewer cases detected by the latter method (3 cases 4.3%); benign stricture was detected more at the latter method in 5 cases (7.2%), as well as no negative cases detected at the latter method.

Comparing benign and malignant causes regarding the demographic data, our study showed higher male affection in the malignant group by 64% while females showed higher affection in the benign group by 53%; the
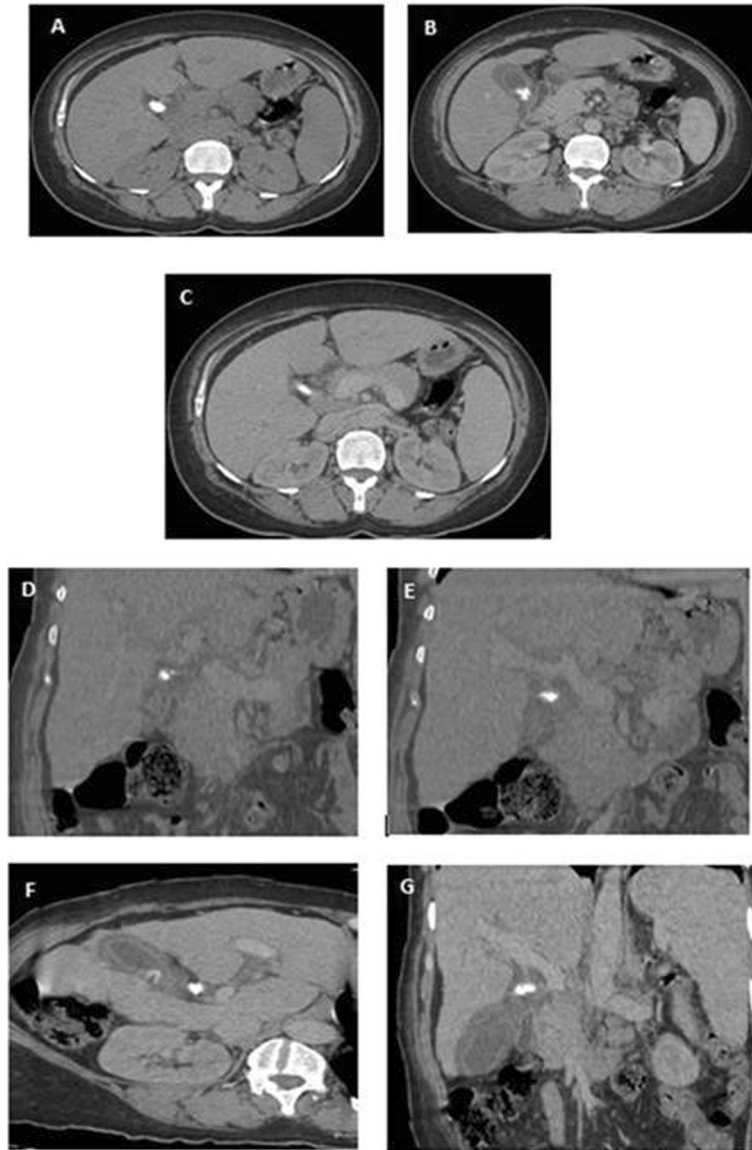
Fig. 2 Mirizzi syndrome. Mirizzi syndrome due to impacted cystic duct stones exerting minimal extrinsic intra-hepatic biliary dilatation in a patient with calcular cholecystitis. Female patient, 48 years old, presented with epigastric pain, intermittent attacks of jaundice, and fever. **a** Axial pre-contrast image showing impacted stone at the level of the cystic duct. **b** Axial (arterial phase) and **c** axial (portal phase) images that show partially contracted GB over dense GB stones with surrounding minimal peri-cholecystic free fluid associated with two impacted cystic duct stones exerting extrinsic minimal intrahepatic biliary dilatation and normal caliber CBD. **d, e** Coronal reformatted MDCT cholangiography images showing two adjacent impacted cystic duct stones more clearly. **f, g** Axial and coronal oblique reformatted MDCT cholangiography images showing the cystic duct with its impacted stones and the GB in one plane

most affected age group was 60:<70 years in both the malignant and benign groups 17 (43.6%) and 8 (26.7%), respectively. The mean age for the affection in the malignant group is 58.4 years compared to 50.9 years in the benign group. Both sex and age differences between the malignant and benign groups showed non-significant difference statistically through calculating their p values using the chi-square test (Table 2).

Our study showed a statistically significant difference only for the prevalence of cachexia (considering the clinical presentation) towards the malignant group and fever towards the benign group through

Fig. 3 Post-ERCP duodenal diverticulum. Benign obstructive jaundice with moderate IHBRD and pneumobilia caused by a duodenal diverticulum arising from the third part of the duodenum following iatrogenic ERCP trauma. "Male patient 58 years old presented by epigastric pain and progressive jaundice. (History of ERCP two months ago). **a**, **b** Axial pre-contrast and portal phase images showing mild to moderate pneumobilia more prominent at the LT hepatic lobe. **c** Coronal portal phase image showing dilated CBD with free air inside. **d** Axial oblique reformatted post-contrast (portal venous phase) image showing dilated CBD with air inside and posterior to it a cystic lesion with air fluid level within. **e** Coronal oblique reformatted post-contrast (portal venous phase) MDCT cholangiography image showing cystic lesion assuming a medial location to the second part of the duodenum and superior location to the 3rd part of the duodenum which is being continuous inferiorly via a wide isthmus. **f** Sagittal oblique reformatted MDCT cholangiography image showing the relation of the cystic lesion to the CBD (posterior to it) and the third part of the duodenum (superior to it)

calculating their p values using the chi-square test, while other clinical presentations did not show significant statistical difference.

MDCT cholangiography findings at the benign and malignant groups showed high statistically significant difference regarding the presence of mass (towards the malignant group at 37 cases 90.3%) and also regarding the presence of calcification (towards the benign group at 6 cases 21.4%) while the findings showed a statistically non-significant difference for the degree of biliary dilatation and level of obstruction by calculating their p values using the chi-square test (Table 3); mild degree of obstruction was dominant at either category, at 20 cases (71.4%) and at 20 cases (48.8%) for the benign and malignant groups, respectively.

Table 1 MDCT cholangiography and gold standard method diagnosis of the studied cross-section (N=69)

Diagnosis	MDCT cholangiography		Gold standard	
	No.	%	No.	%
Malignant stricture	**36**	**52.2%**	**36**	**52.2%**
Cholangiocarcinoma	14	20.3%	15	21.7%
Pancreatic carcinoma	14	20.3%	14	20.3%
Periampullary carcinoma	3	4.3%	3	4.3%
Hepatic focal lesions	3	4.3%	2	2.9%
GB carcinoma	1	1.4%	1	1.4%
Gastric carcinoma	1	1.4%	1	1.4%
Calcular	17	24.6%	17	24.6%
Iatrogenic	4	5.8%	4	5.8%
Portahepatis lesions	4	5.8%	3	4.3%
Benign stricture	3	4.3%	5	7.2%
Inflammatory	3	4.3%	3	4.3%
Congenital	1	1.4%	1	1.4%
Negative	1	1.4%	–	–
Total	69	100%	69	100%

The presence of arterial and portal phase enhancement in this study showed a high statistically significant difference towards the malignant group (for the former phase, it was present in 3 cases 56.1% {with 10 cases 24.4% showing rim pattern as the dominant pattern} and in 30 cases 73.2% {with 11 cases 26.8% showing heterogeneous pattern as the dominant pattern}) for the latter phase while it showed a statistically non-significant difference for the delayed phase enhancement by calculating their *p* values using the chi-square test (Table 4), which was absent at 40 cases (97%) for the malignant group while at 27 cases (96.4%) for the benign group.

There was a very good agreement between the standard method for the detection of the site (Table 5) and cause (Table 6) of biliary obstruction and MDCT by getting a *p* value of kappa equal to 1 (the highest possible score for agreement) and 0.87, respectively, using the Stuart-Maxwell test and high significance in the detection of the site of obstruction

Table 7 shows very good agreement between MDCT and standard method regarding the detection of malignant stricture type by getting a *p* value of kappa 0.91 using the Stuart-Maxwell test and high significance in the detection of the type of malignant lesion.

The results of this study presented high diagnostic performance for the MDCT cholangiography regarding the level and cause of obstruction that was highest in malignant (100% sensitivity), iatrogenic (Fig. 7),

inflammatory, and congenital causes while it yields the lowest diagnostic performance in the detection of benign stricture 40% sensitivity (Table 8).

Discussion

Imaging evaluation of the biliary tree includes ultrasound, CT, CT cholangiography with a biliary contrast agent, MRCP, ERCP, and PTC. Both ultrasound and MRCP do not imply an ionizing radiation. Both do not utilize contrast agents. Sonography is not superior to evaluate the main biliary tract, with a reported sensitivity ranging from 20 to 80%, at biliary stone detection [26].

Though MRCP is a reliable non-invasive technique, its use is hindered in those with pacemakers or aneurysm clips and those who are claustrophobic [27].

ERCP has the privilege of providing diagnostic and therapeutic intervention in the same session (endoscopic sphincterotomy, stone extraction, and endoscopic guided biopsy). However, it yields a little information about solid abdominal organs, is invasive as well, and poses a 0.5–5.0% complication rate (diverse reaction to sedatives, cardio-respiratory dysfunction, pancreatitis, perforation of the gut, bleeding, cholangitis, sepsis, and death) [28].

MDCT pre-contrast series is useful in those with an elevated bilirubin level or abnormal liver or renal functions. By using CPR/MPR, all intra-hepatic ducts can be viewed, a feature that is not possible at ERCP or PTC. Contrast series data set is used as well to reproduce angiography images to delineate tumoral vascular invasion [25]. MDCT cholangiography assesses globally the biliary obstruction regarding the biliary tree, vessels, and solid abdominal organs (liver, pancreas, and duodenum), a feature that does not exist at ERCP and PTC [29, 30].

In our series, all our patients were complaining of yellowish discoloration of the skin and sclera as the most common clinical complaint presented in all patients except for 6 cases. Our result agrees with Mathew et al. [31].

In this study, MDCT identified the level of biliary obstruction in 69 patients with 100% accuracy which agreed with Mohamed et al. [16].

Our study showed a higher prevalence for male affection to biliary obstruction than for females by 56.5 to 43.5%. Rishi et al. [20] showed different prevalence which is equal to male to female affection.

Regarding the most affected age group, our study showed that 60–70 years is the most affected group, while Rishi et al. [20] stated that the majority of cases are in the age group 41–60 years.

Moderate degree of biliary duct dilatation initiated by malignant sources was more severe (41.5%) than that of
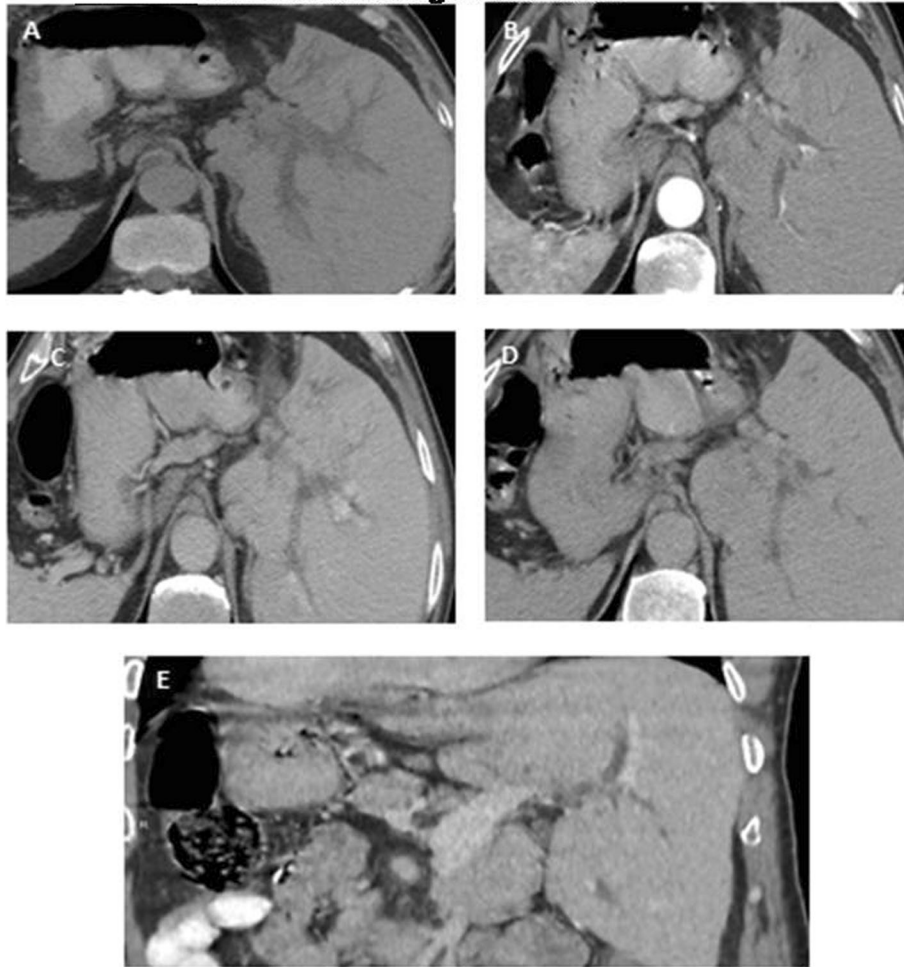
Fig. 4 Peri-hilarcholangiocarcinoma. Malignant obstructive jaundice due to common hepatic duct confluence peri-hilarcholangiocarcinoma (pathologically proved) exerting mild biliary obstruction in the patient with situs inversustotalis. Male patient, 58 years old, presented with intermittent attacks of jaundice and pruritus. **a** Axial non-contrast image showing a situs inversustotalis patient with mild left and right intra-hepatic biliary dilatation that stopped abruptly at the level of confluence of the hepatic ducts. **b–d** Axial contrast (arterial, portal, and delayed phases) images showing soft tissue mass at the common hepatic duct extending to hepatic ductal bifurcation that showed faint arterial phase enhancement and no enhancement at the portal and delayed phases. **e** Coronal oblique reformatted MDCT cholangiography image shows the soft tissue mass at the common hepatic duct

benign sources (21.4%), findings similar to the findings of Mohamed et al. [16].

In our study, it was found that calcular obstructive jaundice was the main cause of benign OJ (24.6%); these were as those of Mathew et al. [31] who showed calcular cause was responsible for 22% of cases of biliary obstruction.

Regarding the nature of the cause of biliary obstruction, our study showed malignant dominance by 59.4% compared to 40.6% for benign which agrees with Narayanaswamy et al. [21] which showed 66.7% for malignancy while 33.3 for benign causes. But

Mathew et al. [31] stated benign causes were 56% while malignant was only 44%.

Malignant stricture was identified by MDCT in 36 cases; 34 cases were confirmed by standard examination; a case had a slight left-sided intrahepatic dilatation with hyper-enhancement of the duct wall and abrupt duct narrowing, identified as cholangiocarcinoma. ERCP identification was acute cholangitis. The second case was a well-known case of colon cancer on follow-up, a hepatic focal lesion identified as necrotic metastasis but cytology confirmed an abscess. Alternatively, a case of metastatic portahepatis LN was confirmed to be cholangiocarcinoma.
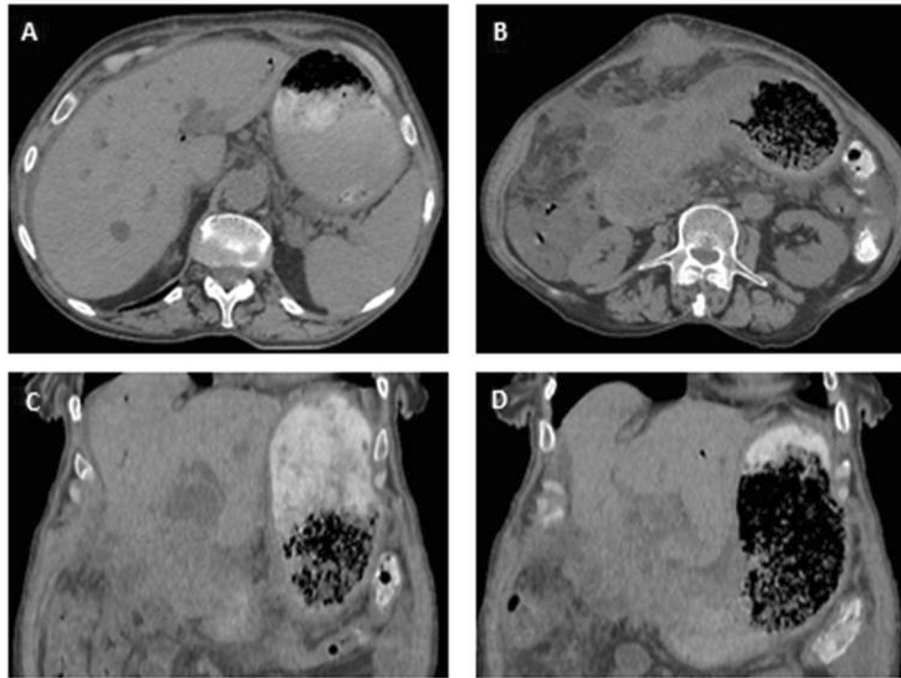
Fig. 5 Metastatic gastric outlet carcinoma. Malignant obstructive jaundice caused by gastric outlet carcinoma (pathologically proved) exerting mild intra-hepatic biliary radical dilatation. Female patient, 69 years old, presented with progressive jaundice, abdominal swellings, vomiting, and cachexia. **a** Axial post-oral contrast image shows minimal intrahepatic biliary radicle dilatation; also, an anterior abdominal wall solid mass lesion is noted. **b** Axial post-oral contrast image shows diffuse irregular gastric outlet abnormal wall thickening forming gastric outlet focal mass seen encroaching upon contrast filled lumen and exerting proximal gastric dilatation. **c, d** Coronal reformatted MDCT cholangiography images showing obliterated related fat planes with inferior surface of the left liver lobe with compression of the hepatic hilum

The SN, SP, PPV, NPV, and ACC of MDCT cholangiography in the detection of malignant stricture were 94.4%, 93.94, 94.44%, 93.93%, and 94.2%, respectively, that come to an agreement with Mohamed et al. [16] which the results were 96.8%, 94.9, 98.2%, 96.7%, and 95.6%.

In our series, pancreatic carcinoma is present in 14 patients responsible for 20.3% of the total cases; in the study of Mohamed et al. [16], pancreatic carcinoma was responsible for 17.8% of the causes of biliary obstruction. Mathew et al. [31] claimed that it affected 20% of cases. MDCT identified all the cases of pancreatic carcinoma with 100% accuracy. Most studies agree with the basis of diagnosing as ours: a hypodense mass relative to enhanced pancreatic tissue that may show faint peripheral enhancement.

In other malignancies, there were 5 cases, 3 cases diagnosed as hepatic focal lesion, 1 case as GB carcinoma and gastric carcinoma, and one case was wrongly diagnosed as metastatic focal lesion but proven as an abscess. Mohamed et al.'s [16] results included 8 cases of intrahepatic malignant masses,

one case was diagnosed as benign stricture but pathologically proven to be metastasis from non-Hodgkin lymphoma. Tummala et al. [32] reported extrinsic compression by focal lesion adjacent to the bile duct in 3.2% of their patients (compared to 4.3% in our study).

Periampullary carcinoma was found in 3 cases, all were proven pathologically to be periampullary carcinoma; it represented 4.3% of the cases. Mohamed et al. [16] showed a higher affection rate (14%) with 100% accuracy that agreed with our results while Narayanaswamy et al. [21] was 96%.

Calcular etiology was diagnosed in 17 cases, 1 case was diagnosed by MDCT as calcular but proven to be a benign stricture (sludge) and another case which was diagnosed by MDCT as negative (no detected cause) proven to be a black cholesterol stone that was not visible. It was the most common cause of benign biliary obstruction in our study by contributing to 24.6% of the cases with SN 94.1%, SP 98%, PPV 94.1%, NPV 98% and, ACC 97.1%. Our results agree with Rishi et al. [20] that revealed in their study ACC of MDCT in the detection
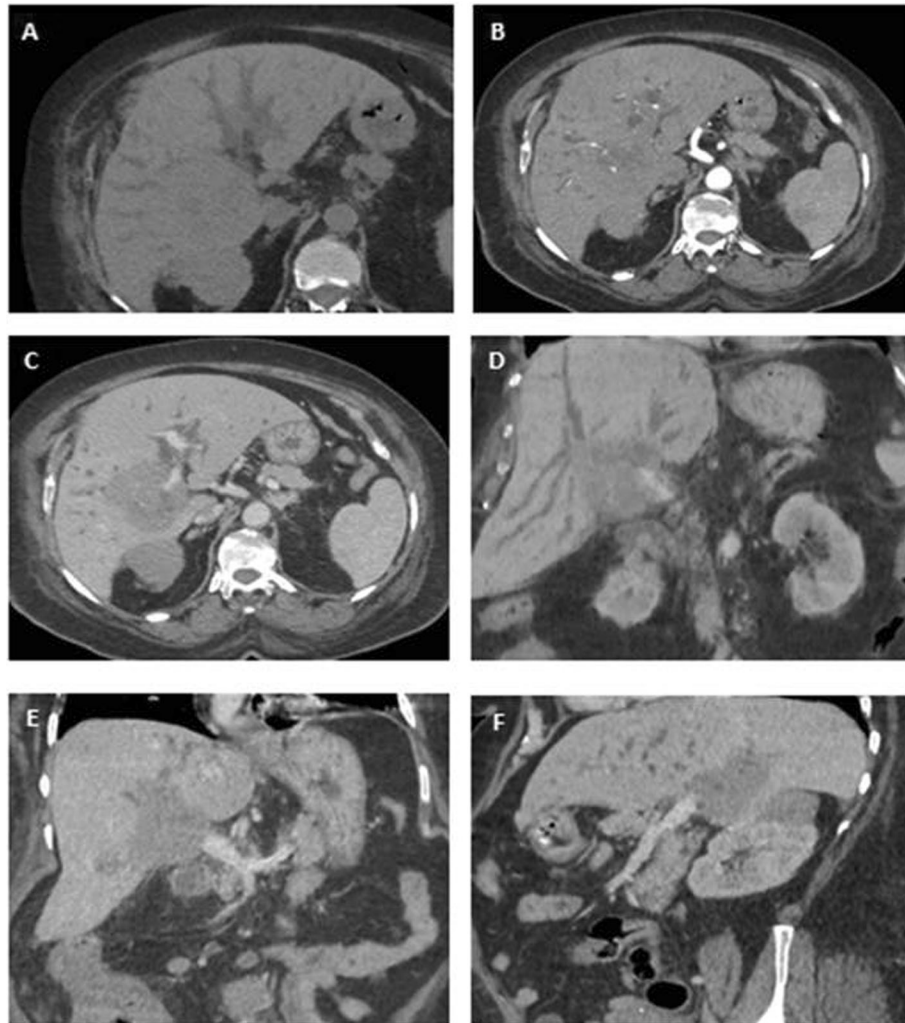
Fig. 6 Portahepatis LN due to lymphoma. Malignant obstructive jaundice due to soft tissue mass lesion involving portahepatis LNs of lymphoma. Male patient, 75 years old, presented with dark urine, pale stool, and jaundice. **a** Axial pre-contrast image showing moderate intra-hepatic biliary radical dilatation. **b**, **c** Axial contrast (arterial and portal phase) images showing large ill-defined faintly enhanced soft tissue density mass lesion involving the portahepatis region centered at the confluence of the RT and LT hepatic ducts and encroaching upon the right PV branch. **d** Coronal oblique MinIP reformatted MDCT cholangiography showing the mass at the portahepatis with its consequent moderate IHBRD. **e**, **f** Coronal and sagittal oblique reformatted MDCT cholangiography images showing the soft tissue lesion involving the portahepatis region

of choledocholithiasis is 98%, SN of 100%, and SP of 97.4% showed also was the most frequently diagnosed cause of obstruction by 24%. You et al. [9] mentioned intraductal high attenuating focal lesions were detected in enhanced or unenhanced scans subsequent to the course of CBD as criteria for diagnosis which agreed with our findings.

Four patients with post-operative iatrogenic bile duct injury were included which represented 5.8% of the total causes. Heller et al. [4] imply that iatrogenic is the second most common reason for benign biliary tract strictures after calcular which agreed with ours. The study showed free fluid in most cases which was noted in the abdomen accompanying fluid at the GB bed. MDCT diagnosed all the patients correctly based on the history and findings making statistical measures for the diagnostic performance of MDCT in detecting bile duct injury as follows: SN 100%, SP 100%, PPV 100%, NPV 100%, and ACC 100%. El-gerby et al. [33] and Meng et al.'s [34] results showed the same SN, SP, PPV, NPV, and ACC as ours for biliary leakage detection.

Table 2 Comparison between benign and malignant causes as regards demographic data

Demographic data	Malignant causes (N=39)		Benign causes (N=30)		Test	p value (Sig.)
	No.	%	No.	%		
Sex						
Male	25	64.1%	14	46.7%	2.956±	0.086 (NS)
Female	14	35.9%	16	53.3%		
Total	39	100%	30	100%		
Age (years)						
0:<10 years	0	0%	0	0%	5.349±	0.148 (NS)
10:<20 years	0	0%	1	3.3%		
20:<30 years	1	2.6%	6	20%		
30:<40 years	2	5.1%	2	6.7%		
40:<50 years	3	7.7%	4	13.3%		
50:<60 years	10	25.6%	5	16.7%		
60:<70 years	17	43.6%	8	26.7%		
70:<80 years	5	12.8%	2	6.7%		
80:<90 years	1	2.6%	2	6.7%		
Total	39	100%	30	100%		
Mean±SD	58.39±12.14		50.87±18.38		1.957	0.056 (NS)
Median (range)	60 (29–82)		57 (13–80)			

Table 3 Comparison between benign and malignant causes as regards MDCT cholangiography findings

MDCT Cholangiography findings	Malignant causes (N=41)		Benign causes (N=28)		Test±	p value (Sig.)
	No.	%	No.	%		
Mass						
Absent	4	9.6%	26	92.8%	57.424	<0.001 (HS)
Present	37	90.3%	2	7.2%		
Calcification						
Absent	40	97.4%	22	78.6%	5.238	0.040 (S)
Present	1	2.6%	6	21.4%		
Biliary dilatation						
Mild	20	48.8%	20	71.4%	2.942	0.230 (NS)
Moderate	17	41.5%	6	21.4%		
Severe	4	9.7%	2	7.1%		
Level of obstruction						
Intrahepatic	10	24.4%	2	7.2%	5.171	0.075 (NS)
Hilar	9	21.9%	5	17.9%		
Distal	22	53.7%	21	75%		

Table 4 Comparison between benign and malignant causes as regards post-contrast enhancement in MDCT cholangiography

Enhancement in MDCT cholangiography	Malignant causes (N=41)		Benign causes (N=28)		Test±	*p* value (Sig.)
	No.	%	No.	%		
Arterial phase						
Absent	18	43.9%	23	82.1%	13.956	<0.001 (HS)
Present	23	56.1%	5	17.9%		
Rim	10	24.4%	3	10.7%	15.840	0.001 (S)
Homogenous	4	9.8%	2	7.1%		
Heterogeneous	9	21.9%	0	0%		
Porto-venous phase						
Absent	30	73.2%	25	89.3%	3.920	0.048 (S)
Present	11	26.8%	3	10.7%		
Rim	0	0%	2	7.1%	9.910	0.019 (S)
Homogenous	7	17.1%	1	3.6%		
Heterogeneous	4	9.7%	0	0%		
Delayed phase						
Absent	40	97.6%	27	96.4%	0.021	1.000 (NS)
Present	1	2.4%	1	3.6%		
Rim	0	0%	1	3.6%	2.042	0.360 (NS)
Homogenous	1	2.4%	0	0%		
Heterogeneous	0	0%	0	0%		

Four patients had portahepatis lesions in our study. It contributed by 5.8% of the causes which showed different results from Mohamed et al. [16] which was 4.4% only. Two cases were diagnosed as lymphoma involving portahepatis LN and other two cases as malignant metastatic portahepatis LN. Rishi et al. [20] stated that lymphoma represented 6% of the causes of obstruction compared to 2.9% in our study and 100% ACC in detecting lymphoma which was the same finding as Mathew et al. [31]. Our diagnostic

Table 5 Agreement between MDCT cholangiography and gold standard method in the detection of the site of biliary obstruction

Site of biliary obstruction	Standard method			Total
	Intrahepatic	Hilar	Distal	
MDCT cholangiography				
Intrahepatic	12 (17.4%)	0 (0%)	0 (0%)	12 (17.4%)
Hilar	0 (0%)	14 (20.3%)	0 (0%)	14 (20.3%)
Distal	0 (0%)	0 (0%)	43 (62.3%)	43 (62.3%)
Total	12 (17.4%)	14 (20.3%)	43 (62.3%)	69 (100%)

performance was as follows: SN 100%, SP 98.48%, PPV 75%, NPV 100%, and ACC 98.55%.

Benign stricture was diagnosed by MDCT in three cases; two cases were proven to be due to recurrent cholangitis which agrees with Heller et al. [4] who stated cholangitis is considered one of the commonest causes of benign strictures. Mohamed et al. [16] mentioned the MDCT criterion for identifying a benign stricture which includes a smooth and gradually elongated narrowing of CBD in a short section measuring less than 1 cm without the presence of a mass. Our diagnostic performance for the detection of the benign strictures was as follows: SN 40%, SP 98.44%, PPV 66.67%, NPV 95.45%, and ACC 94.20%. Mohamed et al.'s [16] statistical results were SN 66.7%, SP 80.2%, PPV 80.2%, NPV 91.7%, and ACC 92.6% which were near to our results except for sensitivity as one case was diagnosed by MDCT as benign stricture proven by biopsy as a small cholangiocarcinoma, while Mathew et al. [31] showed higher percentages as follows: SN 100%, SP 97.8%, PPV 83.3%, NPV 100%, and ACC 98%.

Inflammatory was diagnosed by MDCT in three cases, two cases were due to acute pancreatitis and one case was due to acute cholecystitis. Patel et al. [35] stated that

Table 6 Agreement between MDCT cholangiography and gold standard method in the detection of the cause of obstruction

Cause of obstruction	Standard method								Total
	-ve	Calcular	Benign stricture	Mal. stricture	Iatrog.	Inflam.	Portahepatis	Cong.	
MDCT cholangiography									
Malignant stricture	0 (0%)	0 (0%)	2 (2.9%)	34 (49.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	36 (52.2%)
Calcular	0 (0%)	16 (23.2%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	17 (24.6%)
Iatrogenic	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (5.8%)	0 (0%)	0 (0%)	0 (0%)	4 (5.8%)
Portahepatis	0 (0%)	0 (0%)	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	3 (4.3%)	0 (0%)	4 (5.8%)
Benign stricture	0 (0%)	0 (0%)	2 (2.9%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (4.3%)
Inflammatory	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (4.3%)	0 (0%)	0 (0%)	3 (4.3%)
Congenital	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.4%)	1 (1.4%)
-ve	0 (0%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.4%)
Total	0 (0%)	17 (24.6%)	5 (7.2%)	36 (52.2%)	4 (5.8%)	3 (4.3%)	3 (4.3%)	1 (1.4%)	69 (100%)

acute cholecystitis diagnosis is confirmed in the presence of GB wall thickening, GB distention peri-cholecystic fluid, inflammatory stranding and sub-serosal edema which agreed with our findings. Bonheur et al. [36] mentioned that biliary obstruction can occur from external compression of the bile duct due to inflammation as pancreatitis or cholecystitis. Bollen [10], also mentioned that acute pancreatitis could lead to biliary complications including biliary obstruction.

Our study showed 100% SN, SP, PPV, NPV, and ACC regarding the results of inflammatory causes. Mathew et al.'s [31] study results presented that the inflammatory cause of biliary obstruction has SN, SP, PPV, NPV, and ACC of 100% which in turn agrees with our results.

A 13-year-old female case with a cystic dilated segment involving extrahepatic biliary tree was diagnosed as congenital choledocal cyst type IA. Our study showed 100% SN, SP, PPV, NPV, and ACC to diagnose congenital biliary obstruction. Mathew et al.'s [31] study results showed choledocal cyst has SN, SP, PPV, NPV, and ACC of 100% which agrees with our results.

One of the limitations of this work includes the small number of cases, particularly in the benign stricture group. The main limitations of the use of intravenous agents are the relatively high rate of allergic reactions and the risk of renal and/or hepatic toxicity so patients with biliary obstruction and high renal functions could not be assessed and risk of radiation and anesthesia for young patients.

Conclusion

MDCT cholangiography displayed high sensitivity in the detection of the cause and the level of biliary

Table 7 Agreement between MDCT cholangiography and gold standard method in the detection of malignant lesion type

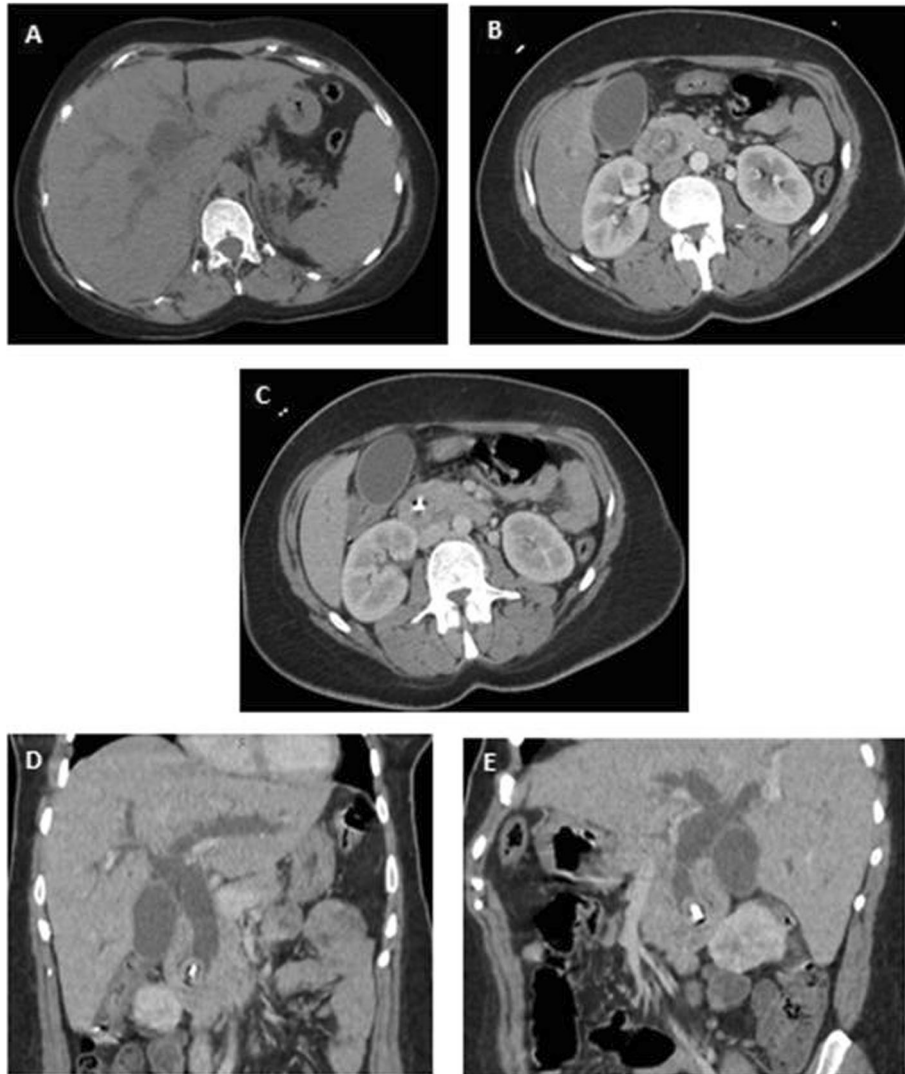| Cause of obstruction	Standard method					Total
	No malignant stricture	Cholangiocarcinoma	Periampullary carcinoma	Pancreatic carcinoma	Other malignancies	
MDCT cholangiography						
No malignant stricture	31 (44.9%)	2 (2.9%)	0 (0%)	0 (0%)	0 (0%)	33 (47.8%)
Cholangiocarcinoma	1 (1.4%)	13 (18.8%)	0 (0%)	0 (0%)	0 (0%)	14 (20.3%)
Periampullary carcinoma	0 (0%)	0 (0%)	3 (4.3%)	0 (0%)	0 (0%)	3 (4.3%)
Pancreatic carcinoma	0 (0%)	0 (0%)	0 (0%)	14 (20.3%)	0 (0%)	14 (20.3%)
Other malignancies	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	4 (5.8%)	5 (7.2%)
Total	33 (47.8%)	15 (21.7%)	3 (4.3%)	14 (20.3%)	4 (5.8%)	69 (100%)

Fig. 7 Neglected separated distal CBD stent fragment. Benign obstructive jaundice due to distal CBD sludge surrounding neglected separated CBD stent fragment. Female patient, 34 years old, presented with persistent jaundice, fever, and pruritus (history of CBD stent removal). **a** Axial pre-contrast image showing moderate intra-hepatic biliary radical dilatation. **b**, **c** Axial contrast (arterial and portal phase) images showing distal CBD dense and turbid surrounding separated dense CBD stent fragment. **d**, **e** Coronal and sagittal oblique reformatted MDCT cholangiography images showing more clearly the markedly dilated CBD with distal impacted stent fragment surrounded by concentric sludge

Table 8 Diagnostic performance of MDCT cholangiography

	SN (%) (95%CI)	SP (%) (95%CI)	PPV (%) (95%CI)	NPV (%) (95%CI)	Acc (%) (95%CI)
Intrahepatic	100%	100%	100%	100%	100%
	(73.54–100)	(93.73–100)	(73.54–100)	(93.73–100)	(94.79–100)
Hilar	100%	100%	100%	100%	100%
	(76.84–100)	(93.51–100)	(76.84–100)	(93.51–100)	(94.79–100)
Distal	100%	100%	100%	100%	100%
	(91.78–100)	(86.77–100)	(91.78–100)	(86.77–100)	(94.79–100)
Malignant cause	100%	90.32%	92.68%	100%	95.65%
	(90.75–100)	(74.25–97.96)	(80.08–98.46)	(87.66–100)	(87.82–99.09)
Calcular	94.12%	98.08%	94.12%	98.08%	97.10%
	(71.31–99.85)	(89.74–99.95)	(71.31–99.85)	(89.74–99.95)	(89.92–99.65)
Benign stricture	40%	98.44%	66.67%	95.45%	94.20%
	(5.27–85.34)	(91.60–99.96)	(9.43–99.16)	(87.29–99.05)	(85.82–98.40)
Malignant stricture	94.44%	93.94%	94.44%	93.94%	94.20%
	(81.34–99.32)	(79.77–99.26)	(81.34–99.32)	(79.77–99.26)	(85.82–98.40)
Iatrogenic	100%	100%	100%	100%	100%
	(39.76–100)	(94.48–100)	(39.76–100)	(94.48–100)	(94.79–100)
Inflammatory	100%	100%	100%	100%	100%
	(29.24–100)	(94.56–100)	(29.24–100)	(94.56–100)	(94.79–100)
Portahepatis lesions	100%	98.48%	75%	100%	98.55%
	(29.24–100)	(91.84–99.96)	(19.41–99.37)	(94.48–100)	(92.19–99.96)
Congenital	100%	100%	100%	100%	100%
	(2.50–100)	(94.72–100)	(2.50–100)	(94.72–100)	(94.79–100)

obstruction; it is fast, non-invasive, and sensitive in cases of malignant obstruction (94%) for lesion characterization and differentiating it from benign stricture. It is also considered a promising diagnostic tool and used as an alternative to ERCP or PTC in the assessment of patients with bile duct obstruction. Limitations for such an exam include the risk of radiation and the use of intravenous agents (relatively high rate of allergic reactions and unfeasibility at renal insufficiency cases).

Availability of data and materials
This prospective cross-section study included 69 patients with the majority belonged to the 5th to 6th decade age that were clinically presented with obstructive jaundice. They were referred from the internal and tropical medicine departments to the radio-diagnosis department from December 2019 to October 2020.

Declarations

Ethics approval and consent to participate
This study was approved by the Institutional Review Board (IRB) of Zagazig University. Written informed consents from all patients before the study were filled and signed, which are also approved by the Institutional Review Board (IRB) of Zagazig University with reference number: 4539-4-4-2019.

Consent for publication
All patients included in this research gave written informed consent to publish the data contained within this study by their parents.

Competing interests
The authors declare that they have no competing interests.

References

1. Tirumani SH, Shanbhogue AKP, Vikram R, Prasad SR, Menias CO (2014) Imaging of the portahepatis: spectrum of disease. RadioGraphics 34(1):73–92. https://doi.org/10.1148/rg.341125190
2. Han JK, Choi JY (2014) Cholangiocarcinoma. In: Choi BI (ed) Radiology illustrated: hepatobiliary and pancreatic radiology, 1st edn. Springer, pp 471–501. https://doi.org/10.1007/978-3-642-35825-8_12
3. Choi J, Choi BI (2014) Other malignant tumor of the liver. In: Choi BI (ed) Radiology illustrated: hepatobiliary and pancreatic radiology, 1st edn. Springer, pp 169–390. https://doi.org/10.1007/978-3-642-35825-8
4. Heller MT, Borhani AA, Furlan A, Tublin ME (2015) Biliary strictures and masses: an expanded differential diagnosis. Abdom Imaging 40(6):1944–1960. https://doi.org/10.1007/s00261-014-0336-1
5. Nikolaidis P, Hammond NA, Day K, Yaghmai V, Mosbach DS, Harmath CB, Taffel MT, Horowitz JM, Berggruen M, Miller FH (2014) Imaging features of benign and malignant ampullary and peri-ampullary lesions. Radiographics 34(3):624–641. https://doi.org/10.1148/rg.343125191
6. Engelbrecht MR, Katz SS, Gulik TM, Laméris JS, Delden OM (2015) Imaging of perihilar cholangiocarcinoma. Am J Roentgenol 204(3):782–791. https://doi.org/10.2214/AJR.15.14740
7. Brunetti JC (2018) Imaging in gall stones (chloelithiasis). Medscape, pp 1–11
8. Kim CW, Chang JH, Lim YS, Kim TH, Lee IS, Han SW (2013) Common bile duct stones on multidetector computed tomography: attenuation patterns and detectability. World J Gastroenterol 19(11):1788–1796. https://doi.org/10.3748/wjg.v19.i11.1788
9. You M, Jung YY, Shin J (2018) Role of magnetic resonance cholangiopancreatography in evaluation of choledocholithiasis in patients with suspected cholecystitis. J Korean Soc Radiol 78:147–156. https://doi.org/10.3348/jksr.2018.78.3.147
10. Bollen TL (2016) Imaging assessment of etiology and severity of acute pancreatitis. Pancreapedia:1–28. https://doi.org/10.3998/panc.2016.31
11. Fidler JL, Knudsen JM, Collins DC, McGee KP, Lahr B, Thistle JL, Tiopazian M (2013) Prospective assessment of dynamic CT and MR cholangiography in functional biliary pain. AJR Jour 201(2):271–282. https://doi.org/10.2214/AJR.12.9538
12. Levy AD (2014) A pattern approach to disease of the gall bladder and bile ducts. In: Holder J, Kubik-Huch RA, Von Schulthess GH, Zollikofer CL (eds) Disease of the abdomen and pelvis: diagnostic imaging and interventional technique, 1st edn. Springer, pp 120–127. https://doi.org/10.1007/978-88-470-5659-6_14
13. Miraglia R, Caruso S, Maruzzelli L, Spada M, Riva S, Sciveres M, Luca A (2011) MDCT, MR and interventional radiology in biliary atresia candidates for liver transplantation. World J Radiol 3(9):215–223. https://doi.org/10.4329/wjr.v3.i9.215
14. Agrawal P, Bo GJ, Bhattarai M, Shah SP, Agrawal M (2018) Role of multidetector computed tomography in differentiating benign and malignant common bile duct strictures. West Afr J Radiol 25:21–27. https://doi.org/10.4103/wajr.wajr.57.16
15. Gorsi U, Gupta P, Kalra N, Kang M, Singh R, Gupta R, Gupta V, Khandelwal N (2015) Multidetector computed tomography evaluation of post cholecystectomy complications: a tertiary care center experience. Trop Gastroenterol 36(4):236–243. https://doi.org/10.7869/tg.297
16. Mohamed HH, Koryem EM, El Olimy ASA, Abdelaal E (2016) Accuracy of the multislice CT in diagnosis of biliary tract obstruction. Inte J Sci Technoledge 4:228–237. https://doi.org/10.12659/PJR.896680
17. Tadros MY, Elia RZ (2017) Current status of multi-detector row helical CT in imaging of adult acquired pancreatic diseases and assessing surgical neoplastic respectability. Alex J Med 53(1):7–14. https://doi.org/10.1016/j.ajme.2016.01.004
18. Awan MW, Nasir N, Yasrab, Ather S (2016) Accuracy of MDCT cholangiography using image reformation in cases of biliary tract obstruction comparing with ERCP. ISRA Med J 8(4):220–223
19. Hirose T, Igami T, Koga K, Hayashi Y, Ebata T, Yokoyama Y, Sugawara G, Mizuno T, Yamaguchi J, Mori K, Nagino M (2017) The development of an automatically produced cholangiography procedure using the reconstruction of portal-phase multidetector-row computed tomography images: preliminary experience. Surg Today 47(3):365–374. https://doi.org/10.1007/s00595-016-1394-5
20. Rishi M, Abdunnisar M, Suresh H (2015) Value and accuracy of multidetector computed tomography in obstructive jaundice. Panacea J Med Sci 5:137–144. https://doi.org/10.12659/PJR.896680
21. Narayanaswamy I, Erasu AR, Parkash R (2015) The role of multidetector row computed tomography in biliary tract malignancy. Cancer Res J 3:104–109. https://doi.org/10.11648/j.crj.20150305.13
22. Oikarinen H (2014) Overview of current strategies for diagnostic imaging of biliary tract and gall bladder tumors. In: Herman JM, Pawlik TM, Thomas CR (eds) Biliary tract and gall bladder cancer: a multisciplinary approach, 2nd edn. Springer, pp 118–129. https://doi.org/10.1007/978-3-642-40558-7_8
23. Zhang ZY, Wang D, Ni JM, Yu XR, Zhang L, Wu WJ, Gong L, Hu MH (2012) Comparison of three-dimensional negative contrast CT cholangiopancreatography with three-dimensional MR cholangiopancreatography for the diagnosis of obstructive biliary diseases. Eur J Radiol 81(5):830–837. https://doi.org/10.1016/j.ejrad.2011.02.036
24. Hyodo T, Kumano S, Kushihata F, Okada M, Hirata M, Tsuda T, Takada Y, Murakami T (2012) CT and MR cholangiography: advantages and pitfalls in perioperative evaluation of biliary tree. Bi J Radiol 85(1015):887–896. https://doi.org/10.1259/bjr/21209407
25. Ahmetoglu A, Kosucu P, Kul S et al (2004) MDCT cholangiography with volume rendering for the assessment of patients with biliary obstruction. AJR 183(5):1327–1332. https://doi.org/10.2214/ajr.183.5.1831327
26. Elsayed EE, Houseni MM, AliAbdElwahab RA (2017) Staging of cholangiocarcinoma by multidetector computed tomography. Menoufia Med J 30:862–869. https://doi.org/10.4103/1110-2098.218254
27. Darwish AN, El Fert AA, El Badry AM, Moussa E (2013) Evaluation of the role of multidetector computed tomography in biliary obstruction. Tanta Med J 41(4):318–326. https://doi.org/10.4103/1110-1415.126194
28. Singh SS, Shafi F, Singh NR (2017) Comparative study of multidetector computed tomography and magnetic resonance cholangiopancreatography in obstructive jaundice. J Med Soc 31:162–168. https://doi.org/10.4103/jms.jms.70.16
29. Lee DH, Kim B, Lee ES, Kim HJ, Min JH, Lee JM, Choi MH, Seo N, Choi SH, Kim SH, Lee SS, Park YS, Chung YE (2021) Radiologic evaluation and structured reporting form for extrahepatic bile duct cancer: 2019 consensus recommendations from the Korean Society of Abdominal Radiology. Korean J Radiol 22(1):41–62. https://doi.org/10.3348/kjr.2019.0803
30. Jang SI, Cho JH, Lee DK (2020) Magnetic compression anastomosis for the treatment of post-transplant biliary stricture. Clin Endosc 53(3):266–275. https://doi.org/10.5946/ce.2020.095
31. Mathew RP, Moorkath A, Basti RS, Suresh HB (2016) Value and accuracy of multidetector computed tomography in obstructive jaundice. Pol J Radiol 81:303–309. https://doi.org/10.12659/pjr.896680
32. Tummala P, Munigala S, Eloubeidi MA, Agarwal B (2013) Patients with obstructive jaundice and biliary stricture ± mass lesion on imaging prevalence of malignancy and potential role of EUS-FNA. J Clin Gastroenterol 47(6):532–537. https://doi.org/10.1097/MCG.0b013e3182745d9f
33. El-gerby KM, Elsamak A, Khalil OE, Shawky KM, El-Kady H (2006) Role of magnetic resonance imaging and magnetic resonance cholangiopancreatography versus helical computed tomography in evaluation of biliary obstruction. MD thesis, Faculty of Medicine, Zagazig University. https://doi.org/10.21608/ZUMJ.2019.14168.1291
34. Meng X, Huang W, Xie P, Chen X, Cai M, Shan H, Zhu KS (2014) Role of multi-detector computed tomography for biliary complications after liver transplantation. World J Gastroenterol 20(33):11856–11864. https://doi.org/10.3748/wjg.v20.i33.11856
35. Patel NB, Oto A, Thomas S (2013) Multidetector CT of emergent biliary pathologic conditions. Radiographics 33(7):1867–1888. https://doi.org/10.1148/rg.337125038
36. Bonheur JL, Ells PF, Minocha A (2019) Biliary obstruction. Drugs Dis> Gastroenterol, Medscape:1–5. https://emedicine.medscape.com/article/187001-overview

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.