Research Square

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Research on Differentiating Benign and Malignant Distal Bile Duct Obstruction Based on MRCP

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Abstract

Objective To measure the luminal diameter at different locations of the intrahepatic and extrahepatic bile ducts on Magnetic Resonance Cholangiopancreatography (MRCP) images, in order to explore the optimal measurement site and corresponding luminal diameter ratio for differentiating benign from malignant distal common bile duct obstruction (DCBDO). The aim is to provide an objective, reproducible, and non-invasive diagnostic basis for clinical practice.

Methods Clinical and imaging data of patients who underwent 3D-MRCP examination for "obstructive jaundice" from April 2020 to March 2025 were retrospectively collected. Based on MRCP images, luminal diameters were measured at the start, widest point, and midpoint of the common bile duct and at various levels of intrahepatic ducts. Corresponding ratios were calculated. Patients were divided into a benign group (Group 1) and a malignant group (Group 2) based on surgical pathology results. Independent samples t-test was used to compare ratio differences between groups. Diagnostic performance was evaluated using Receiver Operating Characteristic (ROC) curves. The measurement location most significantly correlated with the nature of the obstruction was identified, and the optimal cutoff ratio was determined by combining it with the Youden index.

Results A total of 126 patients were included: 62 in the benign group (mean age 65±17 years, 35 females, 27 males) and 64 in the malignant group (mean age 66±13 years, 33 females, 31 males). All bile duct diameter ratios showed statistically significant differences between the benign and malignant groups (all $P < 0.05$). The ratio of the diameter at the common bile duct midpoint to the widest point of the tertiary bile duct (CM/TW) showed the strongest correlation with the nature of the obstruction ($P < 0.001$), with an area under the ROC curve (AUC) of 0.922 (95% CI: 0.869-0.974, $P < 0.001$). The optimal diagnostic cutoff value was 6.75 (ratio > 6.75 suggests benign obstruction), with a sensitivity of 82.3% and a specificity of 92.2%. Furthermore, the visualization rate of fourth-order bile ducts was significantly higher in the malignant group (89.1%) than in the benign group (8.1%) ($P < 0.05$).

Conclusion Measurement of bile duct diameter ratios based on 3D-MRCP is an effective non-invasive method for differentiating benign from malignant distal common bile duct obstruction. Among these, the CM/TW ratio is the optimal quantitative indicator, which can provide an objective imaging basis for clinical decision-making, especially for patients with contraindications or high risks for ERCP.

Introduction

Distal Common Bile Duct Obstruction (DCBDO) is a common acute condition in hepatobiliary and pancreatic surgery, referring to the blockage of the biliary drainage pathway caused by pathological factors in the pancreatic segment, ampullary segment of the common bile duct, and the major duodenal papilla region[1]. Its etiology is broadly categorized into benign and malignant types: benign obstruction primarily includes choledocholithiasis, chronic pancreatitis, and sphincter of Oddi dysfunction[2]; malignant obstruction mainly encompasses pancreatic head cancer, periampullary carcinoma, and cholangiocarcinoma, among others[3]. If not timely intervened, DCBDO can lead to cholestasis,

cholangitis, biliary pancreatitis, and even liver failure, posing a severe threat to patient life[4]. Accurately differentiating benign from malignant DCBDO is a core step in clinical decision-making, directly influencing treatment strategy selection and patient prognosis[5]. Benign obstruction generally has a good prognosis after endoscopic or surgical intervention, whereas malignant obstruction requires a multidisciplinary team approach for staged treatment strategies, with a relatively low 5-year survival rate[6]. Misdiagnosis or delayed diagnosis may result in suppurative cholangitis in patients with benign obstruction or cause malignant obstruction patients to miss the optimal treatment window[7–9]. Therefore, exploring accurate, non-invasive differential diagnostic methods holds significant clinical value.

Currently, common diagnostic methods for DCBDO include Ultrasonography (US), Endoscopic Ultrasonography (EUS), Computed Tomography (CT), Percutaneous Transhepatic Cholangiography (PTC), Endoscopic Retrograde Cholangiopancreatography (ERCP), and Magnetic Resonance Cholangiopancreatography (MRCP)[10]. As an initial screening tool, US is non-invasive, economical, and convenient. However, it has limitations in clearly visualizing the distal common bile duct, especially due to intestinal gas and obesity, and its results are subject to operator dependency[11]. EUS offers high sensitivity for detecting minute lesions but is an invasive procedure, and its efficacy depends on the operator's experience[12]. CT is effective for evaluating the level of biliary obstruction and its etiology, with high detection sensitivity for tumors, pancreatic pathologies, and calcified stones. However, it has low sensitivity for radiolucent stones and carries risks of radiation exposure and contrast agent allergy[13]. PTC, being invasive and associated with complications such as bleeding, bile leakage, and infection, is now rarely used for diagnosis alone[14]. ERCP is the gold standard for diagnosing distal common bile duct obstruction and allows for simultaneous therapeutic intervention. Nevertheless, it carries risks of pancreatitis, bleeding, and perforation, is not suitable for high-risk patients, and requires advanced technical skill[15].

MRCP, as a non-invasive imaging technique, clearly displays the pancreatobiliary system using heavily T2-weighted sequences. It is free from ionizing radiation and contrast agent-related risks, and is not affected by intestinal gas, making it the preferred examination for biliary dilatation[16]. However, current research on differentiating benign from malignant obstruction based on MRCP primarily focuses on subjective morphological feature analysis, which is prone to significant interobserver variability and diagnostic difficulty in atypical presentations[17]. Although diagnostic approaches combining multi-modal MRI or artificial intelligence can improve accuracy, they are operationally complex and have limited clinical accessibility[7, 18]. Therefore, there is an urgent need to establish objective quantitative indices based on MRCP alone to simplify the diagnostic process. In light of the current challenges, such as "reliance on subjective morphological signs and a lack of standardized quantitative indices" and "the operational complexity and insufficient clinical validation of combined diagnostic methods," this study aims to systematically measure the diameters of the intrahepatic and extrahepatic bile ducts at key anatomical locations. The study will calculate and screen for the optimal diameter ratio to differentiate benign from malignant DCBDO and determine the best diagnostic cutoff value. By focusing on quantitative analysis of MRCP alone, without requiring additional examinations, this study seeks to fully

leverage the non-invasive advantages of MRCP. It aims to establish an objective "common bile duct to intrahepatic bile duct ratio" index to replace traditional subjective morphological judgments, identify the optimal combination of measurement sites, improve diagnostic accuracy and reproducibility, and facilitate widespread adoption in primary hospitals.

Materials and Methods

Study Subjects

A retrospective analysis was conducted on the clinical and imaging data of patients admitted to our hospital for "obstructive jaundice" who underwent MRCP examination between April 2020 and March 2025. Patients were classified into a benign obstruction group and a malignant obstruction group based on postoperative pathological results (Fig. 1). Inclusion criteria were: (1) having undergone preoperative MRCP examination; (2) not having received any treatment or surgery on the liver or biliary system prior to the MRCP examination; (3) having complete postoperative pathological results clearly defining the nature of the obstruction; and (4) having complete clinical records (including clinical history, laboratory tests, and imaging reports). Exclusion criteria were: (1) history of cholecystectomy; (2) concurrent intrahepatic bile duct diseases such as intrahepatic bile duct stones or intrahepatic cholangitis; (3) secondary intrahepatic bile duct dilatation caused by intrahepatic space-occupying lesions (such as hepatocellular carcinoma or liver metastases); (4) history of common bile duct or liver surgery; (5) concurrent common bile duct cyst; and (6) MRCP images with artifacts that affect observation.

Imaging Equipment and Scan Parameters

3D-MRCP scans were performed using a United Imaging UMR790 3.0T magnetic resonance imaging system. The scanning parameters were as follows: voxel size 1.54×1.16×2.40 mm, relative Signal-to-Noise Ratio (rSNR) 1.00, 35 slices, slice interpolation factor 2, slice thickness 2.40 mm, field of view (FOV) 352×352 mm, readout resolution 304, phase resolution 75, phase oversampling 8, slice oversampling 0, repetition time (TR) 1100 ms, echo time (TE) 255 ms, number of averages 1, and number of concatenations 1. Post-processing of the images employed Maximum Intensity Projection (MIP) to generate three-dimensional reconstructions of the pancreatobiliary system.

Bile Duct Diameter Measurement

The selection of measurement locations and the actual measurement of the diameters of intrahepatic and extrahepatic bile ducts were jointly performed by two diagnostic radiologists, each with over 5 years of experience. In cases of disagreement, a consensus was reached through discussion. Diameter measurements were performed by referring to both 3D-MRCP images and MRCP MIP images, with the 3D-MRCP images used for anatomical localization. Each site was measured three times, and the average value was taken as the final result. A schematic diagram of the measurement is shown in Fig. 2.

Common Bile Duct Measurement

Three key locations on the dilated common bile duct were selected for diameter measurement: the widest point (CW) of the dilated common bile duct, the start (CS), and the midpoint (CM) of the dilated segment (Fig. 2).

Intrahepatic Bile Duct

Intrahepatic Bile Duct Classification

Based on Couinaud's segmental anatomy, the intrahepatic bile ducts were classified into four orders: First-order ducts (P) are the left and right hepatic ducts (draining the left and right hemilivers), with a normal diameter of approximately 3–5 mm. Second-order ducts (S) are the lobar ducts (right anterior, right posterior, left medial, and left lateral hepatic ducts), with a diameter of about 2–3 mm. Third-order ducts (T) are the segmental ducts (corresponding to Couinaud's hepatic segments), with a diameter of about 1–2 mm. Fourth-order ducts (F) are subsegmental and interlobular ducts, with a diameter < 1 mm (subcapsular bile ducts, typically not visible on imaging). Under normal conditions, MRCP can evaluate up to third-order bile ducts.

Intrahepatic Bile Duct Diameter Measurement

For each order of intrahepatic bile ducts, the most dilated branch was selected for measurement. The measurement sites included: for first-order and second-order ducts, the widest point (PW, SW), the start (PS, SS), and the midpoint of the dilated segment (PM, SM) were measured. For third-order ducts, only the widest point (TW) was measured. For fourth-order ducts, if visualized, only the widest point (FW) was measured.

Ratio Calculation

Based on the above measurements, the following three categories of diameter ratios were calculated:

(1) Common bile duct to primary bile duct ratios: CW/PW, CW/PS, CW/PM; CS/PW, CS/PS, CS/PM; CM/PW, CM/PS, CM/PM.

(2) Common bile duct to second-order bile duct ratios: CW/SW, CW/SS, CW/SM; CS/SW, CS/SS, CS/SM; CM/SW, CM/SS, CM/SM.

(3) Common bile duct to third-order bile duct ratios: CW/TW, CS/TW, CM/TW (Fourth-order bile ducts were excluded from ratio calculation due to their low visualization rate).

Statistical Analysis

Statistical analysis was performed using SPSS 23.0 software. Continuous data are expressed as mean ± standard deviation ($\bar{x}\pm s$). Independent samples t-test was used to compare ratio differences between the benign and malignant groups. The diagnostic performance of each ratio was evaluated using Receiver Operating Characteristic (ROC) curve analysis, calculating the area under the curve (AUC) and 95% confidence interval (95% CI). The optimal diagnostic cutoff value was determined by combining the Youden index (Sensitivity + Specificity − 1). Categorical data are expressed as number (percentage), and intergroup comparisons were performed using the χ^2 test. $P < 0.05$ was considered statistically significant.

Results

Study Subjects

A total of 126 patients were included. Among them, 62 had benign obstruction, including 27 males and 35 females, with a mean age of 65 ± 17 years. Etiologies included common bile duct stones (n = 34, 55%), ampullary inflammation (n = 20, 32%), duodenal diverticulum (n = 5, 8%), pancreatitis (n = 1), suppurative cholangitis (n = 1), and pancreatic uncinate cystadenoma (n = 1). The malignant obstruction group consisted of 64 patients, including 31 males and 33 females, with a mean age of 66 ± 13 years. Pathologies comprised Vater's ampullary carcinoma (n = 54, 84%), pancreatic cancer (n = 9, 14%), and duodenal papillary neuroendocrine carcinoma (n = 1).

Measured Diameters of Bile Ducts

Common Bile Duct Diameters

The overall mean diameters for CW, CS, and CM of the common bile duct were 16.85 ± 5.43 mm, 14.68 ± 5.23 mm, and 13.77 ± 5.00 mm, respectively. The diameters at all measured sites in the malignant group were significantly greater than those in the benign group ($P < 0.05$). Detailed data are presented in Table 1.

Intrahepatic Bile Duct Diameters

(1) primary bile ducts: The overall mean diameters for PW, PS, and PM were 10.10 ± 4.67 mm, 9.17 ± 4.16 mm, and 8.18 ± 4.10 mm, respectively. All diameters were significantly greater in the malignant group compared to the benign group ($P < 0.05$) (Table 1).

(2) Second-order bile ducts: The overall mean diameters for SW, SS, and SM were 5.81 ± 3.64 mm, 5.56 ± 3.57 mm, and 4.67 ± 3.24 mm, respectively. All diameters were significantly greater in the malignant group compared to the benign group ($P < 0.05$) (Table 1).

(3) Third-order bile ducts: The overall mean diameter for TW was 2.95 ± 2.16 mm. The malignant group (4.33 ± 1.88 mm) had a significantly greater diameter than the benign group (1.53 ± 1.38 mm) ($P < 0.05$) (Table 1).

(4) Fourth-order bile ducts: Fourth-order ducts were visualized in 62 patients and not visualized in 64 patients. Specifically, they were visualized in 5 patients and not visualized in 57 patients in the benign group, and visualized in 57 patients and not visualized in 7 patients in the malignant group. The visualization rate of fourth-order bile ducts was significantly higher in the malignant group than in the benign group (Table 2).

Detailed data for the diameters of all bile duct orders are shown in Table 1 and Table 2.

Table 1
Comparison of intrahepatic and extrahepatic bile duct diameters

Measurement Site	Benign Group (n = 62)	Malignant Group (n = 64)	All Patients (n = 126)	P value
Common Bile Duct ($\bar{x}$±s, mm)				
CW	14.81 ± 4.52	18.83 ± 5.55	16.85 ± 5.43	<0.001
CS	12.69 ± 4.30	16.61 ± 5.36	14.68 ± 5.23	<0.001
CM	12.31 ± 4.14	15.19 ± 5.37	13.77 ± 5.00	0.001
Primary Bile Duct ($\bar{x}$±s, mm)				
PW	7.77 ± 3.73	12.34 ± 4.39	10.10 ± 4.67	<0.001
PS	7.00 ± 2.91	11.28 ± 4.12	9.17 ± 4.16	<0.001
PM	6.05 ± 3.19	10.25 ± 3.82	8.18 ± 4.10	<0.001
Second-Order Bile Duct ($\bar{x}$±s, mm)				
SW	3.42 ± 2.50	8.13 ± 3.03	5.81 ± 3.64	<0.001
SS	3.15 ± 2.38	7.89 ± 2.93	5.56 ± 3.57	<0.001
SM	2.56 ± 2.27	6.72 ± 2.70	4.67 ± 3.24	<0.001
Third-Order Bile Duct ($\bar{x}$±s, mm)				
TW	1.53 ± 1.38	4.33 ± 1.88	2.95 ± 2.16	<0.001

Abbreviations for Bile Duct Measurement Sites. CW: widest point of the common bile duct, CS: starting point of the common bile duct, CM: midpoint of the common bile duct, PW: widest point of the primary bile duct, PS: starting point of the primary bile duct, PM: midpoint of the primary bile duct, SW: widest point of the secondary bile duct, SS: starting point of the secondary bile duct, SM: midpoint of the secondary bile duct, TW: widest point of the tertiary bile duct

Table 2
Details of Fourth-Order Bile Duct Visualization (Cases)

Visualized	Benign	Malignant	Total
	5 (8%)	**57 (89%)**	**62**
Not Visualized	57 (92%)	7 (11%)	64
Total	62	64	126

In the benign group, fourth-order bile ducts were visualized in 8% (5/62) of cases and not visualized in 92% (57/62) of cases. In the malignant group, fourth-order bile ducts were visualized in 89% (57/64) of cases and not visualized in 11% (7/64) of cases

Results of Bile Duct Diameter Ratios

Common Bile Duct / Primary Bile duct Ratios

Among all ratios comparing the common bile duct to primary bile duct at various measurement sites, the benign group demonstrated significantly higher values than the malignant group ($P < 0.05$). Detailed data are presented in Table 3.

Table 3 Common Bile Duct / Primary Bile Duct Ratios

	Benign Group (n = 62)	Malignant Group (n = 64)	All Patients (n = 126)	P value
CW ($\bar{x}\pm s$)				
CW/PW	2.18 ± 0.95	1.60 ± 0.40	1.89 ± 0.78	<0.001
CW/PS	2.42 ± 1.09	1.79 ± 0.61	2.10 ± 0.93	<0.001
CW/PM	2.92 ± 1.43	1.97 ± 0.55	2.43 ± 1.17	<0.001
CS ($\bar{x}\pm s$)				
CS/PW	1.82 ± 0.68	1.40 ± 0.33	1.60 ± 0.57	<0.001
CS/PS	2.01 ± 0.77	1.54 ± 0.40	1.77 ± 0.65	<0.001
CS/PM	2.42 ± 1.04	1.72 ± 0.47	2.06 ± 0.87	<0.001
CM ($\bar{x}\pm s$)				
CM/PW	1.79 ± 0.79	1.28 ± 0.36	1.53 ± 0.66	<0.001
CM/PS	1.99 ± 0.91	1.43 ± 0.55	1.70 ± 0.80	<0.001
CM/PM	2.38 ± 1.13	1.57 ± 0.47	1.97 ± 0.95	<0.001

Ratios of common bile duct diameter at the widest point (CW), start (CS), and midpoint (CM) to the diameter of the primary bile duct at the widest point (PW), start (PS), and midpoint (PM), respectively

Common Bile Duct / Second-Order Bile Duct Ratios

In all ratios comparing the common bile duct to second-order bile ducts at different measurement sites, the values in the benign group were significantly higher than those in the malignant group ($P < 0.05$). Specific data are shown in Table 4.

Table 4 Common Bile Duct / Second-Order Bile Duct Ratios

	Benign Group (n = 62)	Malignant Group (n = 64)	All Patients (n = 126)	P value
CW ($\bar{x}\pm s$)				
CW/SW	5.30 ± 2.30	2.49 ± 0.70	3.87 ± 2.20	<0.001
CW/SS	5.80 ± 2.34	2.57 ± 0.73	4.16 ± 2.36	<0.001
CW/SM	7.89 ± 4.01	3.07 ± 0.98	5.44 ± 3.80	<0.001
CS ($\bar{x}\pm s$)				
CS/SW	4.44 ± 1.89	2.18 ± 0.64	3.29 ± 1.80	<0.001
CS/SS	4.89 ± 1.99	2.24 ± 0.63	3.54 ± 1.97	<0.001
CS/SM	6.60 ± 3.32	2.70 ± 0.93	4.62 ± 3.11	<0.001
CM ($\bar{x}\pm s$)				
CM/SW	4.37 ± 1.95	1.98 ± 0.57	3.16 ± 1.86	<0.001
CM/SS	4.77 ± 1.94	2.04 ± 0.62	3.39 ± 1.97	<0.001
CM/SM	6.48 ± 3.35	2.44 ± 0.76	4.43 ± 3.15	<0.001

Ratios of common bile duct diameter at the widest point (CW), start (CS), and midpoint (CM) to the diameter of the second-order bile duct at the widest point (SW), start (SS), and midpoint (SM), respectively

Common Bile Duct / Third-Order Bile Duct Ratios

Among the ratios comparing the common bile duct to the third-order bile duct, all values in the benign group were significantly higher than those in the malignant group ($P < 0.05$). Specific data are shown in Table 5.

Table 5 Common Bile Duct / Third-Order Bile Duct Ratios

	Benign Group (n = 62)	Malignant Group (n = 64)	All Patients (n = 126)	P value
CW ($\bar{x}\pm s$)				
TW	12.42 ± 5.02	5.00 ± 2.15	8.65 ± 5.33	<0.001
CS ($\bar{x}\pm s$)				
TW	10.46 ± 4.08	4.31 ± 1.68	7.34 ± 4.37	<0.001
CM ($\bar{x}\pm s$)				
TW	10.22 ± 4.22	3.96 ± 1.59	7.04 ± 4.45	<0.001

Ratios of common bile duct diameter at the widest point (CW), start (CS), and midpoint (CM) to the diameter of the third-order bile duct at the widest point (TW), respectively

ROC Curve Analysis Results

ROC curve analysis revealed that all measured ratios possessed diagnostic value (AUC > 0.700, P < 0.001 for all). Among them, the CM/TW ratio demonstrated the best diagnostic performance, with an AUC of 0.922 (95% CI: 0.869–0.974). The optimal diagnostic cutoff value, determined by the maximum Youden index (0.745), was 6.75. At this cutoff, the sensitivity was 82.3% and the specificity was 92.2%. Details are presented in Table 6 and Fig. 3.

Table 6
Comparison of AUC Values for Each Diameter Ratio in Diagnosing Malignant Biliary Obstruction

Test Result Variables	AUC	SE	P value	95% CI
CW/PW	0.704	0.047	<0.001	0.612–0.796
CW/PS	0.702	0.047	<0.001	0.610–0.795
CW/PM	0.732	0.045	<0.001	0.643–0.820
CW/SW	0.897	0.031	<0.001	0.836–0.959
CW/SS	0.903	0.031	<0.001	0.843–0.964
CW/SM	0.896	0.032	<0.001	0.832–0.959
CW/TW	0.902	0.030	<0.001	0.842–0.961
CS/PW	0.701	0.047	<0.001	0.608–0.793
CS/PS	0.702	0.047	<0.001	0.609–0.795
CS/PM	0.732	0.045	<0.001	0.645–0.820
CS/SW	0.903	0.029	<0.001	0.847–0.959
CS/SS	0.910	0.028	<0.001	0.855–0.966
CS/SM	0.897	0.030	<0.001	0.838–0.955
CS/TW	0.911	0.028	<0.001	0.857–0.966
CM/PW	0.738	0.045	<0.001	0.649–0.826
CM/PS	0.737	0.045	<0.001	0.649–0.825
CM/PM	0.766	0.043	<0.001	0.681–0.850
CM/SW	0.905	0.030	<0.001	0.847–0.963
CM/SS	0.917	0.029	<0.001	0.861–0.973
CM/SM	0.907	0.030	<0.001	0.848–0.966
CM/TW	0.922	0.027	<0.001	0.869–0.974

Among all the ratios, the CM/TW ratio (common bile duct midpoint diameter / third-order bile duct widest point diameter) achieved the highest AUC value of 0.922 (95% CI: 0.869–0.974), demonstrating the best diagnostic performance

Discussion

This study found that all common bile duct to intrahepatic bile duct diameter ratios were significantly higher in the benign obstruction group compared to the malignant obstruction group, which aligns with the morphological findings of Kumar et al[19] on biliary dilatation. Benign obstructions (e.g., common

bile duct stones) are often intermittent and incomplete. Since stones do not infiltrate the duct wall, bile stasis initially leads to compensatory dilation of the common bile duct (to overcome the obstruction), while the intrahepatic ducts, buffered by the proximal biliary tree, exhibit milder and more localized dilation, primarily in the first- and second-order ducts. Consequently, the ratios are higher, consistent with the results of Patel et al[20]. In contrast, malignant obstructions (e.g., ampullary carcinoma) typically present as progressive, complete strictures. Tumor cells infiltrate along the bile duct wall, causing rigidity and uniform narrowing of the lumen, leading to persistent and worsening obstruction[21]. This not only causes common bile duct dilation but also affects the peripheral intrahepatic ducts (third- and fourth-order), resulting in a "diffuse and balanced dilation" pattern where the intrahepatic and common bile duct dilations are more proportional, leading to lower ratios. The high visualization rate of fourth-order bile ducts in the malignant group (89.1%) in this study further supports this mechanism, aligning with findings from Chryssou et al[22] in MRCP studies of malignant biliary tumors.

ROC curve analysis revealed that the CM/TW ratio (common bile duct midpoint to third-order bile duct widest point diameter ratio) had the best diagnostic performance (AUC = 0.922). The advantage of the CM/TW ratio stems from the anatomical and functional specificity of its measurement sites: The common bile duct midpoint (CM) is close to the obstruction site, sensitively reflecting early pressure changes in the biliary tract[23]. Its location is well-defined, ensuring strong measurement reproducibility. The third-order bile duct (TW) is a segmental duct, belonging to the peripheral intrahepatic biliary system. Its degree of dilation directly reflects the extent of obstruction involvement. Malignant obstructions, due to continuous compression or infiltration, readily cause peripheral duct dilation, whereas benign obstructions have minimal impact on these ducts [24]. Combining these two measurements quantifies the difference between "central extrahepatic dilation" and "peripheral intrahepatic dilation," maximizing the differentiation efficiency between benign and malignant obstructions.

In clinical practice, the interpretation rule for the CM/TW ratio is straightforward: a ratio > 6.75 suggests benign obstruction, while a ratio < 6.75 suggests malignant obstruction. For instance, a high CM/TW ratio (e.g., 8.5) can increase diagnostic confidence in favor of a benign obstruction. Conversely, a low CM/TW ratio (e.g., 4.2) strongly indicates malignancy, warranting further diagnostic procedures such as Endoscopic Ultrasound (EUS) fine-needle aspiration biopsy for confirmation. This study establishes an objective "common bile duct to intrahepatic bile duct ratio" index, replacing traditional subjective morphological assessments and reducing reliance on operator experience. Moreover, its application has a low technical barrier, requiring only standard MRCP images and basic measurement tools, which facilitates its adoption in primary care hospitals.

This study indicates that the fourth-order bile duct dilation rate in the benign obstruction group was 8% (5/62), while the non-dilation rate in the malignant obstruction group was 11% (7/64). This suggests that relying solely on the presence or absence of fourth-order bile duct dilation for distinguishing benign from malignant obstruction lacks objectivity and reliability. Research by Lopes et al[25] suggests that benign conditions such as suppurative cholangitis and sclerosing cholangitis can cause fourth-order bile duct

dilation, and their definitive diagnosis requires integration with other imaging features. Trivedi et al[26] found that primary sclerosing cholangitis, due to diffuse inflammatory and fibrotic changes in the bile duct walls, can lead to intrahepatic fourth-order bile duct dilation, and emphasized that MRCP is a reliable imaging method for evaluating such lesions. Therefore, fourth-order bile duct dilation is not a specific sign of malignant obstruction. In imaging assessment, judgment on the nature of distal common bile duct obstruction should not rely exclusively on this single sign.

The CM/TW ratio proposed in this study demonstrates high diagnostic performance, with an AUC of 0.922, indicating strong discriminatory capability. It is also simple and quick to perform and calculate, requiring no complex equipment or time-consuming processes, achieving a good balance between diagnostic accuracy and clinical utility.

This study has the following limitations: It is a single-center, retrospective study with a relatively limited sample size (126 cases), which may introduce selection bias. Future multicenter, large-scale prospective studies are needed to validate the conclusions. Clinical indicators (such as duration of jaundice, tumor marker CA19-9 levels) and other imaging features were not included. A combined "imaging + laboratory" model could be constructed in the future to further enhance diagnostic accuracy. Inter-observer agreement was not analyzed. Subsequent research could evaluate measurement reproducibility using the Intraclass Correlation Coefficient (ICC).

Conclusion

Bile duct diameter ratio measurement based on MRCP is an effective, non-invasive method for differentiating benign from malignant distal common bile duct obstruction. Among the ratios, the diameter ratio of the common bile duct midpoint to the widest point of the third-order bile duct (CM/TW) is the optimal quantitative indicator, with a cutoff value of 6.75 demonstrating excellent diagnostic performance (AUC = 0.922, sensitivity 82.3%, specificity 92.2%). This index is simple to perform, yields objective results, and can serve as a reliable imaging basis for clinical decision-making. It is particularly suitable for patients with contraindications or high risks for ERCP, contributing to optimized diagnostic and treatment workflows and improved patient outcomes.

Abbreviations

MRCP
Magnetic Resonance Cholangiopancreatography
DCBDO
Distal Common Bile Duct Obstruction
US
Ultrasonography
EUS
Endoscopic Ultrasonography

CT
Computed Tomography
PTC
Percutaneous Transhepatic Cholangiography
ERCP
Endoscopic Retrograde Cholangiopancreatography
ROC
Receiver Operating Characteristic
AUC
Area Under the Curve
CI
Confidence Interval

Declarations

Ethics Approval and Consent to Participate

This retrospective study was approved by the Medical Ethics Committee of Chongqing Yubei District People's Hospital. Due to the retrospective nature of the study and the use of anonymized data, the Ethics Committee waived the requirement for informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Authors' contributions

J.L., W.M and Y.F. conceived and designed the study. Y.W., Yan H and D.D. collected and analyzed the clinical data. Yu.H., D.D. and R.T. performed the MRCP imaging analysis and interpreted the results. J.L.,

W.M and Y.F. drafted the initial manuscript and coordinated the writing process. All authors reviewed, edited, and approved the final version of the manuscript.

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Figures

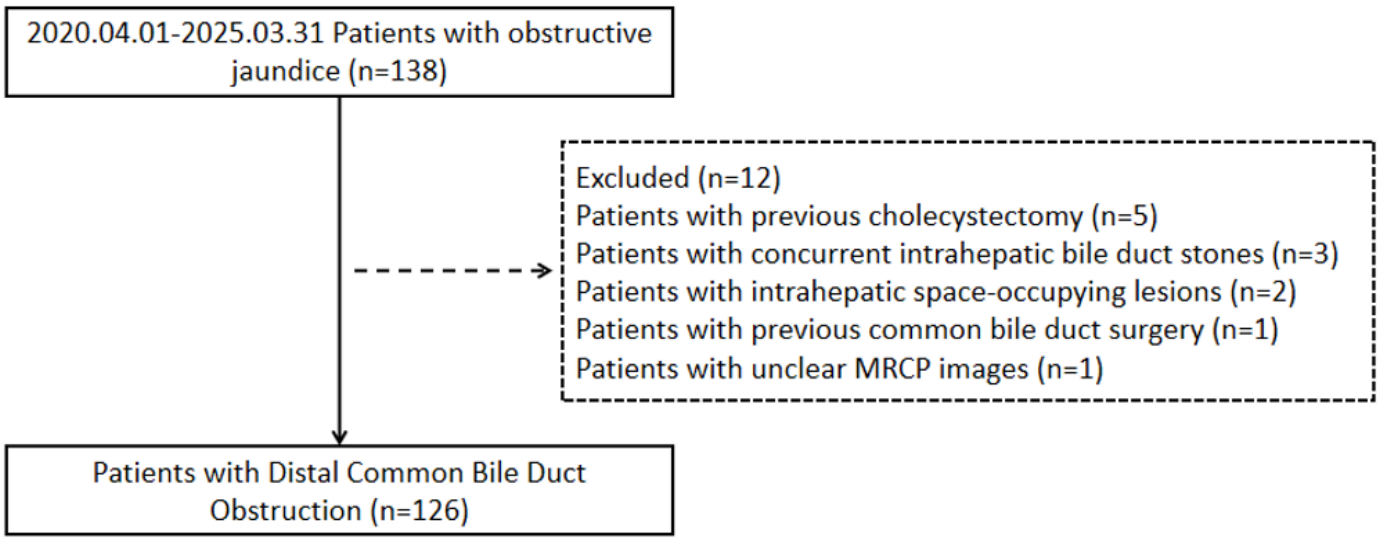


Figure 1

Flowchart of Study Subject Screening

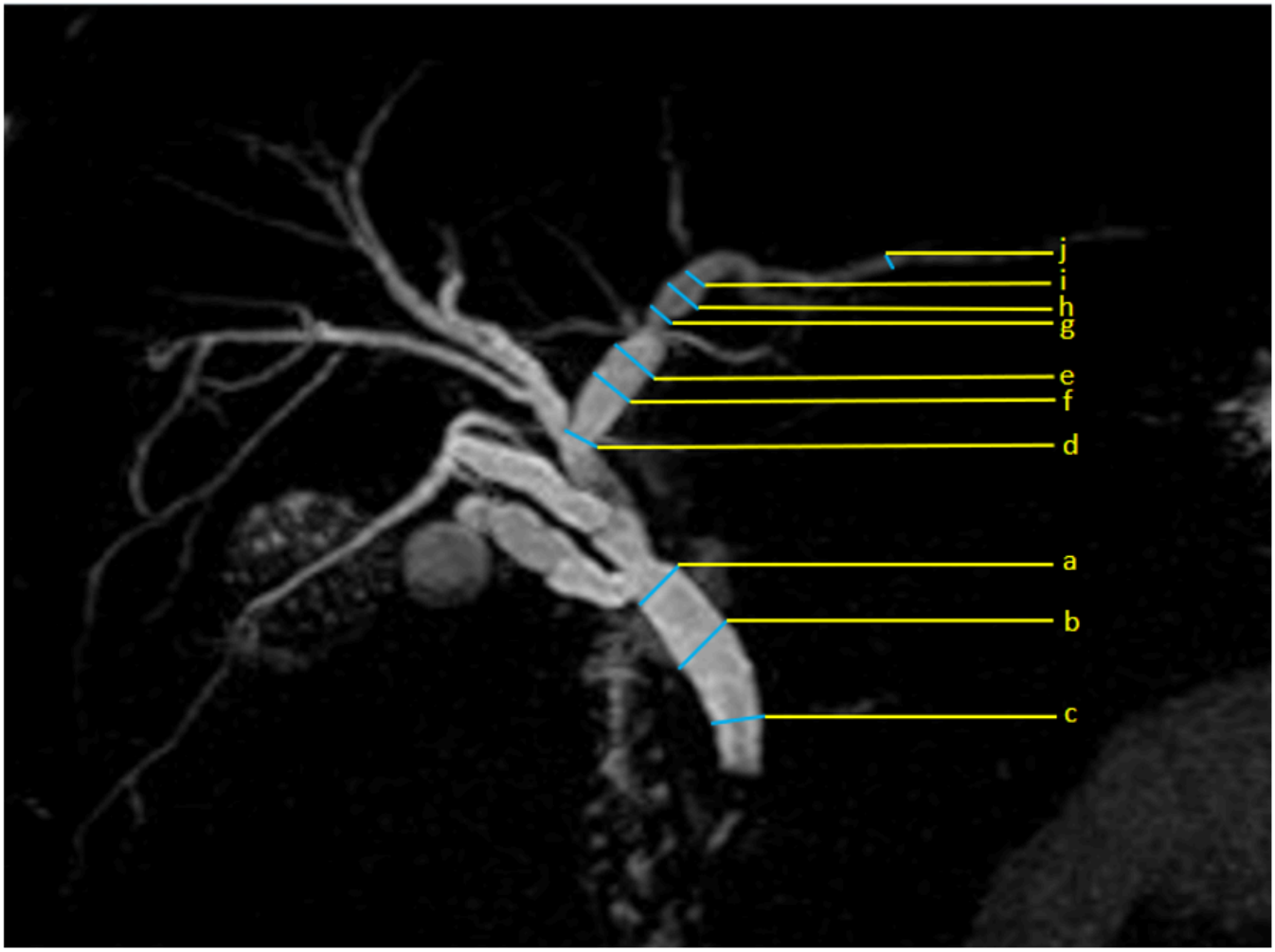


Figure 2

Schematic diagram of the measurement sites for the extrahepatic and intrahepatic bile ducts.a. Start of the common bile duct, b. Widest point of the common bile duct, c. Midpoint of the common bile duct, d. Start of the primary bile duct, e. Widest point of the primary bile duct, f. Midpoint of the primary bile duct, g. Start of the second-order bile duct, h. Widest point of the second-order bile duct, i. Midpoint of the second-order bile duct, j. Widest point of the third-order bile duct.

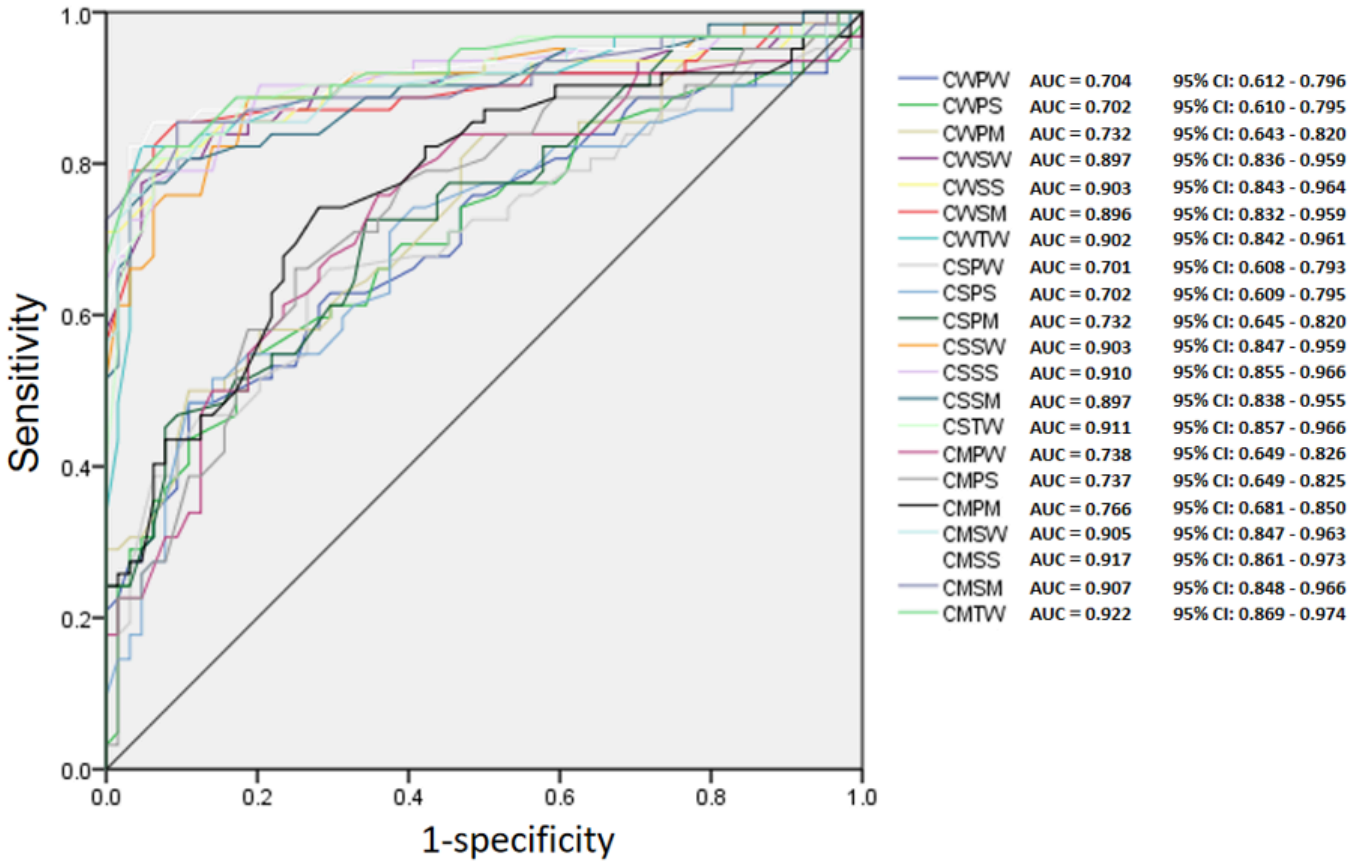


Figure 3

ROC Curves of Various Diameter Ratios for Diagnosing Malignant Biliary Obstruction