ORIGINAL ARTICLE

Added Value of Diffusion-Weighted Imaging to Magnetic Resonance Cholangiopancreatography for The Diagnosis of Bile Duct Obstruction

Sami T. A. Eliba [a,*], Osama L. Elabd [a], Mohamed S. Elwarraky [a], Hassan E. Zaghla [b], Hazem M. Omr [a]

[a] Department of Diagnostic and Interventional Radiology, National Liver Institute-Menoufia University, Menoufia, Egypt
[b] Department of Hepatology and Gastroenterology, National Liver Institute-Menoufia University, Menoufia, Egypt

Abstract

Background: ***Magnetic resonance cholangiopancreatography (MRCP) has evolved over the past decades to evaluate the biliary tract and diagnose pancreato-biliary disease. Diffusion-weighted imaging (DWI) is an auxiliary method utilized to assess the molecular functionality and micro-architecture of the body of a human.***

Objectives: ***To evaluate the supplementary benefit of DWI to magnetic resonance cholangiopancreatography (MRCP) for diagnosing bile duct obstruction, whether malignant or benign.***

Patients and methods: ***This research was performed on 100 cases of obstructive jaundice who underwent MRCP between January 2022 and May 2023. Cases have been recruited from the Radiology Department, National Liver Institute, Menoufia University.***

Results: ***According to the ADC value of malignant bile duct obstruction, the mean of ADC value was 1.34 ± 0.20, and the median was 1.35 (1.25 – 1.44). According to diffusion restrictions a statistically significant variance was observed among examined groups regarding diffusion restriction, which was positive and negative. Regarding the final diagnosis method, a statistically significant variance has been observed among examined groups regarding CNB, MRCP + Clinical picture and medical history, and ERCP.***

Conclusion: ***The use of diffusion-weighted imaging in conventional MRCP significantly enhanced the diagnostic precision in distinguishing between malignant and benign biliary strictures.***

Keywords: MRCP; bile duct obstruction; DWI

1. Introduction

MRCP has advanced in recent decades for the assessment and diagnosis of pancreatic-biliary disorders.[1] The clinical indications for conducting magnetic resonance cholangiopancreatography involve disorders of the gallbladder, liver, pancreas, bile ducts, and porta hepatis. Potential causes can involve stones, tumors, infection, or inflammation. [2]

Diffusion-weighted imaging (DWI), a technique for signal production predicated on variations in Brownian motion, serves as an extra instrument for assessing the molecular function and micro-architecture of the human body.[3] The diffusion-weighted imaging signal can be measured using apparent diffusion coefficient maps, serving as an instrument for evaluating various lesions. [4] Diffusion-weighted imaging can enhance morphological data acquired by standard magnetic resonance cholangiopancreatography by providing supplementary functional insights into tissue cellularity and cell membrane integrity.[5] Additionally, diffusion-weighted imaging may serve as a viable alternate method for evaluating the biliopancreatic tract when there are contraindications to contrast agents, such as renal insufficiency or contrast allergy.[6]

Accepted 06 January 2025.
Available online 31 January 2025

* Corresponding author at: Diagnostic and Interventional Radiology, National Liver Institute-Menoufia University, Menoufia, Egypt.
E-mail address: Samieliba5@gmail.com (S. T. A. Eliba).

https://doi.org/10.21608/aimj.2025.446470

The clinical applications of diffusion-weighted imaging for assessing bile duct dilation involve the following groups.[7] Complications associated with gallstones, including acute cholangitis, the most observed benign inflammatory lesion, and hepatic abscesses. Lesions of the gallbladder, including gallbladder empyema, cholecystitis, and gallbladder cancer.[8] intra-hepatic biliary lesions; the most prevalent case is intra-hepatic Cholangiocarcinoma, which arises from second-order or more distal peripheral branches of the intra-hepatic bile duct. [9] extra-hepatic biliary lesions; around two-thirds of extra-hepatic bile duct carcinoma occur at the hepatic hilum (termed hilar Cholangiocarcinoma or Klatskin tumor), while roughly one-third arise from the distal common bile duct. [10]

The aim of this research was to evaluate the supplementary benefit of DWI to magnetic resonance cholangiopancreatography (MRCP) for diagnosing bile duct obstruction, whether malignant or benign.

2. Patients and methods

This research has been performed on 100 cases with obstructive jaundice underwent MRCP in the period between January 2022 and May 2023. Cases have been recruited from the Radiology Department, National Liver Institute, Menoufia University.

Approval of the study protocol has been obtained by the Ethical Scientific Committee of the National Liver Institute; Menoufia University was obtained.

Inclusion criteria:

Patients with bile duct dilatation due to obstruction, either benign causes (like cholangitis, cholecystitis, and gallbladder empyema) or malignant causes (like gallbladder carcinoma, Intra-hepatic Cholangiocarcinoma or hilar Cholangiocarcinoma [Klatskin tumor]).

Exclusion criteria:

Metallic medical prothesis: Implantable neurostimulation systems, Cardiac implantable electronic device (CIED), Cochlear implants/ear implants, Drug infusion pumps (analgesic medications, chemotherapy pumps, or insulin delivery) & Catheters with metallic components (Swan-Ganz catheter) & Metallic fragments (like metal shrapnel, shotgun pellets, and bullets) & Cerebral artery aneurysm clips & Artificial limb & Magnetic dental implants & Hearing aid and claustrophobia.

Methods:

All cases in the research have been exposed to the following: Full history taking, clinical examinations, laboratory investigations: Serum bilirubin (Total and direct), Complete blood count (CBC), Liver function profile, Tumor markers, C-reactive protein (CRP) & erythrocyte sedimentation rate (ESR) and radiological investigations: Abdominal and pelvic ultrasonography & Magnetic resonance cholangiopancreatography (MRCP)

MR imaging protocol:

Cases underwent examination using a 3-T superconducting MRI system (1.5T; GE Healthcare) equipped with an 8US phased-array surface coil. The technique comprised T2-weighted sequence, heavy T2-weighted sequence, T2 with fat saturation sequence, three-dimensional (3D) thin-section MRCP, and DWI sequence. An apparent diffusion coefficient (ADC) map has been computed utilizing a mono-exponential function with b values of zero and one thousand square millimeters per second.

Findings that were detected by the examination:

Caliber and course of the biliary tree and pancreatic duct, presence or absence of stones, strictures, and/or mass lesions, assessment of liver, pancreas, duodenum, and abdominal lymph nodes (if present) and assessment of the obstructive lesion: Site & size (in maximum dimensions) & Presence or absence of restricted diffusion (for masses).

3. Results

According to demographic data between benign and malignant bile duct obstruction, a statistically significant has been observed among examined groups regarding gender and age (Table 1).

Table 1. Comparative analysis among benign and malignant bile duct obstruction according to demographic data

DEMOGRAPHIC DATA	TYPE OF BILE DUCT OBSTRUCTION				TEST OF SIG.	P
	Benign (n = 50)		Malignant (n = 50)			
	No.	%	No.	%		
GENDER						
MALE	19	38.0	29	58.0	x^2= 4.006*	0.045*
FEMALE	31	62.0	21	42.0		
AGE (YEARS)						
MIN. – MAX.	22.0 – 72.0		39.0 – 85.0		t= 5.140*	<0.001*
MEAN ± SD.	48.58 ± 12.72		59.80 ± 8.74			
MEDIAN (IQR)	49.0 (38.0 – 58.0)		60.0 (54.0 – 64.0)			

IQR: Inter quartile range, SD: Standard deviation, $\chi 2$: Chi square test, t: Student t-test, p: p value for comparing between Benign and Malignant bile duct obstruction, *: Statistically significant at $p \le 0.05$

According to serum bilirubin level, a statistically significant has been observed among examined groups regarding total serum bilirubin level and direct serum bilirubin level (Table 2)

Table 2. Comparative analysis among benign and malignant bile duct obstruction according to serum bilirubin level

SERUM BILIRUBIN LEVEL (MG/DL)	TYPE OF BILE DUCT OBSTRUCTION		T	P
	Benign (n = 50)	Malignant (n = 50)		
TOTAL				
MIN. – MAX.	4.90 – 14.0	5.90 – 24.30	10.983*	<0.001*
MEAN ± SD.	7.86 ± 2.0	13.96 ± 3.37		
MEDIAN (IQR)	7.75 (6.30 – 8.80)	13.6 (12.7 – 15.6)		
DIRECT				
MIN. – MAX.	4.0 – 12.80	4.20 – 22.10	9.964*	<0.001*
MEAN ± SD.	6.98 ± 1.94	12.49 ± 3.39		
MEDIAN (IQR)	7.0 (5.50 – 7.60)	12.1 (10.6 – 14.2)		

Regarding to etiology of benign bile duct obstruction, 78% of patients had stone, 10.3% had intra-hepatic stones, 56.4 % had extra-hepatic stones and33.3 had combined intra- and extra-hepatic stones. 22%of patients had Stricture, 81.8%had iatrogenic stricture, 9.1% had post inflammatory stricture, 9.1% had previous bile duct stone passage (Table 3).

Table 3. Distribution of the examined cases regarding etiology of benign bile duct obstruction (n = 50)

ETIOLOGY	NO.	%
STONE	39	78.0
INTRA-HEPATIC STONES	4	10.3
EXTRA-HEPATIC STONES	22	56.4
COMBINED INTRA- AND EXTRA-HEPATIC STONES	13	33.3
STRICTURE	11	22.0
IATROGENIC STRICTURE	9	81.8
POST INFLAMMATORY STRICTURE	1	9.1
PREVIOUS BILE DUCT STONE PASSAGE	1	9.1

According to pathological type of the lesion of malignant bile duct obstruction, the most pathological type of the lesion was Cholangiocarcinoma represented 32%, Pancreatic cancer18% divided into 16% pancreatic head carcinoma, 2% pancreatic head metastasis, Hepatocellular carcinoma (HCC) was 2%, Liver metastasis was 14%, Duodenal cancer was 4%, Gall bladder cancer was 6%, Porta-hepatis malignant lymph nodes was 14%, Mixed types of cancers was 10% (Table 4)

Table 4. Distribution of the examined cases according to pathological type of the lesion of malignant bile duct obstruction (n = 50)

PATHOLOGICAL TYPE OF THE LESION	NO.	%	ADC VALUE (×10⁻³ MM²/S)
CHOLANGIOCARCINOMA	16	32.0	1.27 ± 0.20
PANCREATIC CANCER	9	18.0	1.14 ± 0.19
PANCREATIC HEAD CARCINOMA	8	16.0	–
PANCREATIC HEAD METASTASIS	1	2.0	–
HEPATOCELLULAR CARCINOMA (HCC)	1	2.0	1.11
LIVER METASTASIS	7	14.0	1.31 ± 0.24
DUODENAL CANCER	2	4.0	1.20 ± 0.02
GALL BLADDER CANCER	3	6.0	1.27 ± 0.11
PORTA-HEPATIS MALIGNANT LYMPH NODES	7	14.0	1.23 ± 0.21
MIXED TYPES OF CANCERS	5	10.0	1.28 ± 0.12
PANCREATIC NEOPLASM + HEPATIC NEOPLASM	2	4.0	–
HCC + PORTA-HEPATIS LYMPH NODES	3	6.0	–

According to anatomical level of the obstruction of malignant bile duct obstruction, 20% was parenchymal, 22% was Hilar, 58% was Distal CBD obstruction (Table 5)

Table 5. Distribution of the examined cases regarding anatomical level of the obstruction of malignant bile duct obstruction (n = 50)

ANATOMICAL LEVEL OF THE OBSTRUCTION	NO.	%
PARENCHYMAL	10	20.0
HILAR	11	22.0
DISTAL CBD OBSTRUCTION	29	58.0

According to diffusion restriction, a statistically significant variation has been observed among examined groups regarding Diffusion restriction positive and negative (Table 6).

Table 6. Comparative analysis among benign and malignant bile duct obstruction according to diffusion restriction

DIFFUSION RESTRICTION	TYPE OF BILE DUCT OBSTRUCTION				χ^2	P
	Benign (n = 50)		Malignant (n = 50)			
	No.	%	No.	%		
NEGATIVE	50	100.0	0	0.0	100.0*	<0.001*
POSITIVE	0	0.0	50	100.0		

χ2: Chi square test, p: p value for comparing between Benign and Malignant bile duct obstruction, *: Statistically significant at p ≤ 0.05

According to ADC value of malignant bile duct obstruction, the mean of ADC value was 1.34 ± 0.20 and median was 1.35 (1.25 – 1.44) (Table 7)

Table 7. Descriptive analysis of the examined cases regarding ADC value of malignant bile duct obstruction (n = 50)

	MIN. – MAX.	MEAN ± SD.	MEDIAN (IQR)
ADC VALUE ($\times 10^{-3}$ MM²/S)	0.94 – 1.94	1.34 ± 0.20	1.35 (1.25 – 1.44)

Regarding the method final diagnosis, a statistically significant variation has been observed among examined group regarding CNB, MRCP + Clinical picture & Medical history and ERCP (Table 8)

Table 8. Comparative analysis among malignant and benign bile duct obstruction regarding the method final diagnosis

FINAL DIAGNOSIS	TYPE OF BILE DUCT OBSTRUCTION: Benign (n = 50)		Malignant (n = 50)		χ^2	P
	No.	%	No.	%		
CNB	–	–	25	50.0	–	–
MRCP + CLINICAL PICTURE & MEDICAL HISTORY	18	36.0	50	100.0	47.059*	<0.001*
ERCP	50	100.0	27	54.0	29.870*	<0.001*

4. Discussion

Demographic data indicated a statistically significant variation has been observed among malignant and benign bile duct obstruction for age and gender.

In accordance with Yoo et al.[11] who aimed to evaluate the efficacy of involving DWI in conventional MRCP for the differentiation of benign and malignant distal biliary strictures, their research involved sixty cases with suspected distal biliary strictures. The possibility of malignancy was assessed by two independent reviewers who analyzed 3 image sets: 1) magnetic resonance cholangiopancreatography alone; 2) magnetic resonance cholangiopancreatography combined with DWI; and 3) MRCP, DWI, and contrast-enhanced T1-weighted imaging (T1WI) combined. They discovered a statistically significant variation in age and gender observed among the examined groups.

According to serum bilirubin level, our results demonstrated that a statistically significant has been observed among examined groups regarding total serum bilirubin level and direct serum bilirubin level.

In accordance with Saluja et al.,[12] revealed that total bilirubin (mg/dl) was 8.6±8.8 and 17.4±9.1, respectively, with p value 0.001. This revealed that statistical significance was observed among examined groups regarding total serum bilirubin level. Malignant tumors often cause total blockage, resulting in elevated bilirubin concentrations in these cases.

Regarding to etiology of benign bile duct obstruction, our results demonstrated that 78% of patients had stone, 10.3% had intra-hepatic stones, 56.4 % had extra-hepatic stones and33.3 had combined intra- and extra-hepatic stones. 22%of patients had StrictureStricture, 81.8%had iatrogenic StrictureStricture, 9.1% had post inflammatory StrictureStricture, and 9.1% had previous bile duct stone passage.

Kim et al.[13] showed that cases with benign strictures had bile duct or gallbladder stones (number = thirteen), while malignant strictures were much thicker (5.0 ± 2.0 millimeters) and longer (27.0 ± 13.6 millimeters) compared to benign strictures.

According to pathological type of the lesion of malignant bile duct obstruction, our results found that the most pathological type of the lesion was Cholangiocarcinoma represented 32%, Pancreatic cancer18% divided into 16% pancreatic head carcinoma, 2% pancreatic head metastasis, Hepatocellular carcinoma (HCC) was 2%, Liver metastasis was 14%, Duodenal cancer was 4%, Gall bladder cancer was 6%, Porta-hepatis malignant lymph nodes was 14%, Mixed types of cancers was 10%.

Rabie et al.[14] identified the following malignant conditions: hepatic and extra-hepatic Cholangiocarcinoma, pancreatic adenocarcinoma, gallbladder cancer, pathological lymph nodes infiltrating the common bile duct, peri-ampullary carcinoma, infiltrative hepatocellular carcinoma, and hepatic deposits exhibiting biliary invasion.

According to the anatomical level of the obstruction of malignant bile duct obstruction, our results demonstrated that 20% was parenchymal, 22% was Hilar, and 58% was Distal CBD obstruction.

According to Yoo et al.,[11] malignant strictures comprised ampulla of Vater adenocarcinomas (number = twenty-one), distal CBD carcinomas (number = eighteen), and peribiliary metastasis from progressed stomach cancer. The identification of a case with peribiliary metastases from advanced gastric cancer has been validated by the malignant cell's detection of the aspirated bile. A definitive diagnosis in a case with hepatic lesions and malignant ampulla of Vater stricture has been established using ultrasound-guided core-needle biopsy of the hepatic metastases.

Our results indicated a statistically significant distinction among the examined groups concerning diffusion restriction, both positive and negative.

Rabie et al.[14] demonstrated that positive diffusion restriction was significantly greater in malignant lesions than in benign lesions, with a p-value less than 0.001.

According to ADC value of malignant bile duct obstruction, our results showed that mean of ADC value was 1.34 ± 0.20 and median was 1.35 (1.25 – 1.44).

Girometti et al.[15] aimed to compare the accuracy of DWI visual analysis (VA) and apparent diffusion coefficient quantification (ADC-Q) in evaluating the malignancy of solid focal liver lesions (FLLs). They reported mean ADC values of 0.87±0.25 (range 0.45–1.26) for metastases and 1.19±0.38 for hepatocellular carcinoma (range 0.67–2.16).

Regarding the final diagnosis method, our results demonstrated that there was statistically significant variance among studied groups regarding CNB, MRCP + Clinical picture and medical history, and ERCP.

Tsai et al.[16] aimed to evaluate the supplementary benefit of DWI in conjunction with conventional T2WI and MRCP for the identification of bile duct dilatations. The incorporation of DWI with T2-weighted magnetic resonance and MR cholangiopancreatography sequences greatly enhances sensitivity and diagnostic accuracy in the assessment of bile duct dilatations, especially malignant ones.

In contrast to Garcea et al.,[17] indicated that a statistically insignificant distinction had been observed among the examined groups concerning MR cholangiopancreatography, with a p-value of 0.96.

4. Conclusion

Adding diffusion weighted imaging into standard MR cholangiopancreatography significantly enhanced the diagnostic precision for distinguishing among malignant and benign biliary strictures.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

References

1. Rahman SU, Dar RA, Wani BA, Dar SA. Role of magnetic resonance cholangiopancreatography in conjunction with 3D assessment in patients of different billiary obstruction causes. International Surgery Journal. 2022 Feb 28;9(3):627-33.
2. Boyd LNC, Ali M, Kam L, Puik JR, Rodrigues SM, Zwart ES, et al. The Diagnostic Value of the CA19-9 and Bilirubin Ratio in Patients with Pancreatic Cancer, Distal Bile Duct Cancer and Benign Periampullary Diseases, a Novel Approach. Cancers (Basel). 2022;14(2):344.
3. Shin DW, Moon SH, Kim JH. Diagnosis of Cholangiocarcinoma. Diagnostics (Basel). 2023;13(2):233.
4. Kierans AS, Costello J, Qayyum A, Taouli B, Venkatesh SK, Yoon JH, et al. Imaging cholangiocarcinoma: CT and MRI techniques. Abdom Radiol (NY).
5. Singhi AD, Nikiforova MN, Chennat J, Papachristou GI, Khalid A, Rabinovitz M et al. Integrating next-generation sequencing to endoscopic retrograde cholangiopancreatography (ERCP)-obtained biliary specimens improves the detection and management of patients with malignant bile duct strictures. Gut. 2020;69(1):52-61.
6. Zhang Y, Jiang Q, Wang Q, Feng Y, Wu D, Guo T et al. Predicting Malignancy of Biliary Stricture with a Nomogram in Patients with a Non-Malignant Endoscopic Tissue Diagnosis: A Retrospective Study. Cancer Manag Res. 2021;13:7735-7745.
7. Yildirim O, Erdogan MA. Predictive factors in the differential diagnosis of benign and malignant causes in patients undergoing endoscopic retrograde cholangiopancreatography for extrahepatic cholestasis. Eur Rev Med Pharmacol Sci. 2023;27(23):11457-11463.
8. Zhu K, Yang J, Chen YZ, Zhang XR, Yu XH, Wang J, et al. Differences in Clinical Features and Diagnostic Strategies Between IgG4-Related Autoimmune Cholangitis and Cholangiocarcinoma. Front Oncol. 2021; 11:540904.
9. Sumiyoshi T, Uemura K, Shintakuya R, Okada K, Baba K, Harada T, et al. Clinical Utility of the Combined Use of CA19-9 and DUPAN-2 in Pancreatic Adenocarcinoma. Ann Surg Oncol. 2024;31(7):4665-4672.
10. Thompson SM, Marcano-Bonilla L, Mounajjed T, Kipp BR, Heimbach JK, Hallemeier CL, et al. Cholangiocarcinoma. Evaluation and Management of Liver Masses. 2020:31-61.
11. Yoo RE, Lee JM, Yoon JH, Kim JH, Han JK, Choi BI. Differential diagnosis of benign and malignant distal biliary strictures: value of adding diffusion-weighted imaging to conventional magnetic resonance cholangiopancreatography. J Magn Reson Imaging. 2014;39(6):1509-1517.
12. Saluja SS, Sharma R, Pal S, Sahni P, Chattopadhyay TK. Differentiation between benign and malignant hilar obstructions using laboratory and radiological investigations: a prospective study. HPB (Oxford). 2007;9(5):373-382.
13. Kim JY, Lee JM, Han JK, Kim SH, Lee JY, Choi JY et al. Contrast-enhanced MRI combined with MR cholangiopancreatography for the evaluation of patients with biliary strictures: differentiation of malignant from benign bile duct strictures. J Magn Reson Imaging. 2007;26(2):304-312
14. Rabie S, Mohallel A, Bessa SS, Hafez A, El-Abd AM. The role of combined diffusion weighted imaging and magnetic resonance cholangiopancreatography in the differential diagnosis of obstructive biliary disorders. Egyptian Journal of Radiology and Nuclear Medicine. 2021 Dec; 52:1-3. https://doi.org/10.1186/s43055-021-00501-5
15. Girometti R, Del Pin M, Pullini S, Cereser L, Como G, Bazzocchi M et al. Accuracy of visual analysis vs. apparent diffusion coefficient quantification in differentiating solid benign and malignant focal liver lesions with diffusion-weighted imaging. Radiol Med. 2013;118(3):343-355.
16. Tsai TH, Hsu JS, Lai ML, Liu GC, Shih MC, Chen CY. Added value of diffusion-weighted imaging to MR cholangiopancreatography for the diagnosis of bile duct dilatations. Abdom Radiol (NY). 2016;41(3):485-492.
17. Garcea G, Ngu W, Neal CP, Dennison AR, Berry DP. Bilirubin levels predict malignancy in patients with obstructive jaundice. HPB (Oxford). 2011;13(6):426-430.