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The Synergistic Role of Integrated Computed Tomography and Magnetic Resonance Cholangiopancreatography in Disorders of the Pancreatobiliary System

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Abstract

Objective The aim of the study was to evaluate the synergistic role and advantages of integrating noncontrast computed tomography (NCCT) and magnetic resonance cholangiopancreatography (MRCP) in disorders of the pancreatobiliary (PB) system.

Methods In this cross-sectional and retrospective record-based study, radiological (NCCT and MRCP) data were collected retrospectively for a period of 3 years (June 2018–August 2020) from 52 patients. The results were compared to the final diagnosis on endoscopic retrograde cholangiopancreatography (ERCP) findings (gold standard). The data collected were analyzed by measuring the sensitivity, specificity, positive predictive value, negative predictive value, diagnostic accuracy, and *p*-value for NCCT, MRCP, and integrated NCCT plus MRCP at different cutoff points. Subsequently, a receiver operating characteristic (ROC) curve was plotted to analyze different thresholds for NCCT, MRCP, and integrated NCCT plus MRCP.

Results The most common pathologies identified were biliary dilations (18.4%), common bile duct (CBD) calculi (13.6%), and biliary strictures (12.0%). Overall, MRCP provided a higher percentage of correct diagnoses (81.6%) compared to CT (56.0%). Integrating NCCT with MRCP showed a significant increase in sensitivities and specificities when compared to NCCT or MRCP alone. Integrated NCCT plus MRCP showed excellent performance with an area under the curve (AUC) of ROC analysis of 0.937.

Conclusion Our study showed that integrating NCCT and MRCP can prove to be an excellent tool in establishing a detailed diagnosis of PB disorders, better than either NCCT or MRCP alone. Due to the concurrent nature of PB disorders, it may be worth considering integrating NCCT and MRCP, given that there is an absence of contra-indications to either modality.

Keywords
- MRCP
- NCCT
- pancreatobiliary
- synergistic

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Introduction

Diagnosis and intervention of pancreatobiliary (PB) diseases remain a challenge even in the present age of growing advancements in both imaging and surgical interventions due to the complex anatomy of the PB system and the invasive nature of PB diseases.[1–3] It often becomes the role of the radiologist to facilitate an early and accurate diagnosis by selecting an appropriate imaging modality and determining the level, nature, and etiology of the PB disease, allowing the physician/surgeon to provide the patient with the best-suited intervention.[4] Although ultrasound (US) remains a common screening modality for the initial evaluation of PB diseases, it fails to provide the true extent and cause of the disease.[1,4,5] Detailed evaluation of PB diseases has thus been attributed to endoscopic retrograde cholangiopancreatography (ERCP) for a long time now. However, being an invasive procedure, ERCP has a reported complication rate of 3 to 9% and a mortality rate of 0.2 to 0.5%. Thus, in the majority of cases, ERCP is currently exclusively used as a therapeutic procedure rather than as a diagnostic procedure.[4,6,7] A multimodality imaging approach is often required for a definite diagnosis of PB disorders.[8] Recent advancements in both magnetic resonance imaging (MRI) and computed tomography (CT) have shown added benefits of a detailed depiction of the biliary tree with a large field of view, high-resolution imaging, and three-dimensional (3D) data sets. Furthermore, CT and magnetic resonance cholangiopancreatography (MRCP), being noninvasive procedures, are much less likely to cause discomfort, injury, or complications to the patient.[6] This has contributed significantly to preoperative evaluation, planning for PB interventions, and postoperative evaluation of suspected complications.[1]

MRI including MRCP can be a valuable component to CT when additional information is required in evaluating PB diseases.[9] In this study, we aim to evaluate the advantages and pitfalls for both noncontrast CT (NCCT) and MRCP in the evaluation of PB systems and pathologies and the synergistic role that integration of NCCT plus MRCP may have in the evaluation of PB disorders when compared to ERCP as the gold standard.

Methodology

This is an institutional-based retrospective record-based study conducted by the Departments of Radiodiagnosis & Imaging, and Gastroenterology, Kasturba Medical College, MAHE, Mangalore, Karnataka, India. After receiving approval from the institutional ethics committee, radiology data were collected after taking the required permissions from the heads of departments. Study participants included cases who underwent MRI (MRCP) and plain NCCT of the abdomen in the same session (or within a gap of 48 hours) for evaluation of PB disorders. Cases, where imaging was restricted severely with motion artefacts, were excluded from the study.

The data were collected retrospectively for a period of 3 years (June 2018–August 2020) by the method of convenient sampling from 52 patients. The results were compared to the final diagnosis on ERCP findings (taken as the gold standard) and on discharge summaries. Each patient was essentially analyzed for the presence or absence of 10 different pathologies including acute pancreatitis, chronic (calcific) pancreatitis, periampullary diverticulum, cholangitis, common bile duct (CBD) calculi (choledocholithiasis), gallbladder (GB) calculi (cholecystolithiasis), biliary strictures, biliary dilations, biliary sludge, and malignancies. For example, if a patient was found to have chronic pancreatitis and a biliary stricture on ERCP, this was considered a positive finding, whereas it was considered a negative finding for other pathologies such as acute pancreatitis, cholangitis, choledocholithiasis, etc. The imaging findings of both NCCT and MRCP were assigned scores ranging from 0 to 4 (0 = not visualized; 1 = poorly visualized; 2 = visualized; 3 = well visualized; and 4 = diagnostic). The data collected were analyzed by measuring the sensitivity (SN %), specificity (SP %), positive predictive value (PPV %), negative predictive value (NPV %), diagnostic accuracy (DA %), and *p*-value for NCCT (vs. ERCP), MRCP (vs. ERCP), and integrated NCCT plus MRCP (vs. ERCP) at different cutoff points (cutoffs at score $\geq$1, $\geq$2, $\geq$3, and at 4) for PB diseases. Subsequently, a receiver operating characteristic (ROC) curve was plotted with true-positive (TP) rate (sensitivity) and false-positive (FP) rate (1-specificity) for NCCT, MRCP, and integrated NCCT plus MRCP. Each point on the ROC represented a sensitivity/specificity pair corresponding to a particular decision threshold. The statistical data were entered and analyzed using the SPSS software, version 26, for Windows (IBM Corporation, IL, United States) and Microsoft Excel for Windows (Microsoft 365 Personal).

Results

The majority of the patients were in the fifth to seventh decades of life with a mean age of 55.01 years and a standard deviation of 18.21 years (55.01 $\pm$ 18.21 years). The youngest patient encountered was 23 years old and the oldest patient encountered was 89 years old. The majority of the patients in this study were males (62%; compared to females at 38%). The male-to-female ratio was 1.6:1. For more details regarding the demography of the patients in this study, kindly refer to ►**Table 1**.

The most common pathologies identified were biliary dilations (18.4%), CBD calculi (13.6%), and biliary strictures (12.0%). Benign pathologies vastly outnumbered the malignant pathologies, with benign pathologies amounting to approximately 90% and malignant pathologies amounting to approximately 10% of the findings. It was observed that overall MRCP provided a higher percentage of correct diagnosis (81.6%) compared to NCCT (56.0%). For more details regarding the distribution of pathologies among patients, kindly refer to ►**Table 2**.

As shown in ►**Tables 3** and **4**, both NCCT and MRCP showed high specificity ranging from 87.59 to 97.97% at all cutoff score values; however, compared to MRCP, NCCT showed significantly low sensitivities at cutoff scores $\geq$1

Table 1 Demography of patients

Demography ($n = 52$)		
	Number	Percentage
Age (y)		
21–30	9	17
31–40	5	10
41–50	5	10
51–60	9	17
61–70	14	27
71–80	8	15
>80	2	4
Total	52	100
Gender		
Male	32	62
Female	20	38
Total	52	100

(81.60 vs. 56.00%), ≥2 (76.00 vs. 54.40%), and ≥3 (52.80 vs. 48.00%). At the cutoff score of 4, both NCCT and MRCP showed a low sensitivity of 24.8%. MRCP also displayed a higher diagnostic accuracy (DA %) at all cutoff scores. At cutoff scores of ≥3 and 4, NCCT displayed a high statistical significance ($p < 0.001$) when compared to ERCP as the gold standard. However, at cutoff scores of ≥1 and ≥2, NCCT displayed no statistical significance when compared to ERCP as the gold standard ($p = 0.426$ at cutoff ≥1 and $p = 0.159$ at cutoff ≥ 2). Similarly, at a cutoff score of ≥2, MRCP displayed no statistical significance when compared to ERCP as the gold standard ($p = 0.336$). However, high statistical significance was observed for MRCP when compared to ERCP at cutoff scores of ≥1 ($p = 0.003$), ≥3 ($p < 0.001$), and 4 ($p < 0.001$). For further details regarding NCCT and MRCP as diagnostic tests when compared to ERCP as the gold standard, refer to ►**Tables 3** and **4**, respectively.

As shown in ►**Table 5**, the integration of NCCT plus MRCP imaging showed a significant improvement in both sensitivity and specificity when compared to NCCT or MRCP alone at all cutoff scores. When ERCP (gold standard) was compared to the integrated NCCT plus MRCP imaging, high statistical significance was observed at all cutoff scores ($p = 0.001$ at cutoff ≥2, and $p < 0.001$ at cutoff scores of ≥1, ≥3, and 4). The cutoff score at ≥2 for the integrated NCCT plus MRCP showed the best sensitivity–specificity pair, with a sensitivity of 88.8% and specificity of 90.38% ($p = 0.001$). The integrated NCCT plus MRCP also showed a high DA% at all cutoff scores ranging from 83.1 to 90.0%.

►**Fig. 1** shows that the ROC curve for MRCP is better than that for NCCT in the diagnosis of PB disorders, with the MRCP curve displaying an area under the curve (AUC) of 0.859 (compared to the AUC of NCCT curve of 0.734). However, the integrated NCCT plus MRCP curve shows a significantly higher AUC of 0.942. ►**Table 6** shows a detailed analysis of the ROC curves and their AUCs as analyzed using SPSS version 26 for Windows.

Discussion

PB disorders represent a vast spectrum of diseases affecting the pancreatic and biliary system and may be associated with similar presentations such as obstructive jaundice.[10,11] The conditions can include but are not limited to pancreatitis (acute/chronic), pancreatic diverticulum, gallstones, acute cholecystitis (calculous/acalculous), chronic cholecystitis, Mirizzi's syndrome, cholangitis, pancreatic and biliary tract malignancies, etc.[12] As was the case with our study, multiple PB pathologies are often present concurrently; for example, in patients with advanced chronic pancreatitis, biliary tract obstruction is often present. Patients with chronic pancreatitis are also at a higher risk of malignancy.[13,14] Due to the

Table 2 Distribution of PB pathologies with the percentage of correct diagnosis for NCCT and MRCP among patients

Pathology	No. of times encountered, *n* (%)	NCCT diagnosis		MRCP diagnosis	
		Correct	Percentage	Correct	Percentage
Acute pancreatitis	10 (8.00)	4	40.00	10	100.00
Chronic (calcific) pancreatitis	11 (8.80)	11	100.00	5	45.45
Periampullary diverticulum	5 (4.00)	5	100.00	2	40.00
Biliary dilations	23 (18.40)	6	26.09	22	95.65
Biliary strictures	15 (12.00)	5	33.33	13	86.67
CBD calculi	17 (13.60)	7	41.18	14	82.35
GB calculi	12 (9.60)	7	58.33	12	100.00
Cholangitis	12 (9.60)	12	100.00	5	41.67
Biliary sludge	7 (5.60)	4	57.14	7	100.00
Malignancies	13 (10.40)	9	69.23	12	92.31
Total	125 (100)	70	56.00	102	81.60

Abbreviations: CBD, common bile duct; GB, gallbladder; MRCP, magnetic resonance cholangiopancreatography; NCCT, noncontrast-enhanced computed tomography; PB, pancreatobiliary.

Table 3 Sensitivity (SN %), specificity (SP %), positive predictive value (PPV %), negative predictive value (NPV %), diagnostic accuracy (DA %), and *p*-value for different score cutoffs of NCCT in the diagnosis of PB disorders

NCCT				
Measure	**Cutoff ≥ 1**	**Cutoff ≥ 2**	**Cutoff ≥ 3**	**Cutoff at 4**
SN % (95% CI)	56.0 (46.8–64.9)	54.4 (45.3–63.3)	48.0 (39.0–57.1)	24.8 (17.5–33.3)
SP % (95% CI)	88.4 (84.8–91.4)	89.4 (85.9–92.2)	94.4 (91.7–96.5)	97.2 (95.1–98.6)
PPV % (95% CI)	60.3 (52.7–67.5)	61.8 (53.9–69.2)	73.2 (63.6–81.0)	73.8 (59.4–84.5)
NPV % (95% CI)	86.4 (83.9–88.6)	86.1 (83.6–88.3)	85.2 (82.9–87.2)	80.3 (78.7–81.9)
DA % (95% CI)	80.6 (76.9–83.9)	81.0 (77.3–84.3)	83.3 (79.8–86.4)	79.8 (76.1–83.2)
p-value	0.426	0.159	<0.001	<0.001

Abbreviations: MRCP, magnetic resonance cholangiopancreatography; NCCT, noncontrast-enhanced computed tomography; PB, pancreatobiliary.

Table 4 Sensitivity (SN %), specificity (SP %), positive predictive value (PPV %), negative predictive value (NPV %), diagnostic accuracy (DA %), and *p*-value for different score cutoffs of MRCP in the diagnosis of PB disorders

MRCP				
Measure	**Cutoff ≥ 1**	**Cutoff ≥ 2**	**Cutoff ≥ 3**	**Cutoff at 4**
SN % (95% CI)	81.6 (73.6–88.0)	76.0 (67.5–83.2)	52.8 (43.7–61.8)	24.8 (17.5–33.3)
SP % (95% CI)	87.6 (83.9–90.7)	90.1 (86.8–92.9)	94.4 (91.7–96.5)	98.0 (96.1–99.1)
PPV % (95% CI)	67.6 (61.3–73.3)	70.9 (64.0–76.9)	75.0 (65.9–82.3)	79.5 (64.7–89.1)
NPV % (95% CI)	93.8 (91.2–95.6)	92.2 (89.7–94.2)	86.3 (84.0–88.4)	80.5 (78.8–82.0)
DA % (95% CI)	86.2 (82.9–89.0)	86.7 (83.5–89.5)	84.4 (81.0–87.4)	80.4 (76.7–83.7)
p-value	0.003	0.336	<0.001	<0.001

Abbreviations: MRCP, magnetic resonance cholangiopancreatography; NCCT, noncontrast-enhanced computed tomography; PB, pancreatobiliary.

Table 5 Sensitivity (SN %), specificity (SP %), positive predictive value (PPV %), negative predictive value (NPV %), diagnostic accuracy (DA %), and *p*-value for different score cutoffs of integrated NCCT plus MRCP in the diagnosis of PB disorders

NCCT + MRCP				
Measure	**Cutoff ≥ 1**	**Cutoff ≥ 2**	**Cutoff ≥ 3**	**Cutoff at 4**
SN % (95% CI)	96.0 (90.0–98.7)	88.8 (81.9–93.7)	62.4 (53.3–70.9)	32.8 (24.7–41.8)
SP % (95% CI)	85.1 (81.2–88.4)	90.4 (87.0–93.1)	96.5 (94.1–98.1)	99.0 (97.4–99.7)
PPV % (95% CI)	67.0 (61.6–72.1)	74.5 (68.2–79.9)	84.8 (76.6–90.5)	91.1 (78.9–96.6)
NPV % (95% CI)	98.5 (96.6–99.4)	96.2 (94.0–97.7)	89.0 (86.6–91.1)	82.3 (80.5–84.0)
DA % (95% CI)	87.7 (84.6–90.4)	90.0 (87.1–92.4)	88.3 (85.2–91.0)	83.1 (79.6–86.2)
p value	< 0.001	0.001	<0.001	<0.001

Abbreviations: MRCP, magnetic resonance cholangiopancreatography; NCCT, noncontrast-enhanced computed tomography; PB, pancreatobiliary.

complex and varied nature of biliary anatomy, it is important to correctly identify and diagnose patients presenting with biliary symptoms to avoid any operative or postoperative complications. The main aim of any imaging modality should be to identify the presence of any obstruction(s), its location, extent, and also any potential etiology.[15] In our study, it was observed that NCCT was able to identify all cases (100%) of chronic (calcific) pancreatitis and periampullary diverticulum. NCCT was better able to diagnose chronic pancreatitis due to better visualization of pancreatic calcifications as compared to MRCP.[16] However, MRCP was better able to identify all other pathologies. MRCP showed especially high accuracy in diagnosing obstructive pathologies such as biliary dilations and strictures, choledocholithiasis (CBD calculi), cholecystolithiasis (GB calculi), biliary sludge, malignancies, and acute pancreatitis.

MRCP is generally considered the first-line imaging modality for PB disorders (especially in evaluating obstructive biliary pathologies). The primary advantage of MRCP over NCCT is that it provides a detailed anatomical picture of the

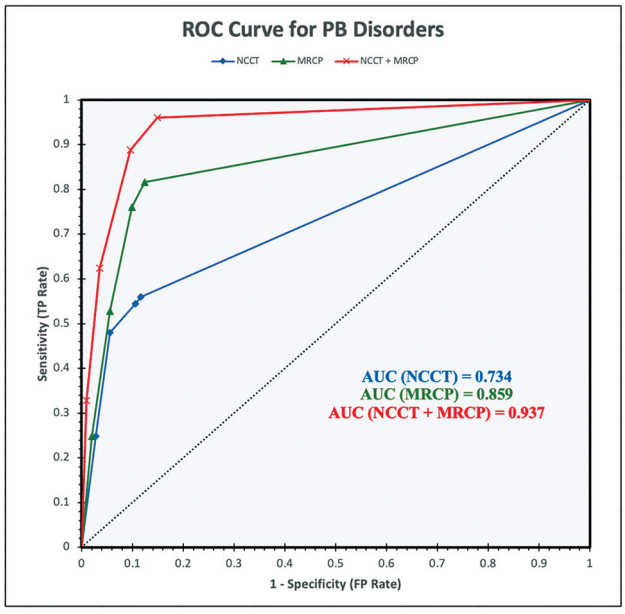

Fig. 1 Receiver operating characteristic (ROC) curve for NCCT, MRCP, and integrated NCCT plus MRCP in the diagnosis of PB disorders. AUC, area under the curve; FP, false positive; MRCP, magnetic resonance cholangiopancreatography; NCCT, noncontrast computed tomography; PB, pancreatobiliary; TP, true positive.

PB system by providing high contrast of extrahepatic bile ducts and information on the pancreatic duct. The high spatial and contrast resolution of MRCP also aids in providing preoperative information regarding the spread (intra- and/or extra-biliary) of possible malignant strictures.[1] Albeit MRCP enables noninvasive, rapid, and high-resolution evaluation of the PB system without the use of contrast agents or the risk of radiation exposure, there are certain limitations that come with the usage of MRCP. MRI scans are prone to artefacts and pseudolesions that may mimic obstructive biliary pathologies or choledocholithiasis (e.g., pseudo-obstruction of the extrahepatic bile duct due to artefact from arterial pulsatile compression).[1,17] Additionally, patient-based artefacts such as inadequate breath-holding or the presence of excess ascites may also be potential sources of limitations of MRCP and should be recognized.[1] NCCT scans hold the advantage of better identification and visualization of calcifications (e.g., pancreatic calcifications in advanced chronic pancreatitis).[16] ►**Fig. 2** shows a case where a diagnosis of chronic calcific pancreatitis was missed on MRCP but was identified on NCCT by visualizing multiple intraparenchymal calcifications in the pancreatic head. However, the main limitation of conducting an NCCT scan is the risk of radiation exposure. Other diagnostic limitations of conducting an NCCT scan for patients with PB disorders are the poor visualization or characterization of conditions such as biliary strictures, GB sludge, and small pancreatic masses.

In our study, it was seen that NCCT alone had lower sensitivity and specificity at different cutoff thresholds when compared to MRCP alone. Upon plotting the ROC curve (►**Fig. 1**) for NCCT alone and MRCP alone in the diagnosis of PB disorders, it was found that NCCT had an AUC of 0.734 (95% CI: 0.677–0.792), whereas MRCP had an AUC of 0.859 (95% CI: 0.816–0.903). The rule regarding AUC in an ROC curve states that an AUC equal to 0.5 suggests no discrimination (ability to diagnose patients with and without the disease), $0.5 < \text{AUC} < 0.7$ suggests poor discrimination, $0.7 \leq \text{AUC} < 0.8$ suggests acceptable discrimination, $0.8 \leq \text{AUC} < 0.9$ suggests excellent discrimination, and $\text{AUC} \geq 0.9$ suggests outstanding discrimination.[18,19] This rule allowed us to label NCCT alone as an acceptable imaging modality and MRCP alone as an excellent imaging modality in the diagnosis of PB disorders. However, when NCCT and MRCP were integrated, their synergistic effect in the diagnosis of PB disorders was significantly higher than either imaging modality alone. When combined, NCCT plus MRCP showed an AUC of 0.942 (95% CI: 0.918–0.967). The significantly higher AUC (≥ 0.9) for integrated NCCT plus MRCP allows us to label the integration of these imaging modalities as an outstanding investigation in the diagnosis of PB disorders.

Conclusion

A multimodality imaging approach toward the evaluation of PB disorders is often necessary. US is used as the initial screening modality but fails to provide adequate information to establish a definitive diagnosis. Although MRCP is generally considered a first-line imaging modality for the evaluation of PB disorders due to its detailed depiction of PB anatomy and high accuracy in visualizing obstructive pathologies, NCCT has proven to be a better modality in diagnosing chronic pancreatitis (due to better visualization of calcifications) and periampullary diverticulum. Our study showed that integrating NCCT and MRCP can prove to be an excellent tool in establishing a detailed diagnosis of PB disorders, better than either NCCT or MRCP alone. Due to the concurrent nature of PB disorders, it may be worth considering

Table 6 ROC curve analysis with AUCs and their 95% confidence interval

Curve	AUC	Standard error	95% confidence interval	
			Lower bound	Upper bound
NCCT	0.734	0.029	0.677	0.792
MRCP	0.859	0.022	0.816	0.903
NCCT + MRCP	0.937	0.013	0.911	0.963

Abbreviations: AUC, area under the curve; MRCP, magnetic resonance cholangiopancreatography; NCCT, noncontrast-enhanced computed tomography; ROC, receiver operating curve.

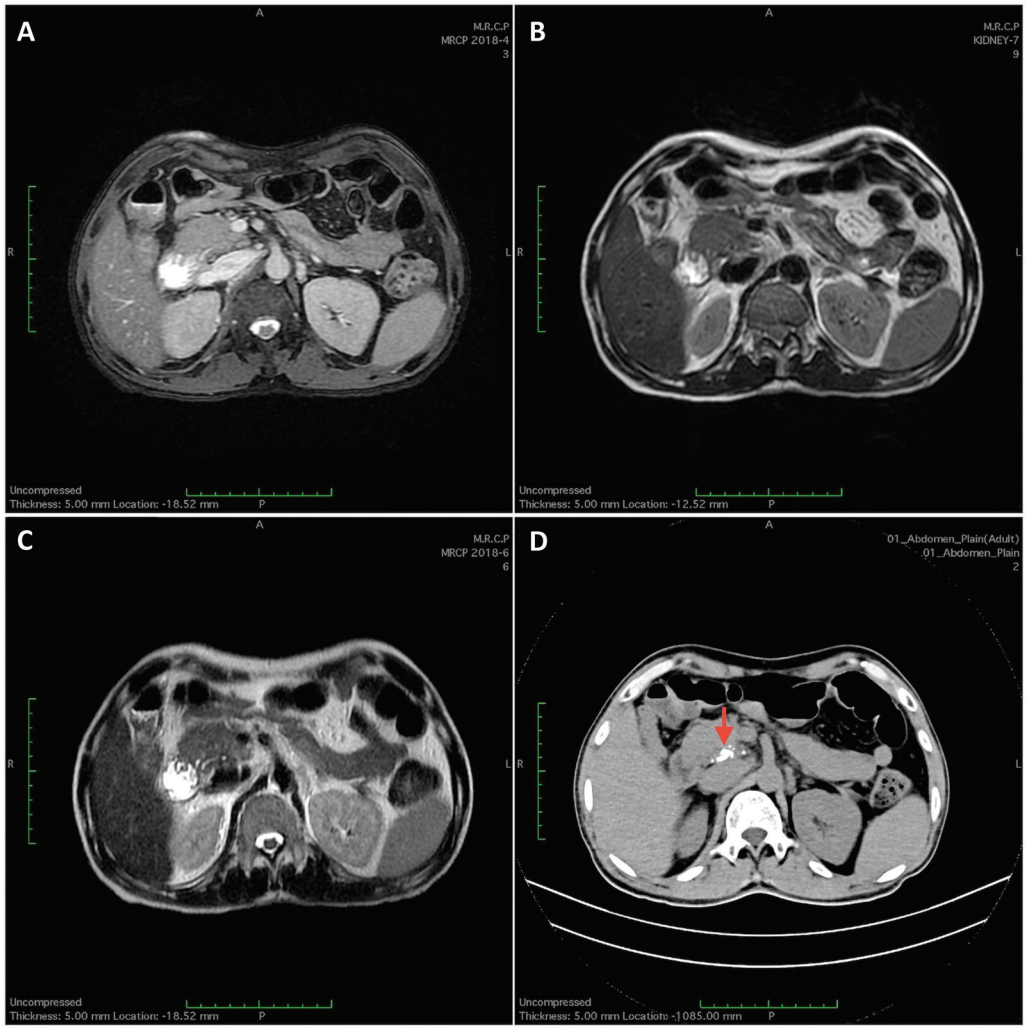

Fig. 2 (**A**) Axial magnetic resonance (MR) two-dimensional (2D) fast imaging employing steady-state acquisition (FIESTA). (**B**) Axial T2-weighted (T2W) fast recovery fast spin echo (FRFSE) sequence and (**C**) axial T2W single-shot fast spin-echo sequence (SSFSE) showing mild bulky head of the pancreas, atrophic proximal body and tail, dilated main pancreatic duct (4.3 mm) with prominent side branches, and mild peripancreatic fat stranding. (**D**) Correlation with noncontrast computed tomography (NCCT) showed multiple intraparenchymal calcifications in the pancreatic head (*red arrow*) suggestive of chronic calcific pancreatitis.

integrating NCCT and MRCP, given that there is an absence of contraindications to either modality.

Recommendation

From the results of our study, we recommend that MRCP performed for PB disorders should be accompanied by NCCT of the abdomen to effectively identify pathologies such as chronic calcific pancreatitis that might be missed on MRCP alone. MRCP accompanied by NCCT produces a synergistic diagnostic effect.

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Conflict of Interest
None declared.

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