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ORIGINAL ARTICLE

Magnetic resonance cholangiopancreatography (MRCP) evaluation of post-laparoscopic cholecystectomy biliary complications using breath-held 3D steady state free precession (SSFP) sequence

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KEYWORDS

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Abstract *Purpose:* To assess the role of breath-held 3D-SSFP MRCP in evaluation of post-laparoscopic cholecystectomy biliary complications.
Patients and methods: This study included 29 patients with post-laparoscopic cholecystectomy symptoms like abdominal pain, vomiting or jaundice during period from March 2013 to March 2015. The ages of patients ranged from 28 to 70 years (mean 49 ± 16 year). MRCP was performed for all patients on 1.5 tesla MRI machine with breath-held multi-slice acquisition. Both 2D and 3D MRCP were done.
Results: The encountered post laparoscopic biliary complications were either major injuries like complete bile duct transection in 8 cases and bile duct ligation in 4 cases or minor injuries like partial thermal tear in 4 cases, slipped clips in 2 cases and benign strictures in 5 cases. The retained biliary stones were another complication and located either intrahepatic in 2 cases or extra-hepatic in 4 cases. 13 cases were managed by ERCP with sphincterotomy, dilatation and/or T-tube insertion. Other 13 patients were managed operatively with removal of ligature or hepaticojujenostomy and the remaining 3 patients were managed conservatively.
Conclusion: The use of breath-held 3D-SSFP MRCP is essential in evaluation of post-laparoscopic cholecystectomy biliary complications and in planning for management regimens.
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1. Introduction

Iatrogenic bile duct injury is a catastrophe associated with significant morbidity, mortality, adverse quality of life and high rates of litigation (1). As laparoscopic cholecystectomy is now considered the gold standard treatment for symptomatic gallstones, higher rates of bile duct injury and other biliary complications like bile leak have been reported in the laparoscopic era (2).

Bile duct injury rates after laparoscopic cholecystectomy have been reported to range from 0.2% to 7% compared to 0.2–0.4% after open cholecystectomy (3,4). Postoperative bile duct injuries include the presence of leak, stricture, or complete transection and excision of a segment of duct, with or without obstruction of the proximal biliary tree by surgical clips (5).

Biliary complications are classified into early and late complications. Early complications occur in the post-operative period and include; retained stones in the cystic duct stump and/or common bile duct, bile duct injury/ligature during surgery, and bile leakage. Late complications occur after months or years and include; recurrent stones in the common bile duct, bile duct strictures, cystic duct remnant harboring stones and/or inflammation, gall bladder remnant harboring stones and/or inflammation, papillary stenosis, and biliary dyskinesia (6).

Prompt identification of these biliary complications is crucial for their appropriate management. Magnetic resonance cholangiopancreatography (MRCP) is a noninvasive imaging technique that has an established role in demonstrating biliary tract anatomy (5) and in providing a roadmap for interventional treatments (7–9). Though several variations of this technique have been developed in the recent years, they all share the use of a heavily T2W pulse sequence, which selectively displays static or slow-moving fluid-filled structures as high intensity areas. The recent development of many three dimensional (3D) sequences have substantially enhanced the quality of the MRCP images. Advances in gradient strength and image processing software have significantly influenced the development of 3D MRCP sequences that can be acquired in suspended respiration or with respiratory gated techniques using fast recovery sequences (FSE) or steady state free precession (SSFP). The near isotropic volumetric data from a 3D MRCP sequence can then be processed using a maximum intensity projection (MIP) or volume rendered technique (VRT) for accurate display of the biliary tree and pancreatic duct (10).

3D-SSFP is a high-resolution breath hold pulse sequence that has high fluid signal intensity (11,12). The feasibility of 3D SSFP for MRCP has been demonstrated (13) where high spatial resolution images depicting the biliary tree with good signal-to-noise ratios (SNR) and contrast to-noise ratio (CNR) were obtained in a single breath-hold (14).

The aim of this study was to demonstrate the role of breath-held 3D-SSFP MRCP in evaluation of post-laparoscopic cholecystectomy biliary complications.

2. Patient and methods

2.1. Patients

This study was approved by the ethics committee of our institution during the period from March 2013 to March 2015; most of the patients were referred from other centers, as our hospital was a referral center. This study included 29 patients with post-laparoscopic cholecystectomy symptoms like abdominal pain, dyspepsia, vomiting, gastrointestinal disorders and jaundice. The ages of the patients ranged from 28 to 70 years (mean 49 ± 16 year). Written informed consent was obtained from each patient.

2.2. MRCP technique

2.2.1. Imaging acquisition and scanning parameters

All the patients were fasting for at least 4 h prior to commencing the MRCP examination in order to reduce fluid secretions within the stomach and duodenum, reduce bowel peristalsis and to ensure that the hepato-biliary and pancreatic ducts were completely filled with fluid and maximally distended. Throughout this period, the patient was permitted to drink clear fluids only (water). No contrast agents or antiperistaltic drugs were used. The patients were instructed to hold their breath (suspend expiration) for approximately 20–40 s. Hyperventilation breathing allowed them to fill their lungs with air to comfortably sustain the period of suspended expiration. Breath-held was a crucial step for the success of the MRCP examination.

MRCP was performed for all patients on 1.5 tesla superconducting unit (Toshiba Medical systems corporation, 1385, Shimoishi Gami, Otawara-Shi, Tochigi-Ken, Japan) using 16 channel phased array body coil with breath-held multi-slice acquisition. We first perform 2D MRCP followed by 3D MRCP.

2.3. 2D MRCP

2D MRCP was performed using heavy T2 sequence with single shot, fast spin echo (SSFSE) sequences. A thick slab single shot turbo-spin echo (TSE) T2 WI sequence was done as a complementary approach. Axial 2D breath-hold acquisitions were obtained, so that the whole of the liver down to the duodenal ampulla was visualized. Then, oblique coronal images were generated, for better anatomical delineation of the biliary tracts.

2.4. 3D MRCP

3D MRCP was performed using steady state free precession (SSFP) sequence. The near isotropic volumetric data from a 3D MRCP then was processed using a maximum intensity projection (MIP) technique for an esthetically pleasing display of the biliary tree. MIP reformates then generated in various coronal and sagittal oblique planes. The protocol imaging parameters are shown in (Table 1).

2.5. Image analysis

All the available images including the 2D and 3D MRCP images and their individual source images were initially evaluated for the global quality of the image. The images were assessed for the presence of biliary stones either intra or extra-hepatic, biliary duct injuries including leakage (either partial or complete transection) and strictures. The MRCP images were considered positive for stone when a signal void was seen in at least two planes following the axial course of CBD and checked it for focal strictures or interruptions.

Table 1 Parameters of the protocol used on the 2D and 3D MRCP.

Parameter	2D coronal oblique planes	3D b-SSFP
TR (ms)	3000	5.2
TE (ms)	510	2.6
Slice thickness (mm)	40	2
Number of sections	1	40
FOV	38	30–36
Flip angle	50	50
Matrix	352 × 352	224 × 256
Acquisition time (s)	3	20–40

Table 2 Post-cholecystectomy biliary complications (n = 29).

Biliary complications	No.	%
1 – Retained stones		
– Intrahepatic	2	6.9
– Extra-hepatic	4	13.8
2 – Biliary duct injury:		
– Biliary duct ligation	4	13.8
– Biliary leakage		
– Partial tear	4	13.8
– Complete transection	8	27.6
– Slipped clips	2	6.9
– CBD strictures	5	17.2
Total	29	100

2.6. Surgical interference

Surgical interference was done for 26 cases and 3 cases passed without interference. The surgical interference was in the form of the following:

a. Endoscopic retro-grade cholangio-pancreatography (ERCP) which was done for 13 cases that were managed by ERCP with sphincterotomy and insertion of biliary stent.

b. Open surgery was performed for 13 cases in the form of removal of the ligature with insertion of T-tube, hepaticojejunostomy with insertion of intra-peritoneal drain. Also, exploration with wash and drainage technique, stone extraction and T-tube insertion was done.

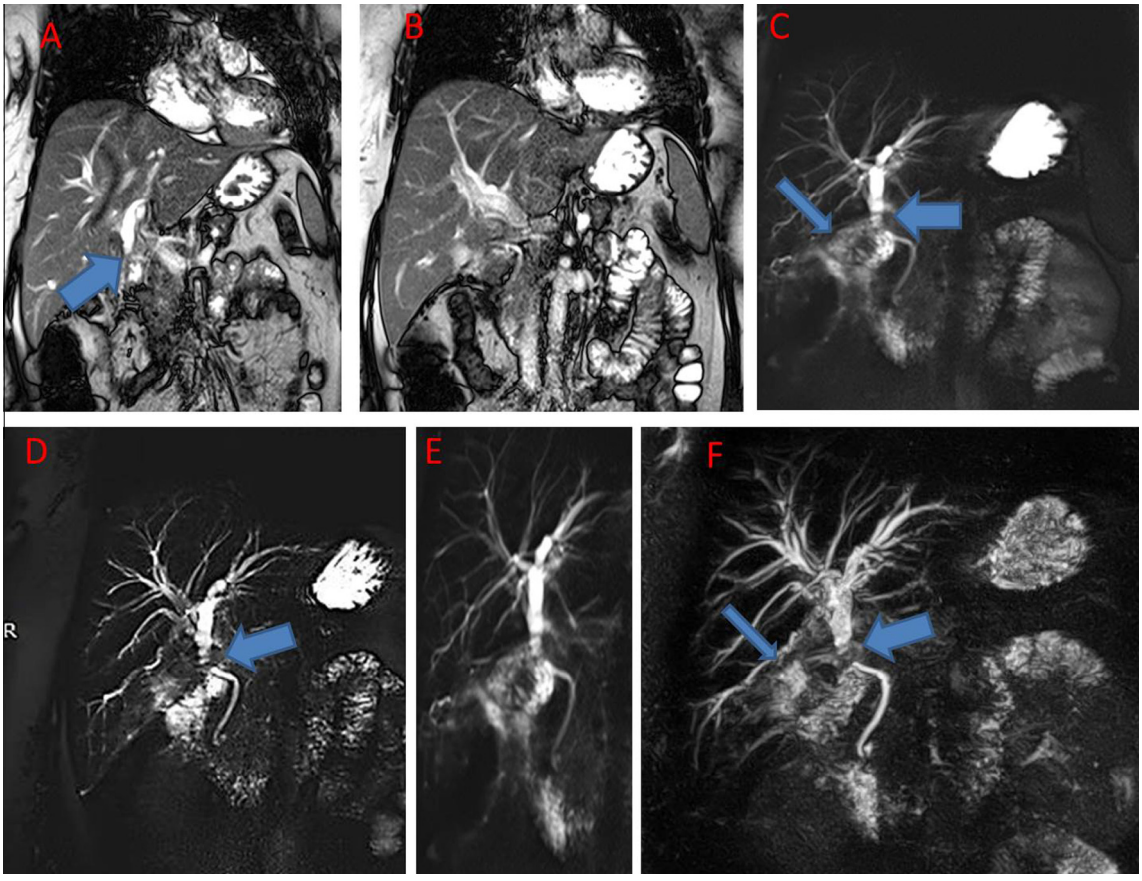

Fig. 1 50 year-old female patient presented 5 days post laparoscopic cholecystectomy, by jaundice and abdominal pain: (A and B): Coronal T2WI revealed interruption of the CBD at site of operation (arrow on A). (C, D & E): 2D MRCP in coronal and oblique coronal planes showed clearly the transected CBD segment (thick arrow on C & D) as well as the biliary leakage detected (thin arrow on C). (F): 3D MRCP in oblique coronal plane revealed more clearly the transected CBD segment as well as the biliary leakage (thin arrow).

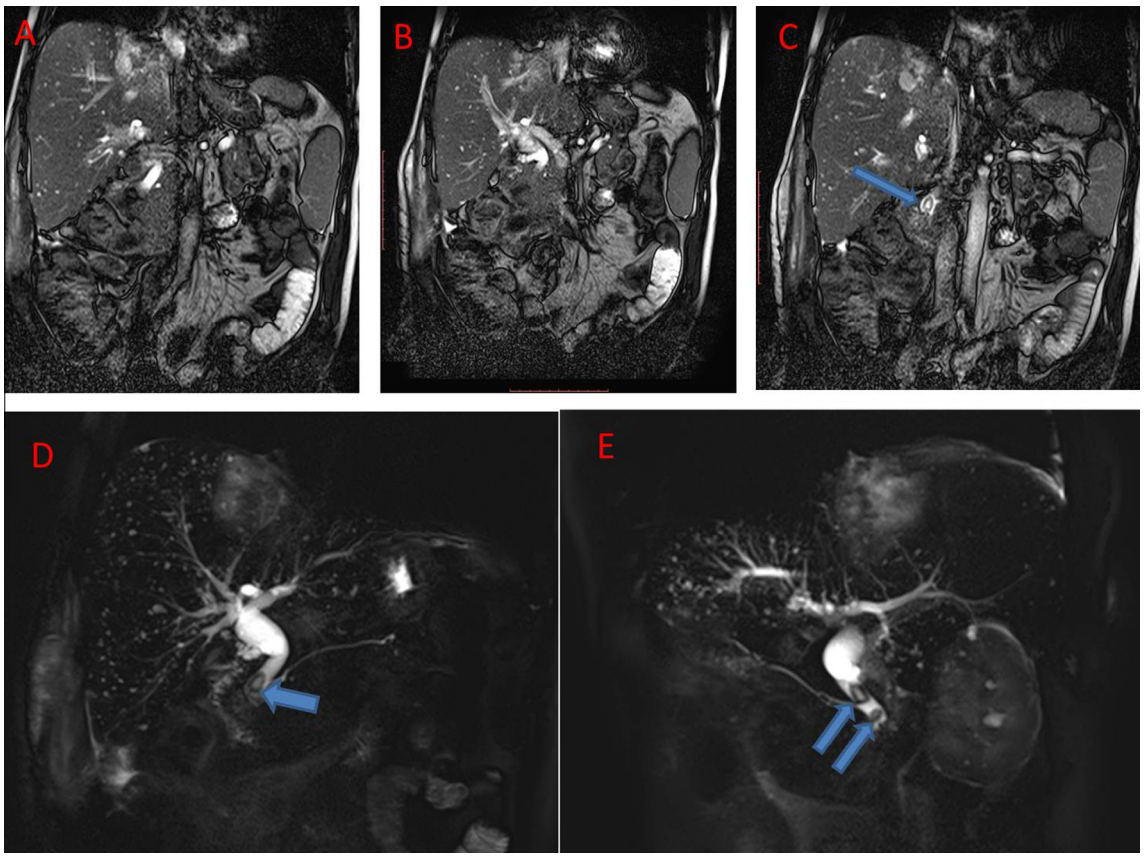

Fig. 2 60 year-old female patient came one week post laparoscopic cholecystectomy by jaundice and epigastric pain: (A,B & C): Coronal T2WI cuts revealed mildly dilated CBD and minimally dilated central portion of the intra-hepatic biliary radicals with evident small missed stone inside the CBD (arrow on C). (D and E): 3D MRCP in different angles showed the mildly dilated main CBD and the missed stone inside the extra-hepatic portion of CBD was clearly seen (arrow).

3. Results

This prospective study included 29 patients with post-operative complain of post-cholecystectomy symptoms (13 males, 16 females). Their ages ranged from 28 to 70 years (mean age was 49 ± 16 year). Post-laparoscopic cholecystectomy biliary complications included retained stones in 6 patients (2 intrahepatic and 4 extra-hepatic), biliary duct injury in 23 patients (4 cases with biliary duct ligation and 14 cases with biliary leakage: 4 cases with partial tear, 8 cases with complete transection and 2 cases with slipped clips). Benign stricture at the site of operation was detected in 5 cases (Table 2) and (Figs. 1–6).

The bile duct injuries were classified according to their severity into (a) minor injuries included; slipped clips from remnant of cystic duct (2 cases), partial thermal bile duct tear (4 cases) and biliary duct strictures (5 cases) and (b) major injuries included; ligation of the bile ducts (4 cases) and complete transection of the bile duct in (8 cases). All the minor injuries were managed by ERCP with dilatation, sphincterotomy or insertion of biliary stent, while the major injuries were treated operatively with either removal of the ligature with insertion of stent or hepaticojujenostomy (Table 3).

The interference for management of the facing post-laparoscopic cholecystectomy biliary complications was either; open surgery that was done for 4 cases of biliary duct ligation and 8 cases of biliary duct transection with large amount of leakage as well as one case of retained intrahepatic biliary stone. ERCP was done for the cases of retained CBD stones (4 cases), biliary duct strictures (5 cases) with dilatation and insertion of biliary stent. Also, ERCP was done for 2 cases of partial CBD injury and minimal leakage with insertion of biliary stent. As well as ERCP was done for 2 cases of slipped clips from remnant of cystic duct with therapeutic sphincterotomy (Table 4).

The remaining 3 patients that hadn't any surgical interference; 2 patients show spontaneous healing of the partial biliary injury and minimal leakage without any interference, and one patient had intra-hepatic retained stone that responded to medical treatment also with no interference.

As regarding the type of repair in cases of biliary duct injuries with open surgery, it was removal of the ligature in 4 cases

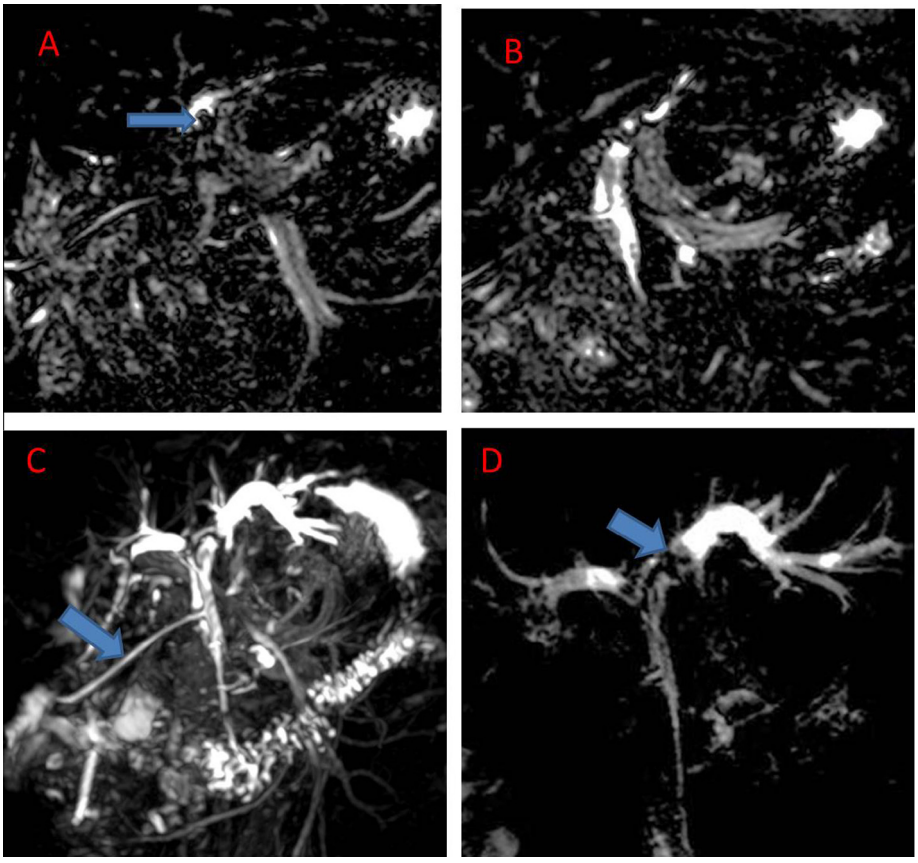

Fig. 3 48 year-old male patient presented 7 days post laparoscopic cholecystectomy by jaundice: (A and B): 2D MRCP in coronal plane revealed a signal void missed stone on the Lt. intrahepatic biliary duct (arrow on A). (C & D): 3D MRCP showed the inserted T-tube (arrow on C) and the intra-hepatic missed stone inside the Lt. hepatic biliary branch as well as the dilated related intrahepatic biliary radicals (arrow on D).

of bile duct ligation, with insertion of T-tube. The tube was removed after 10 days with no encountered complications. While in 8 cases of transection of the biliary duct and significant biliary leakage; hepaticojejunostomy was done with insertion of peritoneal drain for 5–7 days then removed. Also in one case of the missed intrahepatic biliary stone, exploration of CBD with wash and drainage technique, stone extraction and T-tube insertion was done (Table 5).

4. Discussion

Iatrogenic bile duct injury carries high morbidity. After the introduction of laparoscopic cholecystectomy the incidence of these injuries has at least doubled, and even after the learning curve, the incidence has plateaued at the level of 0.5% (15).

Patients presenting in the early post-cholecystectomy period with biliary leak, peritonitis and/or jaundice should be considered to have sustained a biliary injury. Delay in diagnosis is associated with increased morbidity. Once diagnosed, resuscitation, external drainage and control of sepsis should be established. The patient should be immediately referred to a hepatobiliary surgeon for further management as early repair is associated with lower morbidity and mortality, shorter duration of treatment and improved quality of life (16–18). Inadequate and delayed management may lead to severe complications including sepsis and multi-organ failure in the acute phase or late biliary stricture and cirrhosis (19). Therefore, it is of practical interest to evaluate the role of breath-held 3D-SSFP MRCP in evaluation of post-laparoscopic cholecystectomy biliary complications.

In our study, 3D MRCP was performed using breath-held SSFP sequence. Chavhan et al. (20) defined the steady-state sequences as a class of rapid magnetic resonance imaging techniques that based on fast gradient-echo acquisitions in which both longitudinal magnetization (LM) and transverse magnetization (TM) are kept constant. Scheffler and Lehnhardt (21) reported that balanced SSFP is characterized by two unique features: it offers a very high signal-to noise ratio and a T2/T1-weighted image contrast. The technique and imaging parameters for breath-held 3D-SSFP MRCP acquisition were based on Glockner et al. (14) who assessed the potential role of b-SSFP for MRCP, he reported that b-SSFP pulse sequences had a number of features suggesting their potential utility for MRCP imaging, including short TRs and consequent short acquisition times which reduce motion-induced artifact that may be sufficient to degrade the overall image quality, high signal-to-noise ratios (SNR), and T2/T1 contrast weighting, rendering fluid-containing structures bright. B-SSFP sequences are increasingly employed in standard hepatic MRI and

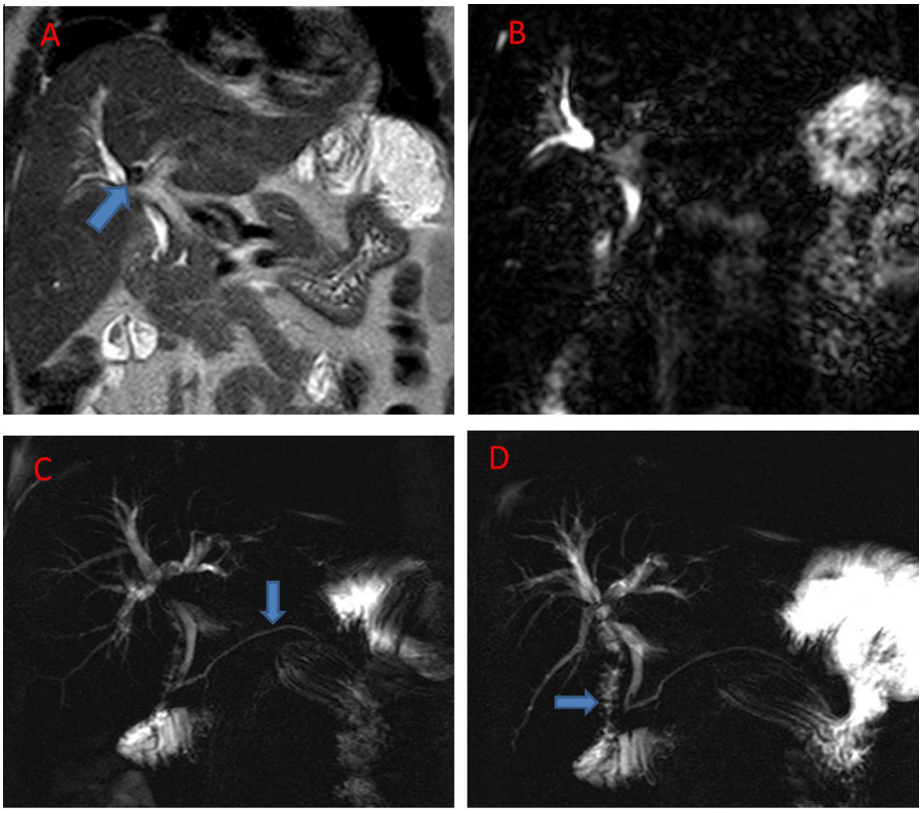

Fig. 4 54 year-old female patient came for follow up after repair of the post laparoscopic cholecystectomy biliary duct injury: (A): Coronal T2WI revealed the injured CBD (site of operation). (B): 2D MRCP in coronal plane revealed well the obstructed segment. (C & D): 3D MRCP in different planes and angles showed the patent continuation between the bile duct and the jejunal loops (hepaticojejunostomy: arrow on D). It was also clearly identified the CBD and the main pancreatic duct (arrow on C).

MRCP protocols with little added cost to the total examination time, or if substituted for the 3D FSE technique would represent a substantial time savings because the breath-held 3D SSFP acquisition is much faster than the standard respiratory-triggered 3D FSE technique.

In this study the 2D and breath-held 3D-SSFP MRCP were interpreted for detecting a spectrum of biliary complications following laparoscopic cholecystectomy which included; retained stones in 6 patients, biliary duct injury in 18 patients and CBD benign strictures in 5 patients. The increased incidence of post-laparoscopic cholecystectomy biliary duct injury was also reported by Karvonen et al. (15), Khan et al. (22), and Ahmad et al. (19).

Biliary complications were ranged from minor ductal leaks, often managed non-operatively, to proximal transection injuries requiring major biliary and occasionally vascular reconstruction (19). In our study the biliary duct injuries were further classified according to their severity into minor and major injuries. Minor injuries included; slipped clips from remnant of cystic duct (8.7%), partial mostly thermal bile duct tear (17.4%) and biliary duct strictures (21.7%), while major injuries included; ligation of the bile ducts (17.4%) and complete transection of the bile duct in (34.8%). This was based on and in accordance with Karvonen et al. (15), Sahajpal et al. (23), and Ahmad et al. (19).

Complete transection and stricture were the two most common types of biliary duct injury encountered in our study, they representing 27.6% and 17.2% respectively. Khalid et al. (24) reported that at MRCP, strictures and transection appear as a focal narrowing or abrupt interruption of the bile duct, respectively, with or without biliary dilatation upstream. The distinction between biliary stricture and transection may be difficult. Nevertheless, a complete lack of visualization on source and projection images is highly suspicious for duct disruption. Moreover, stricture is the most common late biliary complication that results from evolution of duct injury, it developed a few months to years after cholecystectomy, while transection is an early biliary complication that occurred in the post-cholecystectomy period. The site of stricture was the CBD in all the detected stricture complication (5 patients). This was in agreement with Van Hoe et al. (25) who documented that the typical locations of strictures are in the CBD, near the insertion of the cystic duct, or at the hepatic confluence.

Other detectable biliary complication was the retained stones, they were demonstrated in 6 patients, 2 were intrahepatic and 4 were extrahepatic in location. They were interpreted as stones at MRCP when there was a filling defect within the hyperintense fluid filled biliary ducts. This was based on Schofer (7) who described the appearance of stones at MRCP as smoothly marginated filling defects within the CBD or cystic duct remnant, usually in the dependent position, and surrounded by a thin rim of hyperintense bile. MRCP has a sensitivity of 95–100% and a specificity of 88–89% for detecting CBD calculi (7). Other studies conducted using 2D MRCP,

for the detection of CBD stones, have reported a sensitivity, specificity and accuracy of 90%, 88% and 89% respectively, which after the exclusion of stones with diameters smaller than 6 mm, have improved to 100%, 99% and 99% respectively. The detection accuracy of stones <6 mm is likely to improve with the newer 3D sequences (26).

Optimal management of biliary injuries is achieved with a multidisciplinary approach. Successful management depends on the type of injury, timing of injury recognition, presence of complications, condition of the patient, and availability of experienced hepatobiliary surgeons (2). Radiologists play a key role in diagnosis and treatment. Depending on the type of injury, appropriate management methods may include endoscopic, percutaneous, and surgical interventions (27). In this study management of biliary injuries was tailored according to their severity. Management approaches included open surgery which was performed for 13 patients with major biliary injury and ERCP was performed for 13 patients with minor biliary injury.

The indications of ERCP during this study included; retained CBD stones in 4 patients, biliary duct strictures with dilatation and insertion of biliary stent in 5 cases, partial CBD injury and minimal leakage with insertion of biliary stent in 2 patients, and slipped clips from remnant of cystic duct with therapeutic sphincterotomy in 2 patients. Weber et al. (28) reported that with ERCP, the biliary system is evaluated distal to the level of injury. ERCP is more invasive than MRCP, but it allows simultaneous therapeutic interventions such as the placement of biliary stents and drainage catheters, which are standard for treating injuries such as stenosis of the common duct and bile leaks from the cystic duct stump or small peripheral ducts, which require percutaneous drainage. Perini et al. (29) addressed the main limitations of ERCP as following; it does not al-low evaluation of the part of the biliary tree proximal to a major duct transection or ligation and has limited utility after surgical biliary-enteric anastomosis. In addition, transection or ligation of an aberrant right hepatic bile duct is frequently overlooked at ERCP.

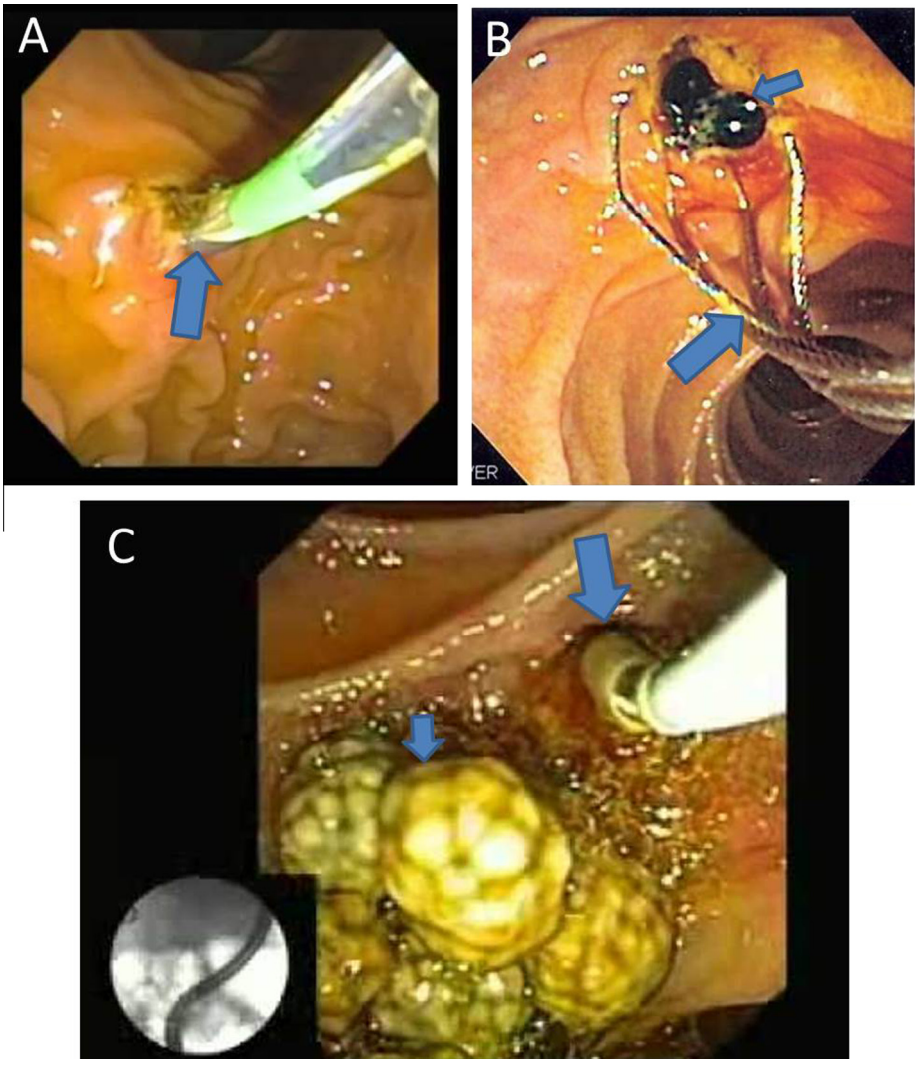

Fig. 5 A photographic illustration of some ERCP interferences for solving complication of post laparoscopic cholecystectomy: (A): Showed that the technique of retrograde CBD cannulation. (B): The Dormia basket appeared (large arrow) with stone extraction technique. (C): The stones were extracted on the lumen of duodenum (small arrow) and the CBD cannulation procedure also seen beside (large arrow).

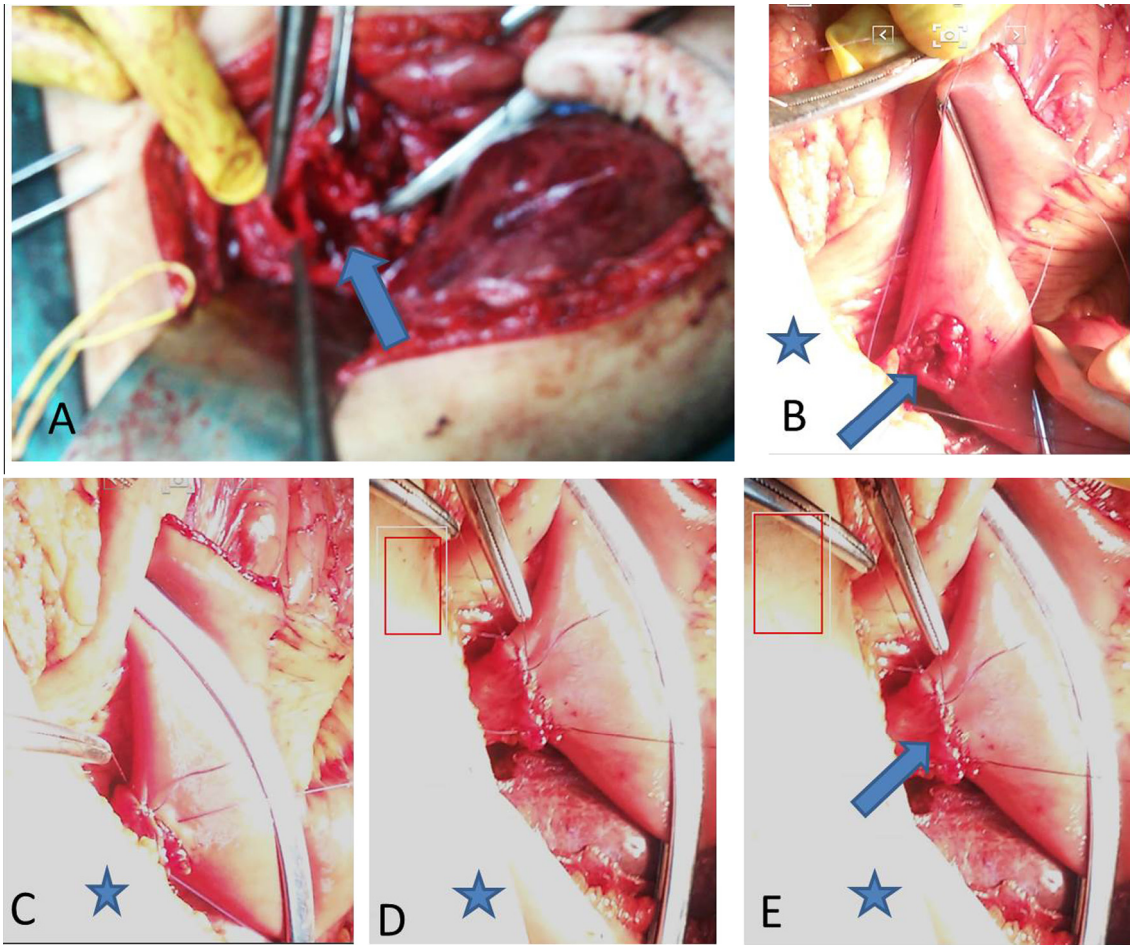

Fig. 6 A photographic illustration to some steps of hepaticojujensotomy operation: (A): Exploration of the hepatic biliary duct (arrow in A). (B): Exploration of the jujenal loop with opening on sits side wall (arrow on B). (C, D & E): Showed the final steps for end to side anastomosis and suturing (arrow on E). The white color on the surgical field is towel used for surgical purposes (Star on B, C, D & E).

Table 3 Classification of bile duct injuries according to their severity (n = 23).

Degree of injury	No.	%
1 – Minor injuries:		
– Slipped clips	2	8.7
– Partial tear (thermal injury)	4	17.4
– Bile duct strictures	5	21.7
2 – Major injuries:		
– Ligation	4	17.4
– Complete transection	8	34.8
Total	23	100

Table 4 Surgical interference for solving the biliary complications (n = 26).

Surgical interference	No.	%
Open surgery:		
– Ligature	4	15.4
– Leakage	8	30.8
– Missed intrahepatic stone	1	3.8
ERCP:		
– Retained extra-hepatic stones	4	15.4
– CBD strictures	5	19.2
– Partial CBD tear with minimal leakage	2	7.7
– Slipped clips from cystic duct	2	7.7
Total	26	100

Injuries that cannot be definitively treated with percutaneous or endoscopic techniques require surgical repair. These include large lateral defects in major ducts, strictures refractory to percutaneous or endoscopic treatment, and nearly all complete transections and ligations (27). The indications for open surgical interference during this study included; biliary duct ligation in 4 patients, biliary duct transection with large amount of leakage in 8 patients, and retained intrahepatic biliary stone in 1 patient. The commonest type of surgical repair performed was hepaticojejunostomy as it was done for 8 patients with transection. Many other studies (2,30,31) proved that Roux-en-Y hepaticojejunostomy is the preferred procedure for most major bile duct injuries; it provides excellent long-term outcomes overall, with long-term patency

Table 5 Type of repair on open surgery for biliary injuries ($n = 13$).

Type of repair	No.	%
Remove the ligature with insertion of T-tube	4	30.8
Hepaticojejunostomy with peritoneal drain	8	61.5
CBD exploration and T-tube insertion	1	7.7
Total	13	100

in more than 90% of patients, when the procedure is performed by an experienced hepatobiliary surgeon.

5. Conclusion

Breath-held 3D-SSFP MRCP is a noninvasive, high resolution imaging technique that does not require the use of a contrast medium, and provides excellent delineation of the biliary anatomy proximal and distal to the level of injury and facilitates the identification of biliary leak. So it is considered the imaging of choice for characterizing the injury and planning management procedures.

Disclosure statement

No disclosure of funding received for this work from any organization.

Author contribution

All authors have appraised the article and actively contributed to the work.
Moustafa A. Kader A. Wahab: Data collection and revision.
Enas Abdel Gawad: Final editing and revision.
Abdel Fatah Saleh: Surgical interference and ERCP.
Medhat M. Suliman: Surgical interference and revision.

Conflict of interest

All authors have materially participated in the research preparation and agree for the submission.
We have no conflict of interest to declare.

References

(1) Connor S, Garden OJ. Bile duct injury in the era of laparoscopic cholecystectomy. Br J Surg 2006;93:158–68.
(2) Lau WY, Lai EC, Lau SH. Management of bile duct injury after laparoscopic cholecystectomy: a review. ANZ J Surg 2010;80:75–81.
(3) Strasberg SM, Hertl M, Soper N. An analysis of the problem of biliary injury during laparoscopic cholecystectomy. J Am Coll Surg 1995;180:101–25.
(4) McGahan JP, Stein M. Complications of laparoscopic cholecystectomy: imaging and intervention. AJR 1995;165:1089–97.
(5) Mungai F, Berti V, Colagrande S. Bile leak after elective laparoscopic cholecystectomy: role of MR imaging. J Radiol Case Rep 2013;7:25–32.
(6) Girometti R, Brondani G, Cereser L, Como G, Del Pin M, Bazzocchi M, et al. Post-cholecystectomy syndrome: spectrum of biliary findings at magnetic resonance cholangiopancreatography. Br J Radiol 2010;83:351–61.
(7) Schofer JM. Biliary causes of postcholecystectomy syndrome. J Emerg Med 2010;39:406–10.
(8) Terhaar OA, Abbas S, Thornton FJ, Duke D, O'Kelly P, Abdullah K. Imaging patients with "post-cholecystectomy syndrome": an algorithmic approach. Clin Radiol 2005;60:78–84.
(9) Ward J, Sheridan MB, Guthrie JA, Davies MH, Millson CE, Lodge JPA. Bile duct strictures after hepatobiliary surgery: assessment with MR cholangiography. Radiology 2004;231:101–8.
(10) Gulati K, Catalano OA, Sahani DV. Review: advances in magnetic resonance cholangiopancreatography: from morphology to functional imaging. Indian J Radiol Imaging 2007;17:247–53.
(11) Lee CU, Glockner JF. Breath-held 3D steady state free precession MRCP: preliminary experience and comparison with respiratory-triggered 3D FRFSE. Proc Int Soc Mag Reson Med 2009;17:4029.
(12) Marcos H, Ho VB, Choyke P, Hood MN, Foo T. 3D Steady state free precession (3D-FIESTA) imaging of the pancreaticobiliary ductal system. Proc Int Soc Mag Reson Med 2001;9:423.
(13) Glockner JF, Stanley DW, Kumar A, Nozaki A, Wood M. 3D MRCP employing fast recovery fast spin echo and steady state free precession sequences: comparison with 2D single shot fast spin echo. Proc Int Soc Mag Reson 2003;11:1438.
(14) Glockner JF, Saranathan M, Bayram E, Lee CU. Breath-held MR cholangiopancreatography (MRCP) using a 3D Dixon fat-water separated balanced steady state free precession sequence. Magn Reson Imaging 2013;31:1263–70.
(15) Karvonen J, Gullichsen R, Laine S, Salminen P, Grönroos JM. Bile duct injuries during laparoscopic cholecystectomy: primary and long-term results from a single institution. Surg Endosc 2007;21:1069–73.
(16) Flum DR, Dellinger EP, Cheadle A, Chan L, Koepsell T. Intraoperative cholangiography and risk of common bile duct injury during cholecystectomy. JAMA 2003;289:1639–44.
(17) Thomson BN, Parks RW, Madhavan KK, Wigmore SJ, Garden OJ. Early specialist repair of biliary injury. Br J Surg 2006;93:216–20.
(18) Flum DR, Cheadle A, Prela C, Dellinger EP, Chan L. Bile duct injury during cholecystectomy and survival in medicare beneficiaries. JAMA 2003;290:2168–73.
(19) Ahmad J, McElvanna K, McKie L, Taylor M, Diamond T. Biliary complications during a decade of increased cholecystectomy rate. Ulster Med J 2012;81:79–82.
(20) Chavhan GB, Babyn PS, Jankharia BG, Cheng HL, Shroff MM. Steady-state MR imaging sequences: physics, classification, and clinical applications. Radiographics 2008;28:1147–60.
(21) Scheffler K, Lehnhardt S. Principles and applications of balanced SSFP techniques. Eur Radiol 2003;13:2409–18.
(22) Khan MH, Howard TJ, Fogel EL, Sherman S, McHenry L, Watkins JL, et al. Frequency of biliary complications after laparoscopic cholecystectomy detected by ERCP: experience at a large tertiary referral center. Gastrointest Endosc 2007;65:247–52.
(23) Sahajpal AK, Chow SC, Dixon E, Greig PD, Gallinger S, Wei AC. Bile duct injuries associated with laparoscopic cholecystectomy: timing of repair and long-term outcomes. Arch Surg 2010;145:757–63.
(24) Khalid TR, Casillas VJ, Montalvo BM, Centeno R, Levi JU. Using MR cholangiopancreatography to evaluate iatrogenic bile duct injury. AJR Am J Roentgenol 2001;177:1347–52.
(25) Van Hoe L, Vanbeckevoort D, Mermuys K, Van Steenbergen W. Extrahepatic bile ducts – traumatic, postoperative, and iatrogenic abnormalities. In: Van Hoe L, Vanbeckevoort D, Mermuys K, Van Steenbergen W, editors. MR Cholangiopancreatography.

Atlas with Cross-sectional Imaging Correlation. Berlin, Germany: Springer-Verlag. p. 172–6.
(26) Guarise A, Baltieri S, Mainardi P, Faccioli N. Diagnostic accuracy of MRCP in choledocholithiasis. Radiol Med 2005;109: 239–51.
(27) Thompson CM, Saad NE, Quazi RR, Darcy MD, Picus DD, Menias CO. Management of iatrogenic bile duct injuries: role of the interventional radiologist. Radiographics 2013;33:117–34.
(28) Weber A, Feussner H, Winkelmann F, Siewert JR, Schmid RM, Prinz C. Long-term outcome of endoscopic therapy in patients with bile duct injury after cholecystectomy. J Gastroenterol Hepatol 2009;24:762–9.
(29) Perini RF, Uflacker R, Cunningham JT, Selby JB, Adams D. Isolated right segmental hepatic duct injury following laparoscopic cholecystectomy. Cardiovasc Intervent Radiol 2005;28: 185–95.
(30) Misra S, Melton GB, Geschwind JF, Venbrux AC, Cameron JL, Lillemoe KD. Percutaneous management of bile duct strictures and injuries associated with laparoscopic cholecystectomy: a decade of experience. J Am Coll Surg 2004;198:218–26.
(31) Walsh RM, Henderson JM, Vogt DP, Brown N. Long-term outcome of biliary reconstruction for bile duct injuries from laparoscopic cholecystectomies. Surgery 2007;142:450–6.