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# Iatrogenic bile duct injuries after laparoscopic cholecystectomy: evaluation by MRCP before management

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## Abstract

**Background** Iatrogenic bile duct injuries are unusual but possibly associated with fatal complications with increased incidence since the introduction of laparoscopic cholecystectomy. Appropriate estimation of these injuries is essential for proper management. Imaging is vital for the initial diagnosis, extent assessment and consequently, treatment guidance of bile duct injury with an ideal outcome. In this study, MRCP was carried out in 37 cases (28 females and 9 males, age range from 19 to 58 years) with suspected BDI following laparoscopic cholecystectomy. MRCP images were assessed for bile duct transection injury, strictures, biliary leakage, and intrahepatic biliary radicles (IHBR) dilatation. In positive cases, Strasberg classification system was used with the definitive diagnosis was done regarding the surgical findings and/or findings on endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography (PTC).

**Results** Our study includes 37 cases with biliary injuries. On MRCP our cases were stratified regarding the Strasberg-Bismuth classification into five types (A to E). Most BDIs were type E2 (29.7%), followed by type E1 (18.9%), type A (16.2%), type E3 (10.8%), type E4 (8.2%), type C (5.4%), and type D and finally type E5 and B injuries with each one representing 2.7%. Twenty cases presented with biliary leakage and seventeen with bile duct obstruction, whether duct ligation or stricture.

**Conclusion** MRCP is an essential imaging modality for assessment of iatrogenic BDIs enabling the radiologists to classify these injuries and helps to govern the management.

**Keywords** Laparoscopic cholecystectomy, Bile duct injuries (BDIs), Intrahepatic biliary radicles (IHBR), Magnetic resonance cholangiopancreatography (MRCP)

## Background

Laparoscopic cholecystectomy is frequently performed worldwide in hepatobiliary surgery for symptomatic cholecystolithiasis [1]. Apart from that it has a faster recovery with better cosmetic outcome, the laparoscopic method displays around 0.6% risk incidence for iatrogenic bile duct injuries (IBDIs) [2–4].

Multiple imaging modalities can be used to identify these complications. Findings on ultrasonography (US) and computed tomography (CT) are often non-specific, manifesting as fluid collections in the surgical bed or

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in the perihepatic space. Magnetic resonance imaging (MRI) can give more specific details and is increasingly being used for these indications. MRCP displays the biliary tract integrity through the structural assessment of biliary tree [5]. It is similar to ERCP in its diagnostic appraisal of ductal pathology, but better in identifying proximal duct pathway in complete duct interruption [6, 7].

BDIs can be caused by imprecise bile duct cutting, dislodged surgical clips, tearing or obstruction by fibrosis as a result of thermal injury by electrocautery resulting in biliary leakage and/or stricture [8, 9]. Over the years, many classifications of IBDIs have been occurred before and after the laparoscopic era to ensure adequate treatment planning [10].

The Bismuth-Corlette system [11] was initiated before laparoscopic procedure and comprised five types of biliary injuries regarding the distance from the hilar biliary confluence and individual right sectoral duct involvement. This is as following: *type I* locates more than 2 cm from the hilar biliary confluence "a low injury". *Type II* locates less than 2 cm from the confluence "a mid-duct injury". *Type III* is a high-level injury completely destroys the CHD stump with preserved hilar confluence. *Type IV* involves the hilar biliary confluence with no right and left hepatic ducts communication. *Type V* involves the variant right segmental branch, with or without CHD affection (Table 1). The length of BDI and associated vascular injuries are not involved in this classification

**Table 1** Bismuth-Corlette classification system

| Types | Description |
|---|---|
| Type 1 | Low CHD injury, with a length of the CHD stump of > 2 cm |
| Type 2 | Middle injury, length of CHD < 2 cm |
| Type 3 | Hilar injury, no remaining CHD, but the confluence is preserved |
| Type 4 | Hilar injury, with involvement of confluence and loss of communication between right and left hepatic ducts |
| Type 5 | Aberrant RHD injury with or without concomitant CHD injury |

*CHD* common hepatic duct, *RHD* right hepatic duct, *CBD* common bile duct

Strasberg et al. [12] developed another classification few years later, like Bismuth category, but containing ancillary biliary injuries seen frequently in the laparoscopic era, especially bile leaks. In the "Strasberg classification" (Fig. 1), biliary injuries were categorized from type A to type E, as the E class is an analogue of the Bismuth pattern. *Class A* includes a cystic duct leak or leak from a minor duct in the gallbladder bed. *Class B* includes an aberrant right segmental bile duct injury which is occluded with no bile leak. *Class C* represents a bile leak from a duct (aberrant RHD) that is not communicating with common bile duct. *Class D* is a lateral partial injury to a major bile duct involving less than half of the circumference. If more than half of the circumference included, the injury was classified as Strasberg Type E. The major drawback of this category is that it does not describe vascular involvement as well as right and left partial injuries.

This prospective study was assumed to do a valuable appraisal of MRI/MRCP in iatrogenic BDIs assessment following laparoscopic cholecystectomy with perfect classification to obtain curable management.

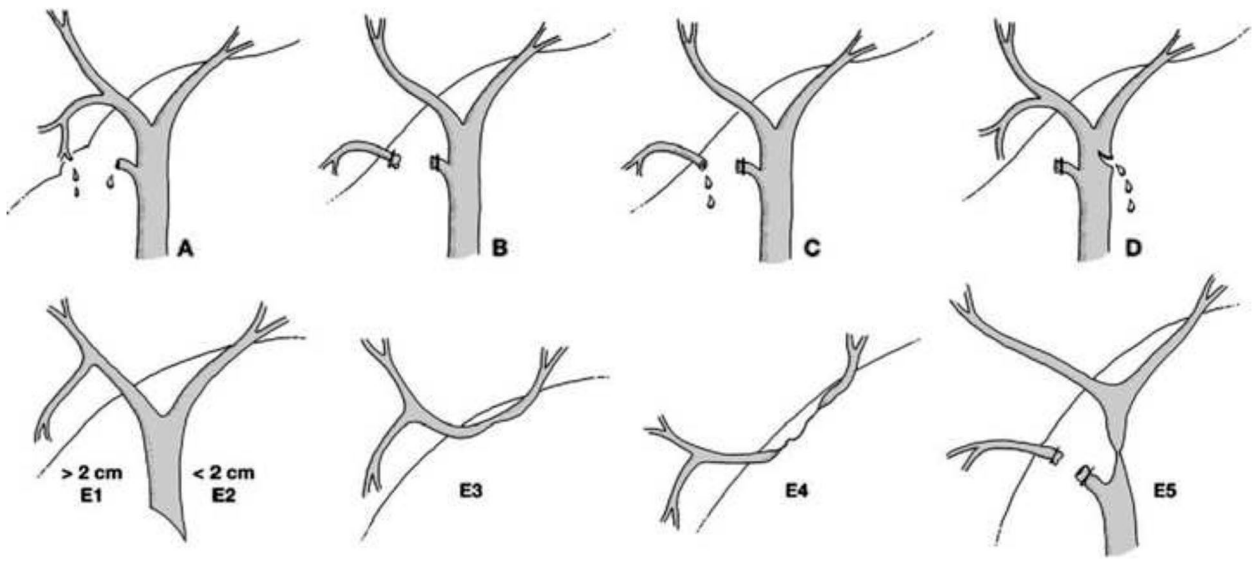


**Fig. 1** Drawings show the Strasberg system for classifying bile duct injuries

## Methods

### Study population

In a period from February 2019 to March 2022 after obtaining the approval of research ethics committee of National Liver Institute, a prospective analysis of 37 patients with suspected post-operative BDI were referred to the National Liver Institute, Menoufia University to undergo MRCP.

All patients underwent clinical and laboratory assessment including liver enzymes (SGPT and SGOT), serum bilirubin, alkaline phosphatase (ALP), γ-glutamyl transferase as well as radiological examinations. All patients had sonographic abdominal examinations with only ten patients underwent non-contrast enhanced abdominal CT. US and CT scan can depict fluid collections and dilated biliary tree. The studied patients were referred for MRCP study to confirm the presence of biliary injury and its extent.

### Timing of recognition

When identifying BDIs as early as possible, the optimal management is obtained leading to proper patient outcome with good life quality. Post-operatively, these are mostly recognized as biliary leakage and/or biliary obstruction. Leak present as anorexia, abdominal pain, bloating and fever. Biliary obstruction present as right hypochondrium pain and jaundice.

### Imaging system

All patients underwent MRCP using a 1.5-T MRI system (GE, Optima 450W, 32 channels), using a body phased-array coil. Patient fasting for 8 h prior to MRCP examination to reduce gastric and duodenal fluid secretions and small bowel motions with maximum distension of the hepato-biliary and pancreatic ducts with internal fluid signal. No contrast agents or antiperistalsis medications were used.

Breath-hold was a vital for better MRCP completion. *Cor T2 RTr PROP*; TR 2727 msec, TE 98 msec; Thickness 5 mm; Gap1; FOV 38 cm and Matrix 320 × 320. *Axial T2 FSE RTr PROP***;** TR 2000 msec, TE 95 msec; Thickness 5 mm; Gap1.5; FOV 38 cm and Matrix 320 × 320. *Cor 3D MRCP RTr*; TR 3000–5000 msec, TE 500–1000 msec; Thickness 1mm; Gap0; FOV 36 cm and Matrix 288 × 288. *Axial 3D thin cut RTr*; TR 2000-5000 msec, TE 400–1000 msec; Thickness 2 mm; Gap05; FOV 36 cm and Matrix 244 × 244. *DWI;* TR 8700 msec, TE 50–200 msec; Thickness 5 mm; Gap1.5; FOV 38 cm and Matrix 96 × 128. Finally, the coronal source images generated 2D and 3D images using MIP algorithm and MPR techniques. The total scanning time ranged between 20 and 25 min.

MRCP was done from 1 to 30 days following the initial surgery; 25 patients out of 37 (67.6%) were imaged within the first 2 weeks post-cholecystectomy. In all patients, the images were considered beneficial in diagnosis and no scanning had to be cancelled as a result of patient resistance.

### Image interpretation

All images were depicted at the time of patient presentation by four experienced radiologists without knowledge of any other radiologic data with final decisions by consensus.

MR images were assessed for BDIs presence either transection injury "partial or complete" and biliary obstruction "duct ligation or stricture". *Transection injury* was defined as a bile duct interruption with associated free and/or localized fluid collection (biliary leakage) and patient presented early post-operative. *Biliary obstruction* was defined as focal tightening or abrupt duct interruption with associated biliary dilatation upstream and presented early in duct ligation and late in biliary stricture after surgery.

### Bile duct injury classification

In the current review, when bile duct injury was identified, the biliary injuries were classified by using "The Strasberg-Bismuth classification system".

This classification was used to describe the BDI type based on MRCP findings and it involves most of the frequent biliary injuries during laparoscopic cholecystectomy, such as bile leaks. It divides into five groups (A to E) where the E class is analog to the Bismuth system, as summarized in Table 2.

To confirm MRCP findings, ERCP, PTC, or intraoperative cholangiography were used for correlation. ERCP was performed by an experienced gastroenterologist for 23 of 37 patients (62.2%), percutaneous transhepatic cholangiography (PTC) by an interventional radiologist

**Table 2** Strasberg Classification System

| Types | Description |
|---|---|
| Type A | Cystic duct leak or leak from small ducts in the liver bed |
| Type B | Partial occlusion of the biliary tree, almost invariably the aberrant right hepatic duct |
| Type C | Transection without ligation of the aberrant right hepatic duct with consequent bile leak |
| Type D | Lateral injury to a major bile duct without loss of continuity |
| Type E | Subdivided as per Bismuth's classification types I–V as into E1–E5 |

for 5 patients (13.5%) and intraoperative cholangiography (IOC) by a surgeon with an interventional radiologist for 9 patients (24.3%).

### Statistical analysis

Statistical analysis was accomplished with statistical software (SPSS, version 26.0 for Windows). Descriptive statistics: e.g., percentage (%), mean or median values were done. The classification of the biliary injuries was presented as the patients' percentage showing each abnormality and correlating findings with ERCP, PTC or intraoperative cholangiogram.

## Results

This prospective study was done on 37 patients including 28 females, 9 males with age range from 19 to 58 years and mean age, 37.5 years, presented with post-cholecystectomy symptoms.

Clinical symptomatology comprised right upper abdominal pain ($n = 34$), dyspepsia ($n = 37$), fever ($n = 17$), and jaundice ($n = 20$).

In the 37 patients, we studied (Fig. 2), 20 patients (54.1%) show bile duct transection with fluid collection, all patients showed free intraabdominal fluid collection on sonography or CT with only seven patients showed associated biloma. *In six patients*, MRCP exhibited biliary tree integrity with localized fluid collection to the porta hepatis, suggesting leak from the cystic duct stump or bile ducts of Luschka (small bile ducts in the gallbladder bed) on the basis of these findings. Three patients (3/20) showed duct transection with minimally dilated intrahepatic biliary radicles and free/localized collection. While, in 17/37 patients (45.9%), MRCP revealed intrahepatic biliary dilatation with no fluid collection or adjacent small biloma, indicating bile duct obstruction, whether duct ligation/stricture.

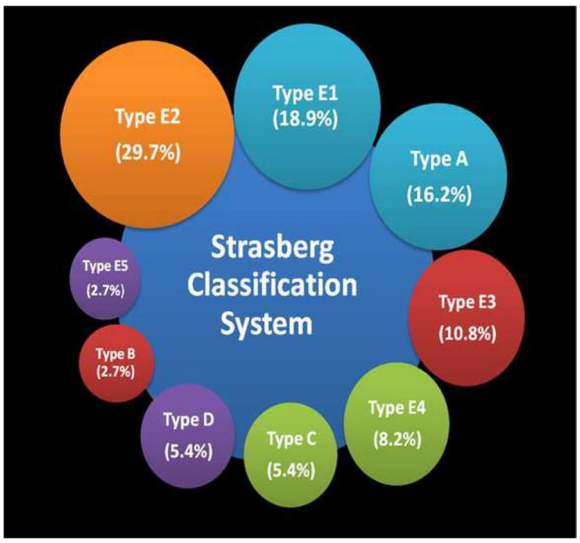


**Fig. 3** A diagram displays the range of bile duct injuries within our cases according to the Strasberg-Bismuth classification

Regarding the Strasberg-Bismuth classification (Fig. 3), most BDIs were type E2 (29.7%), followed by type E1 (18.9%), type A (16.2%), type E3 (10.8%), type E4 (8.2%), type C (5.4%), and type D and finally type E5 and B injuries with each one representing 2.7% (Figs. 4, 5, 6, 7, 8, 9, 10, 11).

### Comparison of MRCP with ERCP, PTC, and Intraoperative cholangiography

ERCP was done in 23 patients (62.2%); with MRCP was superior for surgical planning in transection/ligation duct injury. MRCP displayed the proximal biliary anatomy and the injury site, whereas ERCP showed only the remaining distal duct stump. Failed ERCP cannulation occurred in one patient with suspected cystic duct leakage, whereas MRCP showed findings with suggested diagnosis. The other 14 patients (37.8%) had

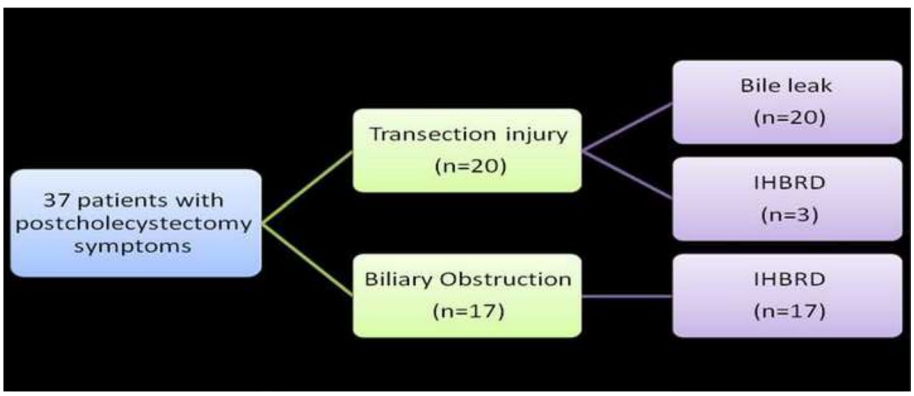


**Fig. 2** A diagrammatic illustration of the studied cases with bile duct injuries

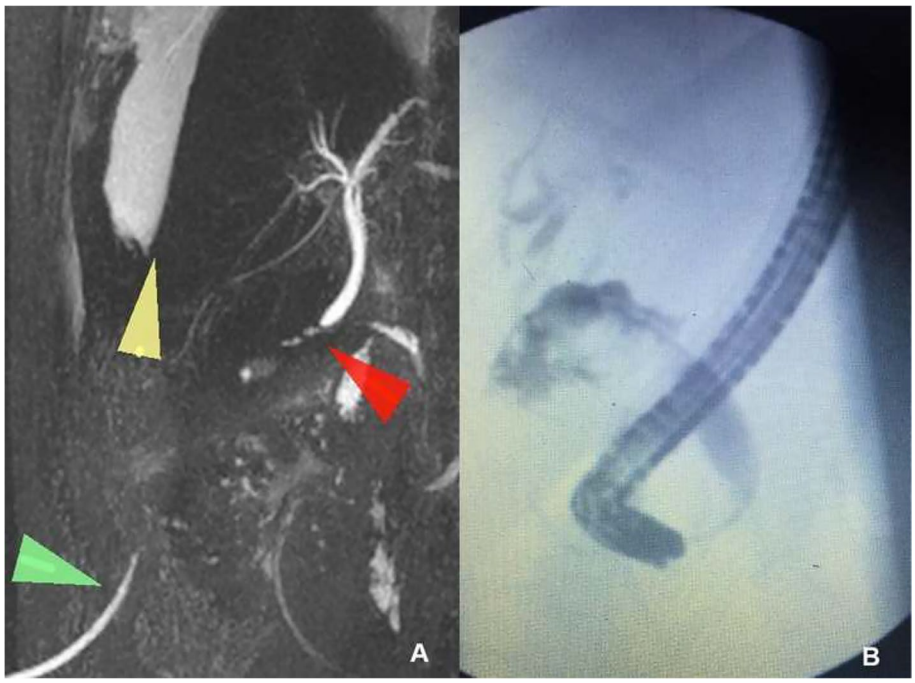


**Fig. 4** 3D-MRCP (**a**) post-cholecystectomy showing interrupted extra-hepatic biliary tree 3 cm distal to the biliary carina with traces of fluid signal at its lower end, representing biliary leak "red arrowhead". Subcapsular collection is noted related to the right hepatic lobe "yellow arrowhead". Percutaneous drainage catheter is noted "green arrowhead". Strasberg Type E1; Bismuth-Corlette Type 1 bile duct injury. ERCP image (**b**) shows an abrupt cutoff of the extrahepatic bile duct with contrast material extravasation indicative of bile leakage

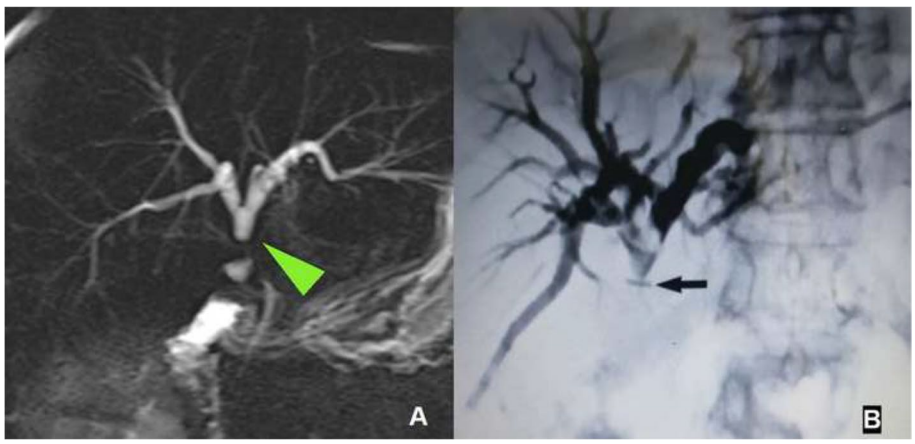


**Fig. 5** 3D-MRCP (**a**) post-cholecystectomy showing abrupt arrest of the CHD about 1.5 cm distal to the biliary carina "green arrowhead" with mild intra-hepatic biliary backpressure changes. Strasberg Type E2; Bismuth-Corlette Type 2 bile duct injury/ligation. PTC (**b**) is done 1 week later, showing a surgical clip "black arrow" occluding the common hepatic duct just below the confluence, confirming bile duct ligation with moderate intra-hepatic biliary radicles dilatation

confirmed by percutaneous transhepatic cholangiography or intraoperative cholangiography at the time of surgical repair with no additional information.

## Discussion

Biliary tract injuries can occur during different surgical procedures such as hepatectomy and gastrectomy

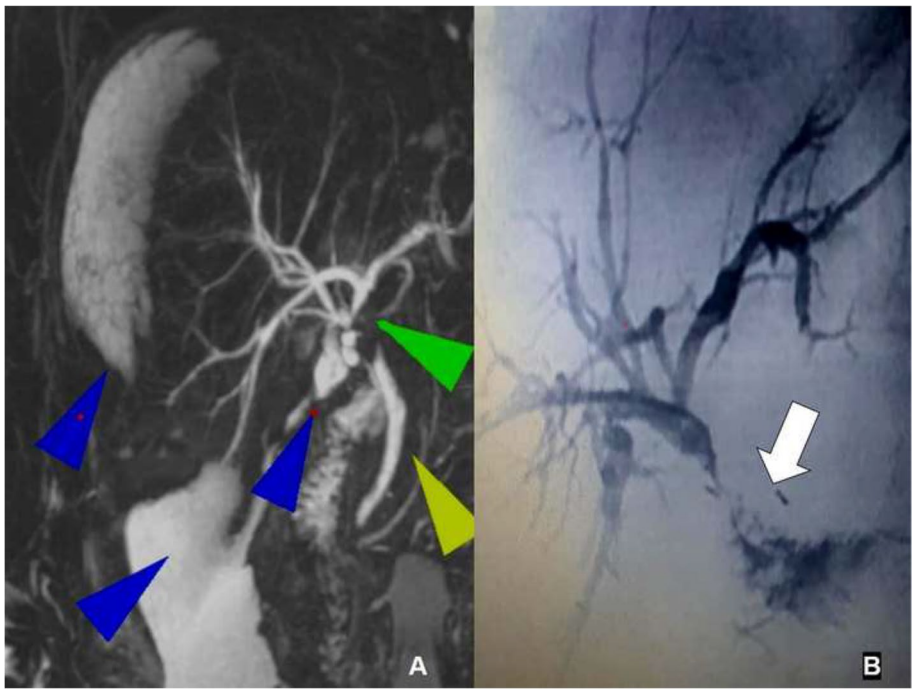


**Fig. 6** 3D-MRCP (**a**) post-cholecystectomy with interruption of the CHD at the biliary confluence "green arrowhead" yet still preserved communication between the right and left hepatic duct. This is associated with biliary leakage "blue arrowheads" at the CHD injury as well as at the subhepatic and sub-phrenic regions. Distal CBD "yellow arrowhead". Strasberg Type E3; Bismuth-Corlette Type 3 hilar bile duct injury. PTC (**b**) demonstrates extraluminal contrast extravasation at the level of hilar biliary confluence "white arrow"

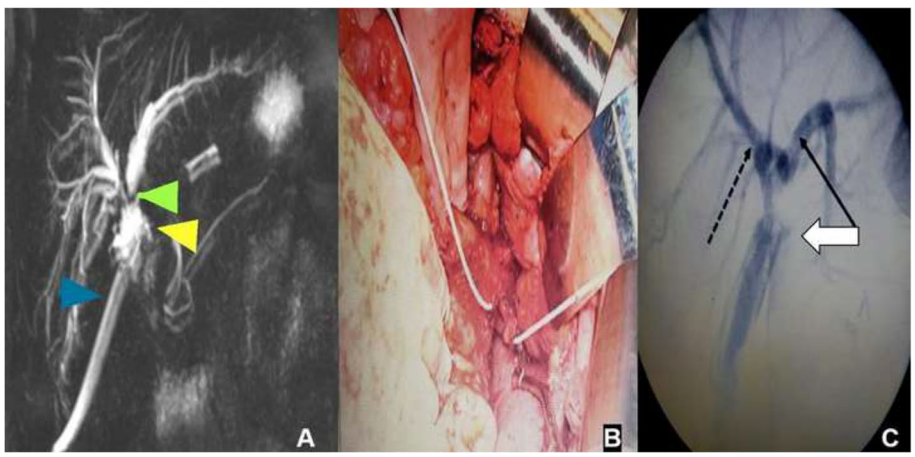


**Fig. 7** 3D-MRCP (**a**) post-cholecystectomy with non-visualized confluence between the right and left hepatic bile ducts "green arrowhead" with mild intra-hepatic biliary backpressure changes. The site of the CHD is replaced by a small biloma "yellow arrowhead". Percutaneous drainage catheter is noted "blue arrowhead"**.** Strasberg Type E4; Bismuth-Corlette Type 4 bile duct injury. Intraoperative photography (**b**) shows the distance between the right and left bile ducts. Intraoperative cholangiography (**c**) after injection of the contrast media through the separate drains, confirming loss of communication between right "black dashed arrow" and left "black arrow" hepatic ducts with bile leak "white arrow"

with the most injuries appear during the biliary tree surgery, particularly cholecystectomy [13]. As the number of cholecystectomies has risen with the development of laparoscopic surgery, the bile duct injuries have increased [14].

Several reviews have debated biliary injury mechanism such as anatomic biliary variants, inflammatory process (acute or chronic), improper surgical clips on the cystic duct, incompetent dissection and misguided use of cautery [15].

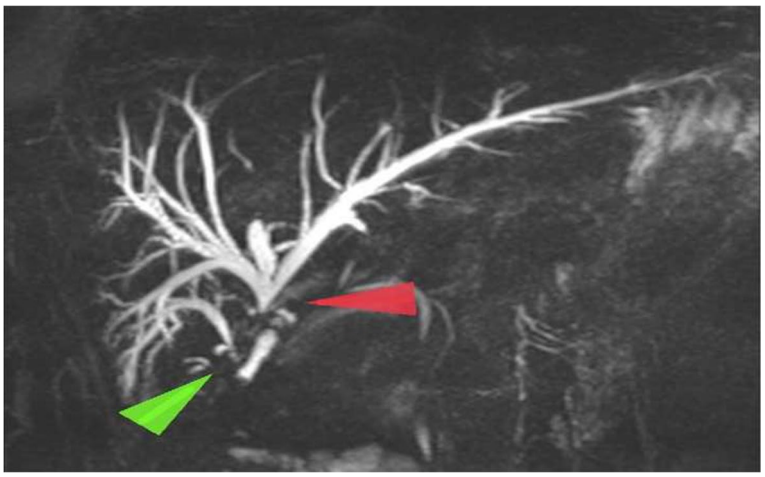

**Fig. 8** 3D-MRCP. Post-cholecystectomy ligation of aberrant right posterior hepatic duct to the CHD "green arrowhead". This is associated with concomitant CHD injury "red arrowhead". Strasberg Type E5; Bismuth-Corlette Type 5 bile duct injury. Consequent moderate intra-hepatic biliary backpressure changes seen

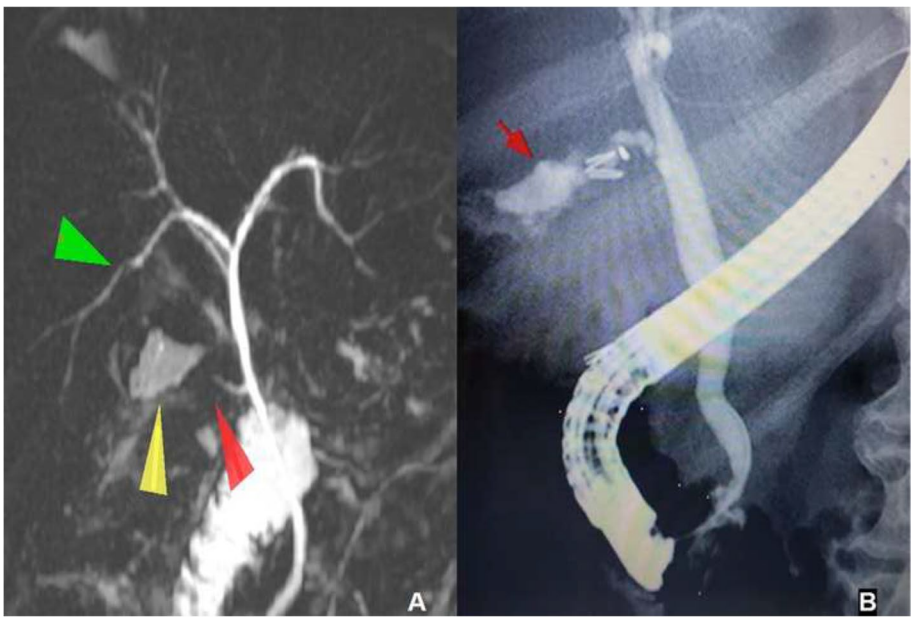


**Fig. 9** 3D-MRCP (**a**) Post-cholecystectomy small localized fluid collection "yellow arrowhead" at the gall bladder bed, near the cystic duct stump "red arrowhead". Strasberg Type A bile duct injury. Aberrant right posterior hepatic duct joins the left bile duct "green arrowhead". No intra-hepatic biliary radicles dilatation. ERCP image (**b**) demonstrates a collection in continuity with the cystic duct stump "red arrow"

Post-operative biliary injuries may be classified as a bile leakage, biliary obstruction, "either ligated duct or biliary stricture" or complete duct transection. A ligated or clipped bile duct presented early post-operative by jaundice sequel to biliary obstruction with or without cholangitis [16].

Several imaging approaches can be used for suspected BDIs with ultrasound and CT [17, 18] were considered the first diagnostic modalities, particularly in suspected bile leak with the following findings: localized fluid collection in the gallbladder bed or near porta hepatis (biloma) and free collection in the perihepatic, subhepatic or other peritoneal spaces. Hepatobiliary isotope scan is sensitive for bile leak detection, but lack spatial resolution with inability to detect the exact leak site. Abdominal pain, tenderness, distension, and fever are symptomatic features of biliary leakage. It has

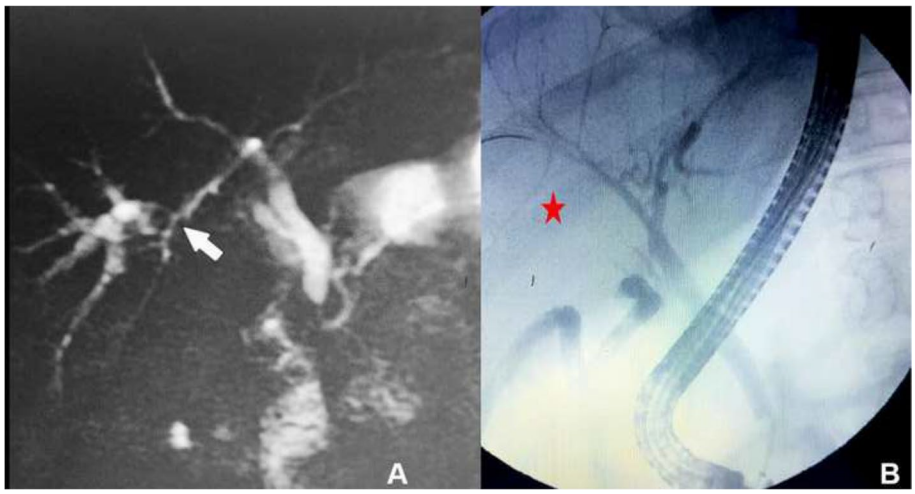


**Fig. 10** 3D-MRCP (**a**) post-cholecystectomy with interrupted aberrant right posterior hepatic bile duct. A finding that is easily demonstrated as the ligated dilated right posterior segmental duct is well visualized "white arrow". Strasberg Type B bile duct injury. ERCP image (**b**) shows a filling defect in the right posterior sectoral system (Red asterisk*)

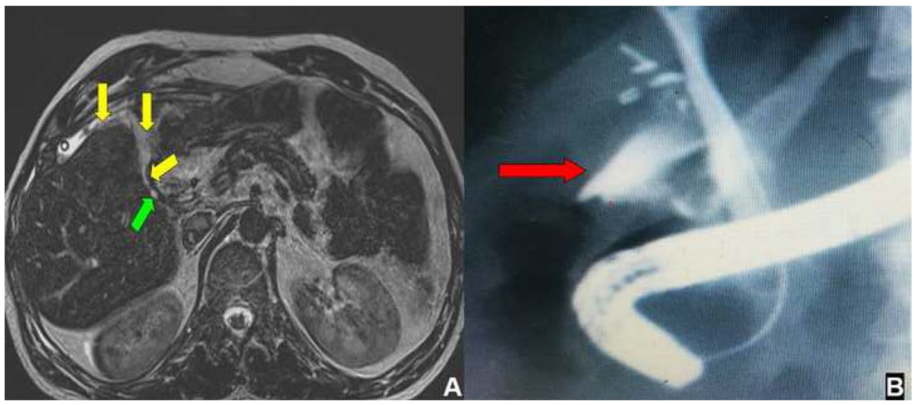


**Fig. 11** Axial thin cuts MRCP (**a**) post-cholecystectomy biliary leaked "yellow arrows" adjacent to the extrahepatic biliary tree with suspected injury to the main bile duct "green arrow". Strasberg Type D bile duct injury. ERCP image (**b**) demonstrates contrast extravasation from the lateral aspect of common bile duct with still preserved duct continuity confirming the previous finding "red arrow"

to be kept in mind that intraperitoneal bile does not get absorbed and may get infected leading to sepsis [19].

MR cholangiography is a safe diagnostic tool in distinguishing the post-operative bile duct injuries with early perfect management and better results. These bile duct injuries may manifest in the early post-operative period or later leading to high morbidity with decline in the patients' quality of life and high medical cost [20].

In this study, MRCP was found to be perfect in assessing patients with BDIs, since it was able to estimate the stenotic segment as well as the supra and infra-stenotic sectors. This imaging tool really diagnosed iatrogenic biliary injuries in all 37 patients with successful visualization of the biliary tree anatomy. As MRCP was done without contrast administration, it is less accurate in recognizing the origin of leak. ERCP is beneficial to localize the biliary leak with therapeutic availability after laparoscopy, but it is an invasive maneuver with major complications. Our data was compatible with other studies Yeh [7] and Khalid [14] who have estimated the role of MRCP in patients with suspected iatrogenic BDIs.

Transection injury was the most common biliary injury encountered in our study, representing 54.1%. On MRCP, a lack of duct visualization with associated fluid collection suspect duct disruption. In transection bile duct injury, associated biliary dilatation was unlikely. The discrimination between biliary transection and obstruction may be difficult. Nevertheless, biliary dilatation

upstream with no associated fluid collection was likely representing post-operative biliary obstruction, either ligated duct (early post-operative) or biliary stricture (late post-operative).

According to the Strasberg-Bismuth classification, showed that E2 and E1 are the most experienced types within our cases, representing 29.7% and 18.9% respectively. This agreed with Van Hoe et al. [21] who reported that the typical biliary injury site is in CBD, near the cystic duct insertion or the hepatic confluence.

MRCP has a limitation as it tends to exaggerate the stricture length as the duct may be collapsed instantly distal to the stricture. Ideal survey of the source images minimizes such drawback. It is essential to identify this limitation, especially with surgical repair, as only the proximal segment of the stricture is applicable with the distal extent overestimated at MRCP. Additionally, MRCP without contrast administration lacks the functional capability in detection of bile duct leaks [22, 23].

Our findings and that of others [24–27] suggest that it is unlikely that a biliary injury will be missed on MRCP. Further MRCP has sensitivity of 100% in localizing the site of biliary obstruction as well as duct transection.

Kapoor [28] documented that, "A classification should address topics related to mechanism, treatment, avoidance and prognosis". None of the suggested classifications deal with all topics namely injury mechanism, means of presentation, patient's status including presence of cholangitis and associated vascular injury. An ideal biliary injury classification still evades us.

## Conclusion

MRCP is a non-invasive, safe imaging tool which allows perfect description of the biliary tree proximal as well as distal to the biliary injury level. So, it is considered a modality of choice for characterizing the bile duct injuries and planning management maneuvers.

### Abbreviations

| | |
|---|---|
| BDI | Bile duct injury |
| MRI | Magnetic resonance imaging |
| MRCP | Magnetic resonance cholangiopancreatography |
| IHBR | Intrahepatic biliary radicles dilatation |
| ERCP | Endoscopic retrograde cholangiopancreatography |
| PTC | Percutaneous transhepatic cholangiography |
| SGPT | Serum glutamic oxaloacetic transaminase |
| SGOT | Serum glutamic pyruvic transaminase |
| US | Ultrasound |
| CT | Computed tomography |
| TR | Repetition time |
| TE | Echo time |
| msec | Millisecond |
| min | Minute |
| 2D | Two-dimensional |
| 3D | Three-dimensional |
| MIP | Maximum intensity projection |
| MPR | Multi-planar reformatting |
| SPSS | Statistical Package for Social Science. |

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Not applicable.

### Authors' contributions

MSA carried out cases on workstation and selection of research cases, prepared the figures for cases demonstration, and helped in the writing and review of the research. ME assessed cases for initial diagnosis. SAK assessed in cases selection and follow-up. MAE performed clinical assessment and ERCP for the cases. RAA contributed to the writing the research, sharing in selection of the cases, and sharing in figures preparation of cases. All authors read and approved the final manuscript.

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This study had no funding from any resource.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (Institutional Review Board (IRB)" of National Liver Institute Menoufia University and with the Helsinki Declaration of 1964 and later versions. Committee's reference number is 03343/2002. Consent was obtained from the patients since it was a retrospective study.

### Consent for publication

All patients included in this research gave written informed consent to publish the data contained within this study.

### Competing interests

The authors declare that they have no competing interests.

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