

Preoperative magnetic resonance cholangiopancreatography before planned laparoscopic cholecystectomy: is it necessary?

Rami Rhaïem¹, Tullio Piardi¹, Yohann Renard¹, Mikael Chetboun¹, Arman Aghaei¹, Christine Hoeffel², Daniele Sommacale¹, Reza Kianmanesh¹

¹Department of Digestive and Hepatobiliary Surgery, Robert Debré University-Hospital, University Champagne-Ardennes, Reims, France,

²Department of Radiology, Robert Debré University-Hospital, University Champagne-Ardennes Reims, France

Background: The most feared complication of laparoscopic cholecystectomy (LC) is biliary tract injuries (BTI). We conducted a prospective study to evaluate the role of preoperative magnetic resonance cholangiopancreatography (MRCP) in describing the biliary tract anatomy and to investigate its potential benefit to prevent BTI. **Materials and Methods:** From January 2012 to December 2016, 402 patients who underwent LC with preoperative MRCP were prospectively included. Routine intraoperative cholangiography was not performed. Patients' characteristics, preoperative diagnosis, biliary anatomy, conversion to laparotomy, and the incidence of BTI were analyzed. **Results:** Preoperative MRCP was performed prospectively in 402 patients. LC was indicated for cholecystitis and pancreatitis, respectively, in 119 (29.6%) and 53 (13.2%) patients. One hundred and five (26%) patients had anatomical variations of biliary tract. Three BTI (0.75%) occurred with a major BTI (Strasberg E) and two bile leakage from the cystic stump (Strasberg A). For these 3 patients, biliary anatomy was modal on MRCP. No BTI occurred in patients presenting "dangerous" biliary anatomical variations. **Conclusion:** MRCP could be a valuable tool to study preoperatively the biliary anatomy and to recognize "dangerous" anatomical variations. Subsequent BTI might be avoided. Further randomized trials should be designed to assess its real value as a routine investigation before LC.

Key words: Bile tract injury, cholangiopancreatography, cholecystectomy, laparoscopy, magnetic resonance

How to cite this article: Rhaïem R, Piardi T, Renard Y, Chetboun M, Aghaei A, Hoeffel C, *et al.* Preoperative magnetic resonance cholangiopancreatography before planned laparoscopic cholecystectomy: is it necessary? *J Res Med Sci* 2019;24:107.

INTRODUCTION

Laparoscopic cholecystectomy (LC) is actually the standard procedure to treat symptomatic cholelithiasis. This led to an increase of the incidence of biliary tract injuries (BTI). BTI is a rare but life-threatening complication of LC, with an incidence ranging from 0.3% to 0.7%.^[1,2]

Several factors are associated with an increased risk of BTI: acute or chronic inflammation, patient obesity, cirrhosis, previous abdominal surgery with adhesions around the hepatoduodenal ligament and bleeding in the surgical field. Anatomical abnormalities and

variations can also expose to BTI. Indeed, their existence can lead to misidentification of biliary anatomy and/or to intraoperative lesions of biliary structures that can be misdiagnosed exposing thus the patient to postoperative complications.^[3]

Intraoperative cholangiography (IOC) is the most common imaging modality to study the biliary tree anatomy. IOC might reduce the incidence of BTI or at least allow intraoperative diagnosis of BTI. However, the real impact of routine IOC on the reduction of incidence of BTI and its morbidity is controversial.^[4-6] Magnetic resonance cholangiopancreatography (MRCP) is a noninvasive imaging technique. Recent series reported excellent sensitivity of MRCP to depict

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

Access this article online	
Quick Response Code: 	Website: www.jmsjournal.net
	DOI: 10.4103/jrms.JRMS_281_19

Address for correspondence: Dr. Rami Rhaïem, Department of Digestive and Hepatobiliary Surgery, Robert Debré University-Hospital, Ave Général Koenig, 51100 Reims, France. E-mail: rraïem@chu-reims.fr

Received: 26-04-2019; **Revised:** 01-08-2019; **Accepted:** 07-10-2019

common bile duct (CBD) stones,^[7,8] bile duct abnormalities such as choledochal cysts^[9] as well as benign or malignant stenoses.^[10,11] Several reports studied the potential benefit of MRCP in the assessment of biliary anatomy, especially in living donor liver transplantation.^[12-14] MRCP before LC is used worldwide mainly in case of associated CBD. Its routine use to study biliary anatomy is not widespread with only few reports in the literature advocating the use of MRCP to reduce the risk of BTI.^[15-17]

Since January 2012, we performed prospectively routine MRCP before scheduled LC to detect preoperatively bile duct stones and bile duct abnormalities. The aim of this prospective study was to evaluate the impact of MRCP on the detection of potential dangerous variations of the biliary tract and therefore on the prevention of BTI.

MATERIALS AND METHODS

Study design and participants

We conducted a prospective descriptive study in the Surgical Department of Robert Debré University-Hospital, Reims (Champagne Ardennes University). From January 2012 to December 2016, all consecutive patients who underwent LC for symptomatic or complicated cholelithiasis were included. Routine preoperative MRCP was performed for all patients. Exclusion criteria included previous major upper abdominal surgery that could not allow LC, open cholecystectomies due to any other reasons, and patients who had undergone LC without preoperative MRCP (mainly because of claustrophobia or emergency early surgery for cholecystitis). In this regard, no patient had routine IOC, unless intraoperative suspicion of BTI. Thus, we included 402 patients. This study was approved by the local ethical committee.

Procedures and outcomes' assessment

MRCP examinations were performed at least 2 weeks before surgery. HASTE sequence and phased array body coil with breath-hold multislice acquisition were performed. Axial T2 fast spin-echo magnetic resonance examination and maximum intensity projection reconstruction were used to obtain three-dimensional MRCP images. All preoperative MRCPs were studied by both radiologists (reports) and hepatobiliary (HBP) surgeons to depict CBD stones and to ascertain the biliary tract anatomy. All variations of cystic and suprahilar ducts were analyzed to predict, preoperatively, "dangerous" LCs.

Were considered as "dangerous" biliary tree variations:

- Perihilar insertion of the cystic duct defined as a short cystic duct with an insertion <1 cm from the hilum^[18]
- Posterior implementation of the cystic duct into the CBD^[19]

- Insertion of a right sectoral/segmental hepatic duct directly into CBD^[20]
- Hepatocystic ducts:^[21] the direct implementation of a segmental/sectoral right hepatic duct into the gallbladder or the cyst duct.

LC was performed with the standard four-port technique.^[22] No monopolar electrocautery was used. The gallbladder was emptied using transparietal puncture. Principles of the critical view of safety (CVS) were followed:^[23,24] the hepatocystic triangle was cleared, the lower part of the gallbladder was separated from the cystic plate, and thus, the cystic duct and artery were dissected and clipped. The gall bladder was then removed mostly by retrograde dissection and extracted in a bag. Drains were not routinely used.

Patients' characteristics (age and sex), preoperative diagnosis, interval between symptoms and surgery for patients who presented with cholecystitis, biliary anatomy with the proportion of "dangerous" variations, incidence of CBD stone and its management, conversion to laparotomy, and the incidence of BTI were evaluated. BTI was defined as the existence of an abnormal bile duct ligation or bile leakage during the procedure, abnormal bile output through surgical drainage, and postoperative collections or peritonitis.^[25] BTI were categorized using Strasberg classification.^[24]

Statistical analysis

Data are shown as mean (standard deviation) for continuous and as absolute number (%) for categorical variables. Calculations were done with IBM SPSS Statistics 20 (SPSS, Chicago, IL, USA).

RESULTS

During the study period, a total of 632 patients had cholecystectomy in our department. Among them, 402 patients met the inclusion criteria with a mean age of 52 years (27.4). Gender proportion (male/female) was 59% (150/252). Indications were cholecystitis and pancreatitis, respectively, in 119 (29.6%) and 53 (13.2%) patients. All patients treated for cholecystitis and included in this study were referred to our department after a median of 6 weeks (2–43 w) of the onset of symptoms and had delayed surgery. The population characteristics are shown in Table 1.

Twenty-one (5.2%) patients had a CBD stone. It was managed successfully by preoperative endoscopic sphincterotomy in 17 patients and intraoperatively using the "rendez-vous" technique in the remaining 4 patients.

Preoperative MRCP showed 129 anatomic variants of the biliary tract in 105 patients (26.1%). Sixty-one (15.2%) patients presented anatomical variants of the cystic duct and 58 (14.4%) of the suprahilar ducts. The 129 anatomic variants were divided into 65 (50.4%) cystic and 64 (49.6%) suprahilar ducts' anatomical abnormalities. The results of biliary tract anatomical variations are shown in Table 2.

Regarding LC, 39 patients (8.7%) were considered to have "dangerous" anatomical variants. The cystic duct had a perihilar [Figure 1] or a posterior implementation into the CBD in, respectively, 12 (3%) and 10 (2.5%) patients. Intrahepatic ducts' variations were at risk of BTI in 17 (4.2%) patients with 14 cases of insertion of a right sectoral/segmental hepatic duct directly into CBD [Figure 2] and 3 hepatocystic ducts [Figure 3].

LC was successfully accomplished in 390 patients while 12 (3%) were converted to open cholecystectomy all for the presence of dissection difficulties due to persisting acute or chronic inflammatory signs of cholecystitis. Only 5 patients had IOC for intraoperative suspicion of BTI.

BTI occurred in 3 patients (0.75%). Only one major BTI occurred. The patient was referred to us 6 weeks after

medical management of a severe acute cholecystitis. It was Strasberg E. The BTI was diagnosed intraoperatively, and immediate hepaticojejunostomy was performed by a

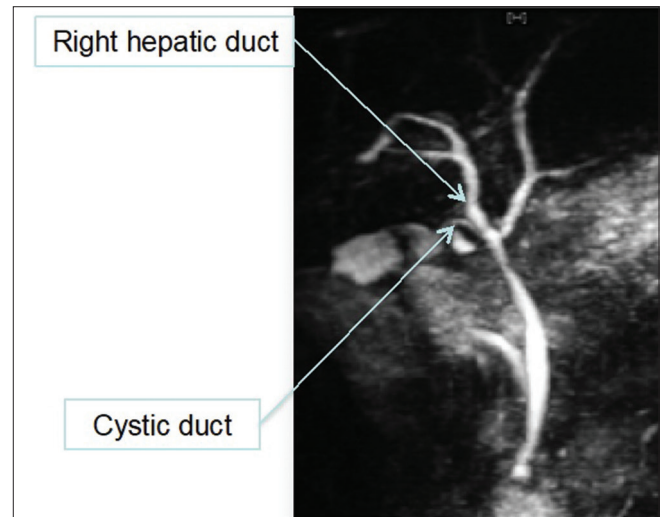


Figure 1: A "dangerous" variation of the cystic duct. Magnetic resonance cholangiopancreatography showing a perihilar insertion of the cystic duct just as the same level as the origin of main right hepatic duct

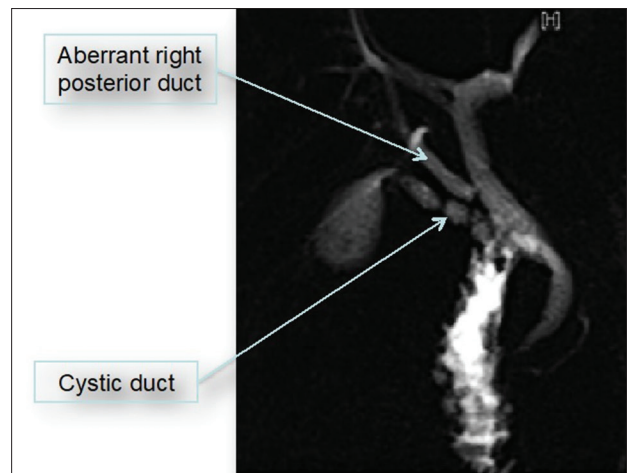


Figure 2: Magnetic resonance cholangiopancreatography showing a "dangerous" low insertion of the right posterior sectoral duct into the common bile duct <1 cm above the insertion of the cystic duct

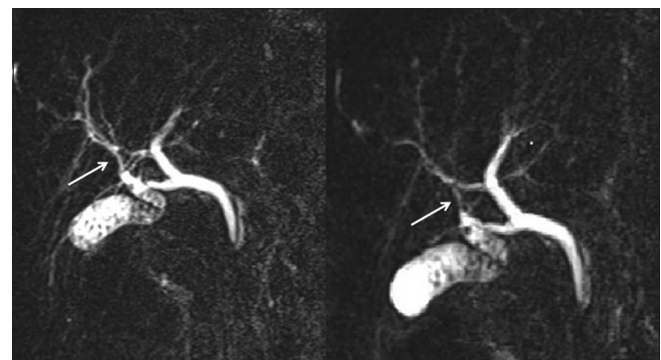


Figure 3: Magnetic resonance cholangiopancreatography showing a hepatocystic duct

Table 1: Epidemiological characteristics of patients and indications for laparoscopic cholecystectomy

Parameters	
Mean age (year) (SD)	52 (27.4)
Gender proportion (male/female), n (%)	150/252 (59)
Indications of LC, n (%)	
Symptomatic gallstone	205 (51)
Cholecystitis	119 (29.6)
Pancreatitis	53 (13.2)
Other	25 (6.2)

LC=Laparoscopic cholecystectomy; SD=Standard deviation

Table 2: Distribution of 129 variations of cystic duct insertion into the common bile duct and intrahepatic ducts on magnetic resonance cholangiopancreatography

Biliary anatomical variation	N (%)
Cystic canal insertion abnormalities	
Low insertion	30 (23.25)
Perihilar insertion	12 (9.3)
Posterior insertion	10 (7.75)
Left insertion	13 (10.1)
Suprahilar ducts abnormalities	
Low insertion of a right sectoral/segmental hepatic duct	14 (10.85)
Separate insertion of the right sectoral hepatic ducts (absence of right hepatic duct)	16 (12.4)
Insertion of a right sectoral/segmental hepatic duct in the left hepatic duct	27 (20.9)
Hepatocystic duct	3 (2.3)
Other variations	4 (3.1)

senior HPB surgeon. The two other BTI were leaks from the cystic duct stump (Strasberg A) diagnosed postoperatively. One patient required surgery while the other patient was managed conservatively. Preoperative MRCP was considered normal in all three patients.

No BTI occurred in patients with biliary anatomical variations including those with “dangerous” abnormalities.

DISCUSSION

The present study was conducted prospectively in a tertiary university center on LC for symptomatic gallstones. It aimed to ascertain the role of preoperative MRCP in describing accurately the biliary anatomy and thus to optimize the preoperative detection of “dangerous” anatomical configurations. It showed that preoperative MRCP before LC helped to diagnose anatomical variations in more than a quarter of patients. Variations were at risk of BTI in nearly 10% of them. In this subgroup, no BTI has occurred and no routine IOC was performed.

Regarding, reducing BTI incidence, both the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the European Association for Endoscopic Surgery raised the issue of prioritizing the preventive measures to reduce the incidence of BTI.^[26,27] The latter has proposed a new classification (ATOM) to homogenize the evaluation of BTI.^[27] Several preventive surgical options have been advocated. The most common was the routine use of IOC during LC. Buddingh *et al.*^[28] have reduced the incidence of BTI from 1.9% to nil by the systematic use of IOC. Alvarez *et al.*^[5] reported a low BTI rate of 0.17% in 11423 LC. Meanwhile, the routine use of IOC in reducing BTI is still debated. Indeed, Ford *et al.*^[4] reported in 2013, a systematic review that failed to proof any evidence to support the routine use of IOC. Sheffield *et al.*,^[29] in a retrospective cohort study of all Texas Medicare claims data about cholecystectomies in 92,932 elderly patients, reported the same conclusions. To advocate routine IOC, pros consider that even with no obvious reduction of the incidence of BTI, IOC allow intraoperative diagnosis and repair of BTI and thus reduce the immediate and even long term morbidity of misdiagnosing a BTI. In the other hand, cons to IOC claimed that it lengthens the operative time and costs, exposes patients and personnel to radiations and in some cases not realizable (acute cholecystitis, thin cystic duct) or even dangerous exposing to BTI.^[30-32] In addition, the misinterpretation of IOC can lead to an abusive exploration of the CBD or to ignore a real BTI.^[33] For all these reasons, our policy is not in favor of routine IOC.

Some data suggested the benefit of routine preoperative MRCP in LC. Nebiker *et al.*^[15] have reported no BTI in

454 LC with preoperative MRCP. Accessory bile ducts were found in 2.4% of patients, aberrant hepatic ducts in 0.4%, and an atypical entry to the CBD in 0.9%. In 22% of procedures, MRCP has been considered as highly helpful even by experienced surgeons. The authors suggested that the low morbidity rate observed in their series might be due to the better understanding of the biliary anatomy before surgery.^[15] A retrospective Chinese study^[16] compared the results of 600 LC with and without preoperative MRCP. They reported one BTI in the group MRCP versus 5 in the control group. Zang *et al.*^[17] compared retrospectively the results of IOC and MRCP in, respectively, 213 and 257 patients undergoing LC. The rate of BTI was 0.2% in the IOC group and 0.13% in the MRCP group. Recently, IRCAD has published its recommendations on safe LC.^[34] The expert group reported that preoperative MRCP might be a preventive measure in BTI avoidance despite the lack of evidence to support its systematic use.

In the era of modern surgery, surgical planning has gained wide acceptance in several fields.^[35] Preoperative imaging may allow surgeons to immerse themselves into the surgical procedure, to study each step and to detect pitfalls that can cause intraoperative complications. The complexity of bile tract anatomy is one of the major risk factors of BTI. Preoperative MRCP, with a thorough analysis of the biliary tract anatomy, allow the surgical team to identify “risky” anatomical situations before LC. Thus, preoperative identification of an accessory bile duct, an aberrant hepatic duct, or an atypical entry of cystic duct may increase the safety of the surgical procedure. The dissection is no longer “blind,” seeking normal anatomy. It becomes guided by the preoperative mapping. Anatomical variations are known before surgery, and the operation could proceed with more caution.

We believe that knowing “Dangerous” anatomical variations could help any surgeon including juniors to prevent BTI inherent to perilous biliary anatomy. In our series, 12 patients (3%) had, on preoperative MRCP, a perihilar insertion <1 cm of the cystic duct [Figure 1]. In 23 others (5.7%), the insertion into the CBD of the cystic duct was either posterior or left sided. Fourteen patients (3.5%) presented with a low insertion of a right sectorial or segmental duct into the CBD [Figure 2]. In three patients (0.75%), MRCP showed a hepatocystic duct whose position renders it particularly vulnerable during LC. The BTI could be unavoidable in the absence of preoperative biliary anatomy mapping. In all these situations, thanks to preoperative knowledge of the complex biliary anatomy, discussed routinely in the surgical staff in the presence of senior HPB surgeons, LC was performed safely.

These preliminary results can suggest that MRCP is useful as a preoperative investigation before LC to assess the

biliary anatomy. However, 3 BTI occurred during the study period: One CBD injury and two minor bile leakages.

The major BTI that we observed was diagnosed intraoperatively and had immediate surgical repair after IOC by a senior HBP surgeon of our department. Preoperative MRCP was considered normal. This led us to do not consider MRCP as a “magic potion” to prevent BTI but as a complementary tool to improve the preoperative stratification of surgical risk. As recommended by SAGES, LC has to be cautious and to follow CVS principles.^[23,24] In addition, in our center, the presence of a senior surgeon is mandatory to guide “risky” dissections.

This study assumes some limitations: It is a purely descriptive study without a group control. This is because we thought of reviewing results of MRCP in our patients before conducting a controlled study. It is also a monocentric study.

But, despite these limitations, we included 402 patients. Anatomical findings on MRCP reflects the nonrarity of “dangerous” anatomical variations. We tried to report our experience and our strategy in managing LC in patients with biliary anatomical variations: Preoperative diagnosis of anatomical variations using MRCP is of paramount importance and thus intraoperative performance of CVS guided by MRCP findings and with the presence of a senior HPB surgeon might safeguard surgical procedure. MRCP is part of our strategy to evaluate preoperatively the risk of BTI during LC.

CONCLUSION

MRCP with a thorough description of biliary tract anatomy can optimize, preoperatively, the selection of LC harboring a higher risk of BTI. Our results highlight the possible role of MRCP in sensitizing surgeons to pay attention to “dangerous” cystic and right or left hepatic duct variations. These results might be encouraging for further clinical trials that could be settled to evaluate the real value of MRCP and its cost-effectiveness in safeguarding LC.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Z'graggen K, Wehrli H, Metzger A, Buehler M, Frei E, Klaiber C, *et al.* Complications of laparoscopic cholecystectomy in Switzerland. A prospective 3-year study of 10,174 patients. Swiss association of laparoscopic and thoracoscopic surgery. *Surg Endosc* 1998;12:1303-10.
- Pesce A, Piccolo G, La Greca G, Puleo S. Utility of fluorescent cholangiography during laparoscopic cholecystectomy: A systematic review. *World J Gastroenterol* 2015;21:7877-83.
- Chaib E, Kanas AF, Galvão FH, D'Albuquerque LA. Bile duct confluence: Anatomic variations and its classification. *Surg Radiol Anat* 2014;36:105-9.
- Ford JA, Soop M, Du J, Loveday BP, Rodgers M. Systematic review of intraoperative cholangiography in cholecystectomy. *Br J Surg* 2012;99:160-7.
- Alvarez FA, de Santibañes M, Palavecino M, Sánchez Clariá R, Mazza O, Arbues G, *et al.* Impact of routine intraoperative cholangiography during laparoscopic cholecystectomy on bile duct injury. *Br J Surg* 2014;101:677-84.
- Rystedt JML, Tingstedt B, Montgomery F, Montgomery AK. Routine intraoperative cholangiography during cholecystectomy is a cost-effective approach when analysing the cost of iatrogenic bile duct injuries. *HPB (Oxford)* 2017;19:881-8.
- Petrescu I, Bratu AM, Petrescu S, Popa BV, Cristian D, Burcos T, *et al.* CT vs. MRCP in choledocholithiasis jaundice. *J Med Life* 2015;8:226-31.
- Ward WH, Fluke LM, Hoagland BD, Zarow GJ, Held JM, Ricca RL, *et al.* The role of magnetic resonance cholangiopancreatography in the diagnosis of choledocholithiasis: Do benefits outweigh the costs? *Am Surg* 2015;81:720-5.
- Sacher VY, Davis JS, Sleeman D, Casillas J. Role of magnetic resonance cholangiopancreatography in diagnosing choledochal cysts: Case series and review. *World J Radiol* 2013;5:304-12.
- Yu XR, Huang WY, Zhang BY, Li HQ, Geng DY. Differentiation of infiltrative cholangiocarcinoma from benign common bile duct stricture using three-dimensional dynamic contrast-enhanced MRI with MRCP. *Clin Radiol* 2014;69:567-73.
- Yoo RE, Lee JM, Yoon JH, Kim JH, Han JK, Choi BI, *et al.* 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;39:1509-17.
- Kinner S, Steinweg V, Maderwald S, Radtke A, Sotiropoulos G, Forsting M, *et al.* Comparison of different magnetic resonance cholangiography techniques in living liver donors including gd-EOB-DTPA enhanced T1-weighted sequences. *PLoS One* 2014;9:e113882.
- Rosenkrantz AB, Block TK, Hindman N, Vega E, Chandarana H. Combination of increased flip angle, radial k-space trajectory, and free breathing acquisition for improved detection of a biliary variant at living donor liver transplant evaluation using gadoteric acid-enhanced MRCP. *J Comput Assist Tomogr* 2014;38:277-80.
- Ragab A, Lopez-Soler RI, Oto A, Testa G. Correlation between 3D-MRCP and intra-operative findings in right liver donors. *Hepatobiliary Surg Nutr* 2013;2:7-13.
- Nebiker CA, Baierlein SA, Beck S, von Flüe M, Ackermann C, Peterli R, *et al.* Is routine MR cholangiopancreatography (MRCP) justified prior to cholecystectomy? *Langenbecks Arch Surg* 2009;394:1005-10.
- Zhang C, Yin M, Liu Q. The guidance impact of preoperative magnetic resonance cholangiopancreatography on laparoscopic cholecystectomy. *J Laparoendosc Adv Surg Tech A* 2015;25:720-3.
- Zang J, Yuan Y, Zhang C, Gao J. Elective laparoscopic cholecystectomy without intraoperative cholangiography: Role of preoperative magnetic resonance cholangiopancreatography – A retrospective cohort study. *BMC Surg* 2016;16:45.
- Sureka B, Bansal K, Patidar Y, Arora A. Magnetic resonance cholangiographic evaluation of intrahepatic and extrahepatic bile duct variations. *Indian J Radiol Imaging* 2016;26:22-32.

19. Sarawagi R, Sundar S, Raghuvanshi S, Gupta SK, Jayaraman G. Common and uncommon anatomical variants of intrahepatic bile ducts in magnetic resonance cholangiopancreatography and its clinical implication. *Pol J Radiol* 2016;81:250-5.
20. Kurata M, Honda G, Okuda Y, Kobayashi S, Sakamoto K, Iwasaki S, *et al.* Preoperative detection and handling of aberrant right posterior sectoral hepatic duct during laparoscopic cholecystectomy. *J Hepatobiliary Pancreat Sci* 2015;22:558-62.
21. Laurenzi A, Allard MA, Vibert E. Hepaticocholecystic duct: A pitfall of cholecystectomy. *Clin Case Rep* 2019;7:227-8.
22. Gurusamy KS, Vaughan J, Ramamoorthy R, Fusai G, Davidson BR. Miniports versus standard ports for laparoscopic cholecystectomy. *Cochrane Database Syst Rev* 2013; 8:CD006804. doi: 10.1002/14651858.CD006804.pub3.
23. Strasberg SM, Brunt LM. Rationale and use of the critical view of safety in laparoscopic cholecystectomy. *J Am Coll Surg* 2010;211:132-8.
24. Strasberg SM, Hertl M, Soper NJ. An analysis of the problem of biliary injury during laparoscopic cholecystectomy. *J Am Coll Surg* 1995;180:101-25.
25. Cohen JT, Charpentier KP, Beard RE. An update on iatrogenic biliary injuries: Identification, classification, and management. *Surg Clin North Am* 2019;99:283-99.
26. Berci G, Hunter J, Morgenstern L, Arregui M, Brunt M, Carroll B, *et al.* Laparoscopic cholecystectomy: First, do no harm; second, take care of bile duct stones. *Surg Endosc* 2013;27:1051-4.
27. Fingerhut A, Dziri C, Garden OJ, Gouma D, Millat B, Neugebauer E, *et al.* ATOM, the all-inclusive, nominal EAES classification of bile duct injuries during cholecystectomy. *Surg Endosc* 2013;27:4608-19.
28. Buddingh KT, Weersma RK, Savenije RA, van Dam GM, Nieuwenhuijs VB. Lower rate of major bile duct injury and increased intraoperative management of common bile duct stones after implementation of routine intraoperative cholangiography. *J Am Coll Surg* 2011;213:267-74.
29. Sheffield KM, Riall TS, Han Y, Kuo YF, Townsend CM Jr., Goodwin JS, *et al.* Association between cholecystectomy with vs. without intraoperative cholangiography and risk of common duct injury. *JAMA* 2013;310:812-20.
30. Ausania F, Holmes LR, Ausania F, Iype S, Ricci P, White SA, *et al.* Intraoperative cholangiography in the laparoscopic cholecystectomy era: Why are we still debating? *Surg Endosc* 2012;26:1193-200.
31. Massarweh NN, Devlin A, Elrod JA, Symons RG, Flum DR. Surgeon knowledge, behavior, and opinions regarding intraoperative cholangiography. *J Am Coll Surg* 2008;207:821-30.
32. Massarweh NN, Devlin A, Symons RG, Broeckel Elrod JA, Flum DR. Risk tolerance and bile duct injury: Surgeon characteristics, risk-taking preference, and common bile duct injuries. *J Am Coll Surg* 2009;209:17-24.
33. Way LW, Stewart L, Gantert W, Liu K, Lee CM, Whang K, *et al.* Causes and prevention of laparoscopic bile duct injuries: Analysis of 252 cases from a human factors and cognitive psychology perspective. *Ann Surg* 2003;237:460-9.
34. Conrad C, Wakabayashi G, Asbun HJ, Dallemagne B, Demartines N, Diana M, *et al.* IRCAD recommendation on safe laparoscopic cholecystectomy. *J Hepatobiliary Pancreat Sci* 2017;24:603-15.
35. Marescaux J, Clément JM, Tassetti V, Koehl C, Cotin S, Russier Y, *et al.* Virtual reality applied to hepatic surgery simulation: The next revolution. *Ann Surg* 1998;228:627-34.