



Anatomic Variations of Biliary Ducts: Magnetic Resonance Cholangiopancreatography Findings of 1041 Consecutive Patients

Bile Ducts and MRCP

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Abstract

Background It is important for surgical purposes to know the biliary tract anatomy and its variations in detail. The aim of the study was to evaluate the frequency of anatomical variations of the biliary tract at hepatic bifurcation level and also at cystic duct level using magnetic resonance cholangiopancreatography (MRCP).

Methods A total of 1041 patients (between 16 and 102 years of age, 600 women 441 men with mean age of 60.6) were included in the study. The MRCP imaging was carried out with a 1.5 Tesla magnetic resonance imaging (MRI) device by using heavily T2-weighted sequences.

Results Among the 1041 patients included in the study, 424 (40.7 %) showed anatomical variations at different levels of the biliary tree, and 12 of these patients (1.15 %) had two anatomical variations. Typical anatomy was present in 57.2 % of the females and 62.1 % males. The highest incidence of variation at the level of bifurcation was trifurcation with 133 patients (12.8 %) and at the level of cystic duct was the medial cystic duct insertion with 56 patients (5.37 %).

Conclusions Trifurcation and medial cystic duct insertion seem to be more frequent in females compared to males. It is necessary to have the knowledge of these variations to avoid possible complications and also help to achieve the most effective result. MRCP

is a helpful and noninvasive technique of diagnosing bile duct variations; a preoperative description of these variations may prevent various surgical complications, and we recommend a routine preoperative MRCP especially before laparoscopic cholecystectomy, liver resection surgery and liver transplant surgery.

Keywords Bile ducts · Magnetic resonance cholangiopancreatography · Anatomical variations of the bile duct · Cystic duct · Anatomical variations of the cystic duct

Introduction

The biliary tract is anatomically divided into two sections as intra- and extrahepatic ducts. The distribution of the intrahepatic biliary ducts is in harmony with the segmental anatomy of the liver. Intrahepatic biliary duct anatomy is coincident with liver segmental anatomy according to Couinaud classification [1, 2]. The individual biliary drainage system is parallel to the portal system. The right hepatic duct has two major branches: the right posterior duct draining the posterior segments, VI and VII, and the right anterior duct draining the anterior segments, V and VIII. The right posterior duct has an almost horizontal course, whereas the right anterior duct tends to have a more vertical course. The right posterior duct usually runs posterior to the right anterior duct and fuses it from a left (medial) approach to form the right hepatic duct. The left hepatic duct is formed by segmental tributaries draining segments II–IV. The common hepatic duct is formed by fusion of the right hepatic duct, which is usually short, and the left hepatic duct. The bile duct draining the caudate lobe usually joins the origin of the left or right hepatic duct. The cystic duct

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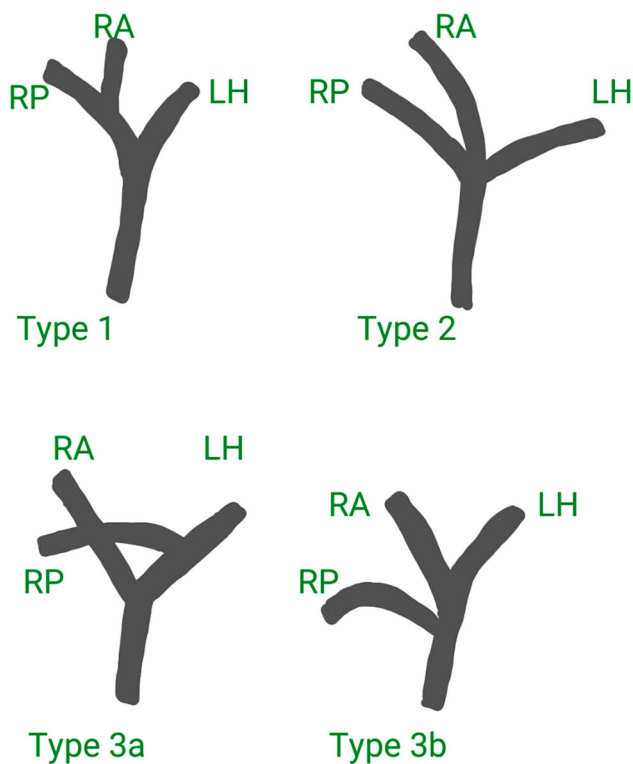


Fig. 1 A schematic figure showing the most frequent variations. Type 1: normal hepatic ductal anatomy. Type 2: the right posterior duct (RP) drained into the junction of the right anterior duct (RA) and the left main duct (LH). Type 3a: right posterior duct (RP), draining into the left main hepatic duct (LP). Type 3b: anomalous drainage of the right posterior duct (RP) draining into the common hepatic duct

classically joins the common hepatic duct below the confluence of the right and left hepatic ducts. This typical biliary anatomy is reported to range between 58 and 68 % of cases (Fig. 1; [1–4]).

The biliary tract is under the risk of iatrogenic damage during open or laparoscopic cholecystectomy, liver resection surgery and liver transplants from live donors because of anatomic variations. Also, the anatomical variations of the biliary system have been reported to lay the ground for the formation of gallstones, recurrent pancreatitis, cholangitis and biliary malignancies [4]. So, studies on the anatomical variations of the biliary ducts, especially before surgery and to identify their frequency, have recently formed a new area of interest. Magnetic resonance cholangiopancreatography (MRCP) is a magnetic resonance imaging (MRI) technique using T2-weighted sequences to evaluate the anatomy and pathologies of the pancreatobiliary system noninvasively and without contrast injection. MRCP can be evaluated rapidly, reliably and without the risk of complications, it becomes the modality of choice for noninvasive evaluation of abnormalities of the biliary tract. The purpose of this study is to evaluate anatomical variations of the intra- and the extrahepatic biliary ducts and to determine the frequency of each variation.



Fig. 2 Normal hepatic ductal anatomies in a 61-year-old woman with diabetes mellitus (Type 1). (* Right posterior hepatic duct, ** right anterior hepatic duct, *** left hepatic duct, + cystic duct, ++ common hepatic duct, +++ junction of common hepatic duct and cystic duct, ++++ Main pancreatic duct [Wirsung])

Materials and methods

Patient population

We retrospectively reviewed MRCPs obtained at our radiology department between January 1, 2013 and July 30, 2015 after obtaining the approval of the ethical board. A total of 1170 cases were examined, 129 cases with less than optimal results due to imaging limitations or with a history of surgery on the biliary tract except for cholecystectomy, were excluded from the study. A total of 1041 cases were included in the study.

Imaging

The MRI examinations of the patients were performed in our radiology department using a 1.5 T MR device (Philips Achiva, Philips Medical System, The Netherlands). Patients were informed about the MRCP imaging and they fasted for 6 hours beforehand, after which any metal items or objects on the patients which may produce artefacts were removed. Oral or intravenous contrast material was not used during the investigations.

In all patients, MR examinations were done including coronal and axial T2-weighted images (TR: 962 ms, TE: 100 ms, matrix: 312 × 268, number of slices: 24, slice thickness: 6 mm, FOV: 35–40 cm), coronal and axial GRE balanced FFE images (TR: 4 ms, TE: 1.24 ms, matrix: 156 × 213, number of slices: 24, slice thickness: 7 mm, FOV: 30–35 cm).



Fig. 3 Type 2 variation (Trifurcation: the right posterior duct (*) drained into the junction of the right anterior duct and the left main duct) in a 48-year old woman with cholelithiasis



Fig. 4 Type 3a variation (right posterior duct (*), draining into the left main hepatic duct) in an 85-year old man with acute cholecystitis

The choledochus was located in the images at the axial-coronal plane, then respiratory-triggered high-resolution 3D-TSE T2-weighted (TR: 1466, TE: 650, ETL: 128, matrix: 256 × 256, NSA: 1, slice thickness: 0.8 mm, FOV: 25–30 cm) para-coronal MRCP source and maximum intensity projection (MIP) reformatted images were obtained. MRCP is usually performed with heavily T2-weighted sequences by using single-shot fast spin-echo or fast spin-echo software and both a thick-collimation (single-section) and thin-collimation (multisection) technique with a torso phased-array coil.

Evaluation of the images

Images of MRCP retrieved from the Picture Archiving and Communication System (PACS) of our hospital were reviewed by two radiologists with experience in abdominal imaging of 1 (M. Adatepe) and 15 years (Z. H. Adibelli). Discordant interpretations were subsequently resolved by consensus of the two radiologists. Biliary system variations were classified mainly into two groups: at the level of bifurcation and at the level of cystic duct.

At the level of bifurcation, the typical biliary anatomy (type 1, Fig. 1 and 2) was defined when the right posterior duct drained into the right hepatic duct, and both the right and left hepatic ducts converged into the common hepatic duct. Trifurcation (type 2, Fig. 1 and 3) was defined when the right posterior duct drained into the junction of the right anterior duct and the left main duct. Abnormal right configuration included an anomalous drainage of the right posterior duct, draining into the left main hep-

atic duct (type 3a; Fig. 1 and 4) or into the common hepatic duct (type 3b; Fig. 1 and 5; [1–5]). Other rare variants at the level of bifurcation were quadrifurcation; filling defects evaluated as vascular compression on the common hepatic duct, aberrant right hepatic duct (insertion into the main hepatic duct proximally at the cystic duct, Fig. 6), duplication variant (fusion of the gallbladder with the right hepatic duct and fusion with the left hepatic duct proximally at the ampulla), insertion of the cystic duct into the right hepatic duct, and high localized gall bladder [5].

At the level of the cystic duct; insertion of the cystic duct into the one-third distal aspect of the extrahepatic bile duct was assessed as a long cystic duct or distal insertion; an insertion from the left was evaluated as a medial insertion (Fig. 7), and a cystic duct length shorter than 5 mm was evaluated as a short cystic duct. Other rare variants at the level of the cystic duct were an aberrant right hepatic duct (insertion into the cystic duct with a right lateral fusion with the main hepatic duct), and an aberrant right posterior duct (insertion into the cystic duct with a medial fusion into the main hepatic duct) [5].

Statistical analysis

Statistical significance was assumed at a P-value of < 0.05. Data documentation and statistical analyses were performed using Excel (v.2007, Microsoft Corporation, Redmond, WA, USA) and SPSS v.14 (SPSS Inc, Chicago, IL, USA).

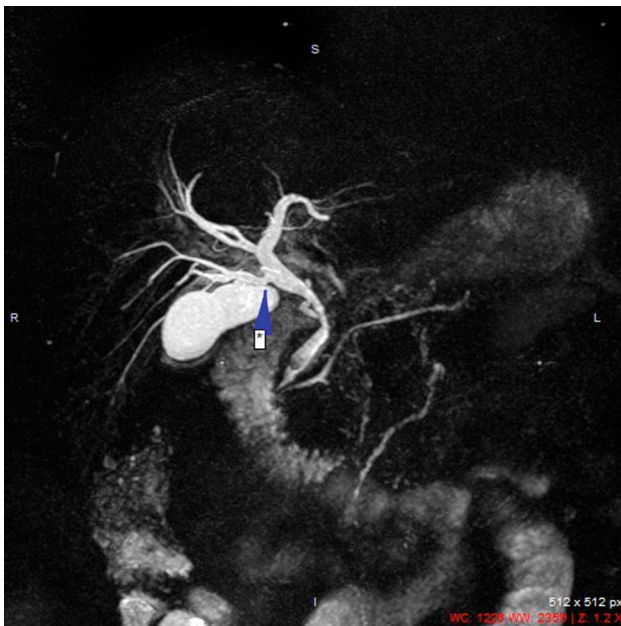


Fig. 5 Type 3b variation (anomalous drainage of the right posterior duct (*) draining into the common hepatic duct) in a 35-year old man with choledocholithiasis



Fig. 6 Uncommon biliary variant in a 71-year old woman evaluated after cholecystectomy operation. MRCP shows aberrant duct of segment 5 draining in to the common hepatic duct



Fig. 7 Distal medial insertion of a cystic duct (*) into a common hepatic duct in a 64-year old woman with acute cholecystitis

Results

We retrospectively evaluated the results of 1041 patients who underwent MRCP in our radiology department prior to liver resection surgery or due to suspicion of pancreatobiliary disease. Among the 1041 patients included in the study, 600 were female (57.6%) and 441 were male (42.4%). The mean age was 60.6 and the ages were between 16 and 102.

Among the 1041 patients, 320 patients (30.7%) had a history of cholecystectomy before MRCP examination, gall stones were found in 332 patients (31.9%) at the time of MRCP examination. Choledocholithiasis was found in 134 (12.8%) patients.

In this study, a total of 424 patients (40.7%) had anatomical variations of the intra- and extrahepatic bile ducts, 12 of them (1.15%) had two anatomic variations (Tab. 1). Among the 424 patients, 257 were female (42.8% of all female patients), 167 were male (37.9% of all male patients). The anatomical variations between the genders are shown in Tab. 2 and Tab. 3.

The most commonly observed variation at the level of the bifurcation was the right posterior duct drained into the junction of the right anterior duct and the left main duct (133 patients, 12.8%) (Tab. 2). On the other hand, the most commonly observed variation at the level of the cystic duct was the medial cystic duct insertion in 56 patients (5.37%) (Tab. 3). The distribution of the variations among the patients at the bifurcation level is summarized in Tab. 2, the distribution of the variations among the patients at the level of cystic duct is summarized in Tab. 3.

Discussion

Knowing the anatomical variations during surgical procedures is very important, especially when working on anatomic areas with high rates of variations, such as the hepatobiliary system. Many anatomical studies have been conducted in order to determine the specific anatomical variations, using cadaveric material, intra-operative data, or imaging

Tab. 1 Distribution of the variations in the patients in whom duplicate variations were detected

Variations	Number of patients	Ratio to the total number of patients (%)	Male, <i>n</i>	Female, <i>n</i>
Distal medial insertion of the cystic duct into the main hepatic duct with trifurcation	6	0.57	3	3
Insertion of the right posterior segmental branch into the common hepatic duct and distal medial cystic duct insertion into the main hepatic duct	1	0.09	1	
Insertion of the right posterior segmental branch into the left hepatic duct and distal medial cystic duct insertion into the main hepatic duct	3	0.28	1	2
Insertion of the right posterior segmental branch into the common hepatic duct and long cystic duct	1	0.09		1
Insertion of the right posterior segmental branch into the left hepatic duct and medial cystic duct insertion into the main hepatic duct	1	0.09		1
Total	12	1.15	5	7

Tab. 2 Normal and anatomical variations at the cystic level

Variations	Number of variations and percent (%)	Male, <i>n</i> (%)	Female, <i>n</i> (%)
Typical cystic duct insertion	952 (91.45)	407 (92.29)	545 (90.83)
Medial cystic duct insertion	20 (1.92)	4 (0.9)	16 (2.66)
Distal medial insertion	56 (5.37)	27 (6.12)	29 (4.83)
Short cystic duct	4 (0.38)	2 (0.45)	2 (0.33)
Long cystic duct	4 (0.38)	1 (0.22)	3 (0.5)
Insertion of the segment 5 duct into the cystic duct	1 (0.09)		1 (0.16)
Insertion of right dorsocaudal branch in to the cystic duct	2 (0.19)		2 (0.33)
Pancreatobiliary junction anomaly	2 (0.19)		2 (0.33)
Total	1041 (100)	441 (100)	600 (100)

Tab. 3 Normal and anatomical variations at the bifurcation level

Variations	Number of variations and percent (%)	Male, <i>n</i> (%)	Female, <i>n</i> (%)
Typical bifurcation (type 1)	693 (66.57)	302(68.48)	391 (65.16)
Trifurcation (type 2)	133 (12.77)	45 (10.22)	88 (14.64)
Right dorsocaudal branch draining into the left hepatic duct (type 3 A)	126 (12.1)	57 (12.92)	69 (11.5)
Aberrant right hepatic duct emptying into the common hepatic duct (type 3B)	52 (4.99)	23 (5.21)	29 (4.83)
Quadrifurcation	4 (0.38)	2 (0.45)	2 (0.33)
Vascular compression on the common hepatic duct	10 (0.96)	4 (0.90)	6 (0.99)
Right anterior hepatic duct insertion into the common hepatic duct	2 (0.19)	1 (0.22)	1 (0.16)
Aberrant segment 5 and 6 ducts (insertion into the common hepatic duct)	1 (0.09)		1 (0.16)
Insertion of the cystic duct into the right hepatic duct	2 (0.19)	1 (0.22)	1 (0.16)
Insertion of the cystic duct into the right dorsocaudal branch	3 (0.28)	1 (0.22)	2 (0.33)
Cystic duct emptying into the hepatic bifurcation	1 (0.09)		1 (0.16)
Aberrant segment 6duct (Insertion into the common hepatic duct)	2 (0.19)	1 (0.22)	1 (0.16)
Aberrant segment 3 duct (Insertion into the common hepatic duct)	3 (0.28)	1 (0.22)	2 (0.33)
Aberrant segment 4 duct (Insertion into the common hepatic duct)	2 (0.19)	1 (0.22)	1 (0.16)
Aberrant segment 5 duct (Insertion into the common hepatic duct)	3 (0.28)	1 (0.22)	2 (0.33)
Caudate segment bile duct draining into common hepatic duct	1 (0.09)		1 (0.16)
Caudate segment bile duct draining into common bile duct	2 (0.19)		2 (0.33)
Total	1041 (100)	441	600

Tab. 4 Review of the literature reporting biliary anatomic variants

First author	Year	Region	Cases, n	Imaging technique	Intrahepatic biliary anatomy, n (%)		
					Type 1	Type 2	Type 3 A/3B
Nakamura [18]	2002	Japan	120	Cholangiography	78 (65.0)	11 (9.2)	29 (24.2)
Vidal [19]	2007	France	45	MRCP	36 (80.0)	2 (4.4)	4 (8.9)
Sirvanci [20]	2007	Turkey	62	Cholangiography	43 (69.3)	6 (9.7)	11 (17.7)
Karakas [21]	2008	Turkey	112	MRCP	61 (54.5)	16 (14.3)	35 (31.2)
Cucchetti [3]	2011	Italy	200	Cholangiography	129 (64.5)	28 (14.0)	40 (20.0)
Mariolis-Sapsakos [2]	2012	Greece	73	Cadaveric	48 (65.7)	7 (9.6)	14 (19.1)
Onder [4]	2012	Turkey	590	MRCP	471 (79.8)	30 (8)	89 (15.1)
Uysal [5]	2013	Turkey	1011	MRCP	803 (79.4)	81 (8)	115 (11.4)
Present Study	2015	Turkey	1041	MRCP	693(66.57)	133(12.7)	178 (17.1)

such as ultrasonography and MRCP [1, 2, 6]. By using direct cholangiography methods (percutaneous transhepatic cholangiography (PTC) and endoscopic retrograde cholangiopancreatography [ERCP]) or indirect cholangiography methods (transabdominal ultrasonography, CT cholangiography and MRCP), we may obtain images of the biliary ducts [5]. MRCP has certain advantages over the other techniques; it is safer (no exposure to ionizing radiation, no using contrast agent, no premedication) than invasive methods (ERP and PTC), it can be also used for staging malignancy and it does not carry the risk of developing complications, it can be applied during acute attacks of pancreatitis and cholangitis, it gives us the chance to view the extraductal structures as well as by using the conventional T1–T2 -weighted images. ERCP and PTC have some superior benefits, such as tissue sampling and therapy, as compared to MRCP. However, these advantages are accompanied by a range of complications (major complications of ERCP 1.38 % and deaths 0.21 %, major complications of therapeutic ERCPs 5.4 % and deaths 0.49 %, the major complication of PTC < 5 % and deaths 0.1 %; [7–9]). The limitations of MRCP are its low resolution, the inability to show minor ductal pathologies and the inability to perform therapeutic interventions during the procedure.

Gallbladder disease is a common problem today; approximately 10–15 % of the western population have gallstones [10–12]. Age, gender, race, obesity, diabetes and parity have all been identified as significant risk factors for the development of gallstones. In one study, a 15.4 % prevalence rate of cholelithiasis was found in a Turkish population sample of postmenopausal women [13]. In our study group, a total of 652 patients had gallstones before and at the time of MRCP (62.6%) and choledocholithiasis was found in 134 (12.8 %) patients. The rate of gallstones and choledocholithiasis in our study group is higher than these rates, because most of our patients were evaluated by MRCP due to suspicion of pancreatobiliary disease. The mean age (which was 60.6) and the female/male ratio (which was 1.3) of our study group

was also cause of that high incidence of cholelithiasis and choledocholithiasis.

Anatomical variations of the biliary tract were observed in 424 (40.7 %) of the 1041 patients included in our study. When the variations were divided into two groups such as those at the bifurcation level and the cystic duct level, it was found that the most frequently observed variation in general was at the bifurcation level. The drainage of the right posterior hepatic duct into junction of the right anterior duct and the left main duct (trifurcation, Type 2) was the most common variation at the bifurcation level with 133 patients (12.8 %) and a typical biliary anatomy (Type 1) was found in 693 patients (66.5 %). (Tab. 2). We report the distributions of normal biliary anatomy and its variants published in the last 10 years, originating from the literature search shown in Tab. 4. The typical intrahepatic biliary anatomy is present in about 60 % of Europeans and Americans, whereas a slightly higher prevalence was observed in Asians (65 %), and these rates are similar to our study [3].

On the other hand, Uysal et al. [5] evaluated MRCP investigations of 1011 patients in one of the largest studies in Turkey; typical intrahepatic biliary anatomy was present in about 80 % of their study group, trifurcation turned out to be the most common anatomic variation in their study, with the aberrant right hepatic duct emptying into the common hepatic duct (Type 3B) as the second most common finding. In our study, typical biliary anatomy was found in about 66.5 % which is lower than their value. Trifurcation was to be the most common anatomic variation in our study also, but right dorsocaudal branch draining into the left hepatic duct (Type 3 A) was the second most common finding. The partial difference may be due to the study populations. Even though both of the populations are from the Aegean part of Turkey, our patients received MRCP mostly due to suspicion of pancreatobiliary disease. The patients in the study by Uysal et al. were evaluated due to suspicion of pancreatobiliary disease and also to examine the anatomy of liver donor candidates.

The aim of our study, which to the best of our knowledge has the largest sample size in the literature

was to evaluate the frequency of anatomical variations at bifurcation and cystic duct level together during a certain time interval. In an MRCP study of 590 cases by Onder et al. [4] it was found that at the level of the cystic duct, medial insertion of the cystic duct was viewed in 58 patients (9.8%), distal medial insertion was seen in 40 patients (6.8%), a short cystic duct was detected in 10 patients (1.7%). In our study, typical cystic duct insertion was observed in 952 patients (91.4%) and the most frequently observed variation at the level of the cystic duct was medial insertion observed in 56 patients (5.37%). The prevalence rates of anatomic variants especially at cystic level are different in our study group (Tab. 3). Our study population is mostly from Aegean part of Turkey, Onder et al.'s study group was from south eastern part of Turkey, the different prevalence may be because of ethnicity and using 1.5 and 3 T MRI device.

In our study population, the female to male ratio was 1.36. When we consider biliary duct anatomical variations both at the level of bifurcation and cystic duct, we found that 42.8% of the female patients and 37.91% of the male patients of our study population had anatomic variation, 12 patients had two anatomic variations at both levels (Tab. 1–3). Cucchetti et al. informed of a female to male ratio that ranges from 1.7 for an abnormal right configuration of the posterior right duct to 3.7 for biliary trifurcation [3]. Uysal et al. found a female to male ratio ranging from 1.6 for the right dorso-caudal branch draining into the left hepatic duct to 3.3 for biliary trifurcation [5]. We found female to male ratios; 1.34 for Type 1 configuration, 1.96 for trifurcation, 1.21 for Type 3 A, 0.97 for type 3B, 4 for medial cystic duct insertion to common hepatic duct. This may be the consequence of different embryologic development. The knowledge that females can more frequently present an abnormal biliary duct configuration can also help surgeons to avoid surgical injury.

It is very important to identify atypical or anomalous ducts preoperatively or intra-operatively and to use the appropriate the surgical technique in order to avoid serious postoperative complications. The presence of anomalies of the cystic duct and the hepatic bile ducts, for example with drainage of the cystic duct into the left side of the common hepatic duct, constitute one of the major causes of bile duct injuries after laparoscopic cholecystectomy [2, 14]. Also, the knowledge of anatomical variations can help surgeons to plan potential living donor evaluation and liver resection surgery [3]. MRCP is a helpful and non-invasive technique of to diagnose bile duct variations to prevent various surgical complications. However, in times of reduced financial resources, it may not be possible to perform MRCP in every patient preoperatively. It is of interest to evaluate the anatomy during the surgery. The primary method would be clean dissection and accurate visual identification of the contents of Calot's triangle [15]. Therefore, meticulous

surgical preparation of the bile ducts and Calot's triangle are indispensable in finding the exact anatomy intraoperatively, so intraoperative cholangiography to document the bile duct anatomy may be used. Using a routine intraoperative cholangiography in evaluating biliary anatomy and preventing misidentification has been a point of contention amongst biliary surgeons and there is conflicting evidence on its value [15]. Also, there is not consensus on the use of laparoscopic ultrasound or colour Doppler ultrasound for identification of the ducts and arteries [16]. However, cost is also a factor to consider for these alternatives of MRCP. In addition to this, intra-operative errors in perception, judgment, and decision-making occasionally cause bile duct injuries [17] So, we think that intraoperative procedures result in a higher risk on the surgeon's part, and if the surgeon and the radiologist were to examine the biliary anatomy together before surgery by using MRCP, this would reduce rate of surgical injury.

There are some limitations of our study. One of them is that we do not have a reference standard because of ethical issues; the patients did not undergo more invasive imaging techniques such as cholangiography or surgery. The second limitation is that most of our patients underwent MRCP in our radiology department with suspected biliary or pancreatic disease and because of this our study population may not sample the population. The third limitation is the retrospective nature of the study.

In conclusion, the typical intra-hepatic biliary anatomy (Type 1) is present in about 66.7% and typical cystic duct insertion is observed in about 91.4% of our study group. The two most common variations were trifurcation of the right anterior segmental duct, right posterior segmental duct, and left hepatic duct (Type 2, 12.8%) and the right posterior duct draining into the left main hepatic duct (Type 3a, 12.1%). Trifurcation and medial insertion of the cystic duct seem to be more frequent in females than in males. With the increase in hepatic surgical procedures and biliary interventions, it is necessary to have widespread and appropriate knowledge of these anatomical variations, in order to avoid possible complications and also help to achieve the most effective result. We recommend a routine preoperative MRCP especially before laparoscopic cholecystectomy, liver resection surgery and liver transplant surgery. MRCP is a helpful and noninvasive technique to diagnose bile duct variations and a preoperative description of these variations, and may prevent various surgical complications.

Compliance with ethical guidelines

Conflict of interest M. Adatepe, Z.H. Adibelli, O.S. Esen, C. Imamoglu, M. Yildirim and N. Erkan state that there are no conflicts of interest.

Ethical standards All procedures followed in accordance with the ethical standards of the responsible committee on human experimentation (institutional) and with the Helsinki Declaration of 1975, as revised in 2008. This was a retrospective study, informed consent was obtained from all patients before MRI examinations.

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