Section A-Research paper
ISSN 2063-5346

Magnetic resonance cholangiopancreatographic evaluation of intrahepatic bile duct variations

1. Manish Kumar Singh 2. Dr. Yogesh yadav
3. Dr. Ashish Shukla 4. Dr. Mahindra Kumar Anand
1. Department of Anatomy, Santosh Medical College and Hospital Delhi NCR.
2. Professor and Head, Department of Anatomy, Noida international institute of medical sciences greater Noida
3. Professor, Department of Radiology, Santosh Medical College and Hospital, Delhi NCR
4. Professor and Head Department of Anatomy, Santosh Medical College and Hospital, Delhi NCR.

Corresponding Author: Dr. Yogesh yadav

ABSTRACT

Background: Biliary anatomy and its common and uncommon variations are of considerable clinical significance when performing living donor transplantation, radiological interventions in hepatobiliary system, laparoscopic cholecystectomy, and liver resection (hepatectomy, segmentectomy). Because of increasing trend found in the number of liver transplant surgeries being performed, magnetic resonance cholangiopancreatography (MRCP) has become the modality of choice for noninvasive evaluation of abnormalities of the biliary tract. The purpose of this study is to describe the anatomic variations of the intrahepatic biliary tree.

Materials and methods: This quantitative, cross sectional study was performed in patients referred for MRCP examinations for various clinical indications to the Department of Radiology and Imaging, Santosh medical college & hospital Ghaziabad. Data were collected for a period of four months from August to November 2019 after IRB approval. Convenience sampling was employed and a total of 374 examinations were included. Patients with history of hepatic or biliary surgery were excluded from the study. Data were obtained from the 1.5T Magnetom Amira Siemens MRI scanner. Informed consent forms were taken from the patients meeting the inclusion criteria. The routine department protocol was followed for the MRCP examinations. The patients were thoroughly screened as per department guidelines for any ferromagnetic material. Freshly crushed pineapple juice was given to the patients prior to the examination to reduce fluid signal from the stomach.

Result: Among 374 patients, including 288 males and 246 females, a normal morphology of intrahepatic biliary system (Type I) was found in 53.5% of cases. The second most frequent presentation, in about 14.7% of patients, was Type III a with RPD emptying on the left hepatic duct. The triple confluence morphology (Type II) was found in 10.4% of cases.

Conclusion: Delineation of the precise normal biliary anatomy and anatomical variants is mandatory for donor selection and surgical planning to minimize postoperative biliary complications in the donor as well as the recipient.
Keywords: MRCP; intrahepatic biliary tree; intraoperative cholangiography

INTRODUCTION

The anatomy of the biliary tree is complex, with the existence of multiple intrahepatic and extrahepatic anatomical variants. Serious consideration of the surgical anatomy of the liver has begun with the advent of therapeutic interventions for the bile duct, liver resections and partial liver transplantations with increasing frequency and complexity. [1] Accurate widespread knowledge of the biliary anatomy and its variations is needed to plan the surgeries and minimize post-operative complications [2]. MRCP is an accurate and non-invasive imaging technique for demonstration of bile duct anatomy. It is a safer modality, devoid of ionizing radiation, which can be performed in patients allergic to iodinated contrast agents [3].

The intrahepatic bile ducts typically follow the portal veins along their anterior aspect. The right hepatic duct is composed of an anterior segmental branch, which drains Couinaud’s segment 5 and 8 of the liver, and a posterior segmental branch, which drains segment 6 and 7. The right anterior sectoral duct (RASD) is vertically oriented whereas the right posterior sectoral duct (RPSD) is more horizontally oriented. [4] Normally, RPSD passes posterior to RASD and joins it from the medial aspect. The left hepatic duct drains segments 2, 3 and 4 of the liver. The bile duct from the caudate lobe usually joins the origin of the left and right hepatic ducts. The right and left main hepatic ducts unite in the hilum to form the common hepatic duct (CHD). [5] The typical branching pattern is seen in 50–60% of population with a significant number of subjects showing variation in the branching pattern.

Radiologists, are all acquainted with the cross‑sectional segmental anatomy of the liver. Variations in hepatic artery, portal vein, hepatic veins, and biliary tree are common and knowledge of these anatomic variations is of considerable clinical relevance as there has been an increasing trend in the radiological intervention procedures and liver transplantation surgeries. [6]

Intrahepatic and extrahepatic bile duct variations are commonly seen. Normal biliary anatomy is seen in only 58% of the population. There are various techniques available for the visualization of biliary tree. [7] Intravenous cholangiography often does not opacify the intra and extrahepatic biliary tree and rarely allows a detailed visualization of the duct bifurcation. Endoscopic retrograde cholangiopancreatography (ERCP), although very accurate, is an invasive method for imaging the biliary tree. Intraoperative cholangiography is also highly accurate; however, it is an invasive procedure and its routine use remains controversial. [8]

Magnetic resonance cholangiopancreatography (MRCP) is an excellent non‐invasive imaging technique for visualization of detailed biliary anatomy. High‐resolution cross‐sectional, two‐dimensional (2D) and three‐dimensional (3D) projection images provide excellent detailed anatomy which is comparable to ERCP and intraoperative cholangiograms. [9] In this article, we will discuss the different patterns of intra hepatic duct variations. We will also highlight the clinical significance of these anatomic variations.

MATERIALS AND METHODS

This quantitative, cross sectional study was performed in patients referred for MRCP examinations for various clinical indications to the Department of Radiology and Imaging, Santosh medical college & hospital Ghaziabad.

Inclusion Criteria

1. Patients undergoing MRCP Abdomen as a part of their investigations

2. Patients within the range 18 to 70 years were included in the study

Exclusion Criteria

1. Patients in whom MRI is contraindicated

Convenience sampling was employed and a total of 374 examinations were included. Patients with history of hepatic or biliary surgery were excluded from the study. Data were obtained from the 1.5T Magnetom Amira Siemens MRI scanner. Informed consent forms were taken from the patients meeting the inclusion criteria. The routine department protocol was followed for the MRCP examinations. The patients were thoroughly screened as per department guidelines for any ferromagnetic material. Freshly crushed pineapple juice was given to the patients prior to the examination to reduce fluid signal from the stomach. The routinely obtained sequences in TUTH are as follows:

- T2 HASTE coronal respiratory triggering: FOV 350mm, slice thickness 4.5mm, TR 2000ms, TE 93ms, slices 25, distance factor 50%, PAT 2, voxel size 1.1x1.1x4.5mm.
- T2 HASTE transverse respiratory triggering: FOV 370mm, slice thickness 5mm, TR 2000ms, TE 99ms, slices 30, distance factor 40%, PAT 2, voxel size 1.4x1.4x5mm.
- T2 FBLADE FATSAT respiratory triggering: FOV 380mm, slice thickness 6mm, TR 3000ms, TE 90ms, slices 30, distance factor 30%, PAT 2, voxel size 1.2x1.2x6 mm.

- T2 HASTE FATSAT coronal thick slab breath hold: FOV 350mm, slice thickness 4.5mm, TR 2000ms, TE 93ms, slices 25, distance factor 50%, PAT 2, voxel size 1.1x1.1x4.5mm.
- T2 SPACE coronal respiratory triggering: FOV 380mm, slice thickness 1mm, TR 2500ms, TE 520ms, slabs 1, slices per slab 72, no slice oversampling, PAT 2, voxel size 0.5x0.5x1mm.

The 3D SPACE images were reformatted with Maximum Intensity Projection. These images were then visually analyzed to determine the IHBD variations.

The percentage of IHBD variations according to gender were cross tabulated. The percentage of cases having normal (Type 1) and abnormal (Type 2/3A/3B/3C/4/5A/5B/6/7) were determined.

RESULTS

Among 374 patients, including 288 males and 246 females, a normal morphology of intrahepatic biliary system (Type I) was found in 53.5% of cases. The second most frequent presentation, in about 14.7% of patients, was Type III a with RPD emptying on the left hepatic duct. The triple confluence morphology (Type II) was found in 10.4% of cases. Only 5.3% of patients presented Type3b variant with aberrant RPD draining into the common hepatic duct; it was found that, in the presence of this variation, in 42% of patients with Type III b variant, the cystic duct drained directly into the aberrant duct. In about 9.4% of cases, more complex biliary variants were found. Biliary classification was done as per to the ERCP findings of Huang et al., [10]. These were A1 (right and left hepatic ducts forming a common hepatic duct), A2 (trifurcation formed by the right anterior hepatic duct), A3 (drainage of the right posterior hepatic duct into the left hepatic duct), A4 (drainage of the right posterior hepatic duct into the common hepatic duct) and A5 (right posterior hepatic duct into the cystic duct). All anatomic presentations of the intrahepatic biliary tree are summarized in Table 2.

At the time of study review, thirty studies were identified by the literature search (5-32), of which fifteen were MRCP studies, eleven intra-operative cholangiography studies, three CT-cholangiographic reports and one ERCP study. Taking all of the studies into account, the total number of patients was 14,322. Type 1 presentation ranged from 40% to 80%. The largest study was published by Puente et al (11) in 1983 with a sample size of 3,845 patients using cholangiography, the smallest was by Ayuso et al (12) in 2004 on only 25 patients with MRCP.

Table 1. Parameters used in our MRCP protocol. (SSFSE: Shot Fast Spin Echo sequences; FRFSE: Fast Recovery Fast Spin Echo acquisitions)

	THICKNESS	GAP	TIME REQUIRED
THICK SLAB 2D SSFSE	50 mm	n/a	1-2 sec for slice/2 min
THIN-SECTION 2D	3 mm	0-1 mm	20-25 sec

ISSN 2063-5346

SSFSE			
RESPIRATORY-TRIGGERED 3D FRFSE	2-3 mm	1 mm	2-3 min
BREATH-HOLD 3D FRFSE	3 mm	0-1 mm	24-27 sec

Table 2. Anatomical variants of intrahepatic biliary system at MRCP (RPD: right posterior duct; LHD: left hepatic duct)

Intrahepatic bile ducts	**No of patients**	**Percentage (%)**
Normal	200	53.5
RPD on LHD	55	14.7
Triple confluence	39	10.4
Aberrant RPD	20	5.3
Others	35	9.4
Type IV	7	1.9
Type Va	6	1.6
Type Vb	7	1.9
Type VI	5	1.3

Table 3: Anatomical variants of intrahepatic biliary system at MRCP (RPD: right posterior duct; LHD: left hepatic duct)

	No of patients	**Percentage (%)**
Extra Hepatic duct		
Normal	221	59.0909091
Cranial	63	16.8449198
Caudal	90	24.0641711
Unclassified	221	59.0909091
Side-wall insertion		
Posterior	145	38.7700535
Medial	51	13.6363636
Lateral	153	40.9090909
Anterior	12	3.20855615
On aberrant RPD	13	3.47593583
Extra Hepatic Cystic duct course		
Parallel	131	35.026738
Convolute	95	25.4010695
Unclassified	148	39.5721925

Regarding the anatomy of the cystic duct, in 59.9% of patients a normal anatomy was observed, with 38.7% of cases showing implantation on the posterior side wall of the common bile duct, as reported in Table 3. In 16.8% of patients, the implantation of the cystic duct was cranial; in 24% of cases, the cystic duct joined the caudal portion of the common bile duct. In about 12% of cases, the course of the cystic duct was not depicted on MRCP images: consequently, we reported these conditions as "unclassified". By analyzing the course of the cystic duct in relation to the common hepatic duct, a parallel course was detected in 35% of patients and a convolute course in 25.4% of cases.

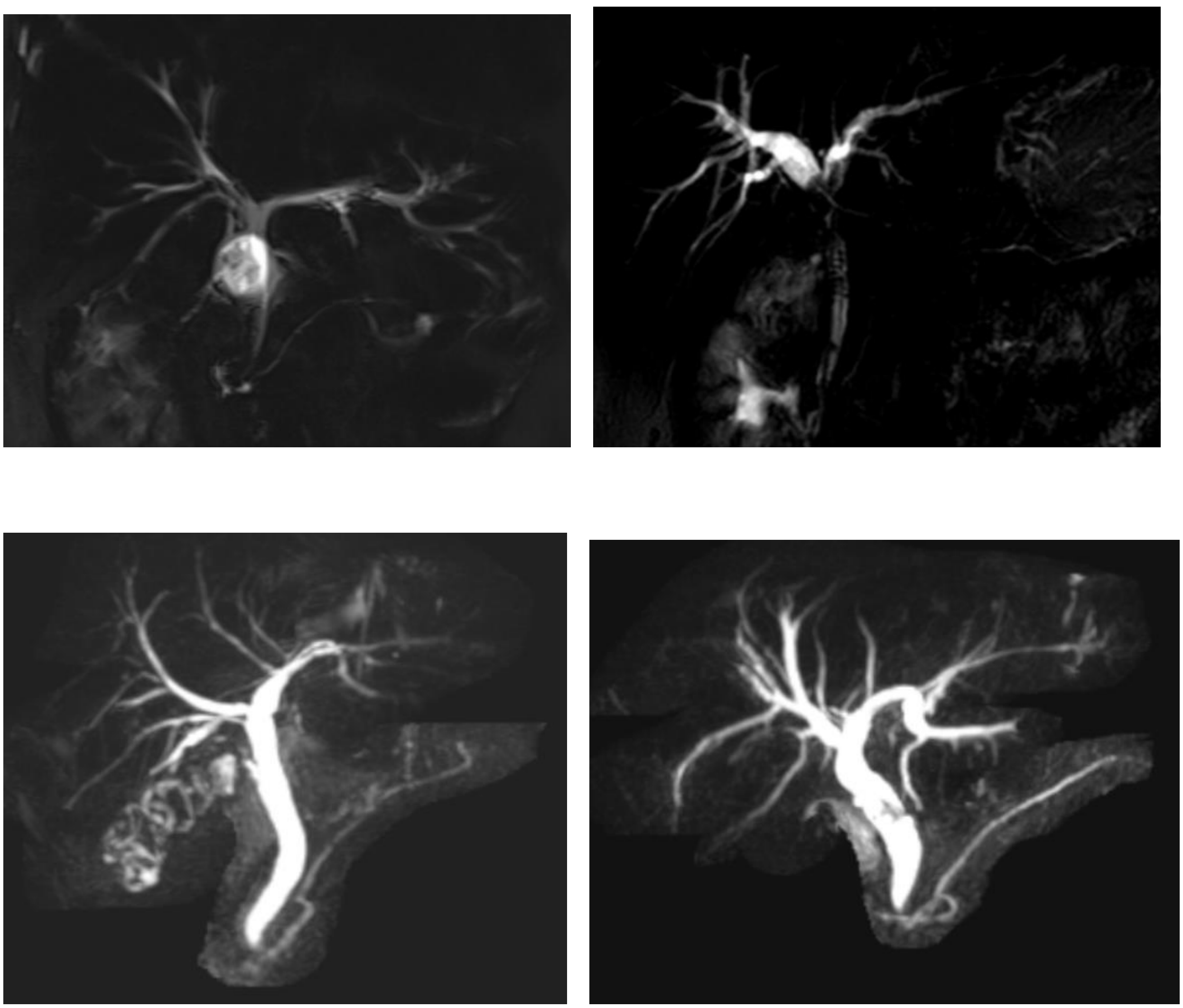

Fig: - Intra hepatic bile duct

DISCUSSION

The biliary tree has a high frequency of variations; as a result, misidentification of the biliary anatomy can result in several complications that may influence the patient's initial prognosis. Biliary anatomy analysis is critical for the surgical results of liver procedures, especially in cases of liver transplantation. Failure to recognize any minor intrahepatic branches that cross the dissection line can ultimately result in unembellished postoperative biliary leakage and complications. Biliary complications following liver transplantation have been stated in 10–25% of cases overall, with approximately 10% of these cases proving fatal. [13]

Over the last two decades, MRCP has evolved considerably, aided by improvements in acquisition speed and spatial resolution. It now has a recognized role in examining many disorders related to the biliary nature, helping as a non-invasive substitute for ERCP. MRCP uses heavily T2-weighted pulse sequences in which slow-moving or static fluids inside the pancreatic duct and the biliary tree appear as high signal strength on MRCP. Simultaneously, the adjacent tissue has reduced signal intensity. Heavily T2-weighted images were initially obtained via modified fast spin-echo (FSE) sequences and gradient-echo (GRE) balanced steady-state free precession techniques. [14]

In the current study, we found that the most frequent morphological presentation of bile ducts was the pattern classified as "Type I"; according to the literature data this pattern ranges from 40% to 80%. [15] The second most common presentation was Type 3a in 20% of cases. An important piece of data in the current study regards the aberrant RPD (observed in 6.7% of cases): it has been found that almost half of these patients (2.8%) showed the cystic duct draining into the aberrant RPD. The percentage reported in our analysis is higher than the value referred by Nayman et al, [16] which classified this biliary variant as "Type 18". This variant was in fact reported in only one patient (0.05%). It is essential to distinguish and recognize all biliary variants, even the rarest, to plan hepatobiliary surgery accurately.

This study adopted the Choi. [17] classification of biliary branching patterns. Type I (classic) showed horizontal RPSD joining the vertical RASD to form RHD, joining the confluence with a stem more than 1 cm in length; type II: trifurcation pattern; type III: RPSD inserted into LHD (a), into CHD (b), and into the cystic duct (c); type IV: RHD inserted into the cystic duct; type V: classic type with accessory duct inserted into CHD (a) or RHD (b); type VI: individual draining of segments II and III into RHD; and type VII: unclassified patterns. Wang. [18] showed that 56% of the donors had a type I classic branching pattern, 11% had a type II trifurcation pattern, 18% had a type III branching pattern, and 8% had a type III-b branching pattern. In a study conducted by Basaran, 67.5% of donors presented with a type I classic branching pattern, 5% with a type II trifurcation pattern, 20% with type III-a, and 2.5% with type III-b. [19]

The type I classic branching pattern was observed in 803 subjects (79.4%), while the remaining 208 subjects (20.6%) presented different anatomical variations. Wang CL. [20] reviewed MRCP examinations of 475 patients with suspected pancreaticobiliary disorders and found 115 individuals (24.2%) with various anatomic abnormalities. Our study yielded similar results. According to the IOC, 23 out of 35 subjects (65.7%) had a type I classic branching pattern, 4 (11.4%) had a type II trifurcation branching pattern, 2 (5.7%) had a type III-a pattern, 2 (5.7%) had a type III-b pattern, 3 (8.6%) had a type IV pattern, and 1 (2.9%) had a type VII unclassified pattern. MRCP revealed type I in 22 subjects (62.9%), type II variant in 6 subjects (17.1%), type III variant in 4 subjects (11.4%), and type IV variant in 3 subjects (8.6%). MRCP could not correctly diagnose type VII, so it was interpreted as type II. Additionally, MRCP falsely diagnosed one of the standard classical types as a pattern. While the IOC precisely delineated the intrahepatic biliary radicles in all subjects, the 3D MRCP accurately delineated 33 subjects, with a diagnostic accuracy of 97.1%.

MRCP data collection has been significantly improved in terms of spatial and temporal resolution, allowing MRCP to remain the gold standard for evaluating hepatobiliary disease. Furthermore, MRCP continues to play a crucial role in the non-invasive evaluation of several pancreatic biliary disorders. [21] Biliary obstruction is one of the best indications for MRCP. MRCP can definitely see dilated biliary ducts and may be used to measure the extent of obstruction in extrahepatic bile ducts. Furthermore, the great spatial and contrast resolution provides preoperative information on the intra- and extra-biliary distribution of potentially malignant strictures. [22]

CONCLUSION

Delineation of the precise normal biliary anatomy and anatomical variants is mandatory for donor selection and surgical planning to minimize postoperative biliary complications in the donor as well as the recipient. MRCP (2D and 3D) is a reliable method for preoperative assessment of the normal intrahepatic biliary anatomy and anatomical variants; nevertheless, adding contrast-enhanced MRCP will significantly improve the diagnostic accuracy and approximate it to the golden standard IOC.

REFERENCES

1. Sahani, D.; Mehta, A.; Blake, M.; Prasad, S.; Harris, G.; Saini, S. Preoperative hepatic vascular evaluation with CT and MR angiography: Implications for surgery. Radiographics 2004, 24, 1367–1380. [CrossRef] [PubMed]
2. Sarawagi, R.; Sundar, S.; Raghuvanshi, S.; Gupta, S.K.; Jayaraman, G. Common and Uncommon Anatomical Variants of Intrahepatic Bile Ducts in Magnetic Resonance Cholangiopancreatography and its Clinical Implication. Pol. J.Radiol. 2016, 81, 250–255. [CrossRef]

3. Plantefève, R.; Peterlik, I.; Haouchine, N.; Cotin, S. Patient-specific biomechanical modeling for guidance during minimallyinvasive hepatic surgery. Ann. Biomed. Eng. 2016, 44, 139–153. [CrossRef] [PubMed]
4. Suzuki, T.; Ebata, T.; Yokoyama, Y.; Mizuno, T.; Igami, T.; Yamaguchi, J.; Onoe, S.; Watanabe, N.; Nagino, M. Left trisectionectomy combined with resection of the right hepatic vein and inferior vena cava after right hepatic vein embolization for advanced intrahepatic cholangiocarcinoma. Surg. Case Rep. 2019, 5, 1–4. [CrossRef] [PubMed]
5. Bhangui, P.; Sah, J.; Choudhary, N.; Gautam, D.; Gupta, V.; Srinivasan, T.; Rastogi, A.; Piplani, T.; Saraf, N.; Saigal, S.; et al. Safe use of right lobe live donor livers with up to 20% macrovesicular steatosis without compromising donor safety and recipient outcome. Transplantation 2020, 104, 308–316. [CrossRef] [PubMed]
6. Cannataci, C.; Degiorgio, S.; Carollo, V.; Mamone, G.; Miraglia, R.; Cortis, K. Biliary variants and their surgical relevance. Eur. Congr. Radiol. 2019. [CrossRef]
7. Catalano, O.A.; Singh, A.H.; Uppot, R.N.; Hahn, P.F.; Ferrone, C.R.; Sahani, D.V. Vascular and biliary variants in the liver: Implications for liver surgery. Radiographics 2008, 28, 359–378. [CrossRef]
8. Gupta RT, Brady CM, Lotz J, Boll DT, Merkle EM. Dynamic MR imaging of the biliary system using hepatocyte‑specific contrast agents. AJR Am J Roentgenol 2010;195:405‑ 13.
9. Kamisawa T, Takuma K, Anjiki H, Egawa N, Kurata M, Honda G, et al. Pancreatico biliary maljunction. *Clin Gastroenterol Hepatol*. 2009; 7: S84-88.
10. Huang TL, Cheng YF, Chen CL, Chen TY, Lee TY. Variants of the bile ducts: clinical application in the potential donor of living-related hepatic transplantation. *Transplant Proc*. 1996;28: 1669–70.
11. Puente SG, Bannura GC. Radiological anatomy of the biliary tract: variations and congenital abnormalities. World J Surg. 1983;7 (2):271-6.
12. Ayuso JR, Ayuso C, Bombuy E, De Juan C, Llovet JM, De Caralt TM, Sánchez M, Pagés M, Bruix J, García-Valdecasas JC. Preoperative evaluation of biliary anatomy in adult live liver donors with volumetric mangafodipir trisodium enhanced magnetic resonance cholangiography. Liver Transpl. 2004;10 (11):1391-7.
13. Mortelé KJ, Ros PR. Anatomic variants of the biliary tree: MR cholangiographic findings and clinical applications. AJR Am J Roentgenol 2001;177:389‑ 94.
14. Gazelle GS, Lee MJ, Mueller PR. Cholangiographic segmental anatomy of the liver. Radiographics 1994;14:1005‑ 13.
15. Gupta A, Rai P, Singh V, Gupta RK, Saraswat VA. Intrahepatic biliary duct branching patterns, cystic duct anomalies, and pancreas divisum in a tertiary referral center: A magnetic resonance cholangiopancreaticographic study. Indian J Gastroenterol. 2016 Sep;35 (5):379-384.

16. Nayman A, Özbek O, Erol S, Karakuş H, Kaya HE. Magnetic Resonance cholangiopancreatography evaluation of intrahepatic bile duct variations with updated classification. Diagn Interv Radiol. 2016;22 (6): 489–494.
17. Choi JW, Kim TK, Kim KW, Kim AY, Kim PN, Ha HK, et al. Anatomic variation in intrahepatic bile ducts: An analysis of intraoperative cholangiograms in 300 consecutive donors for living donor liver transplantation. Korean J Radiol 2003;4:85‑ 90.
18. Basaran, C.; Agildere, M.; Donmez, F.Y.; Sevmis, S.; Budakoglu, I.; Karakayali, H.; Haberal, M. MR cholangiopancreatography with T2-weighted prospective acquisition correction Turbo spin-echo sequence of the biliary anatomy of potential living liver transplant donors. *Am. J. Roentgenol.* **2008**, *190*, 1527–1533.
19. Wang, C.L.; Ding, H.Y.; Dai, Y.; Xie, T.T.; Li, Y.B.; Cheng, L.; Wang, B.; Tang, R.H.; Nie, W.X. Magnetic resonance cholangiopancre- atography study of pancreaticobiliary maljunction and pancreaticobiliary diseases. *World J. Gastroenterol.* **2014**, *20*, 7005–7010.
20. Düs¸ünceli, E.; Erden, A.; Erden, I. Biliyer sistemin anatomik varyasyonlari: MRKP bulgulari [Anatomic variations of the bile ducts: MRCP findings]. *Tani. Girisim. Radyol.* **2004**, *10*, 296–303.
21. Sodickson, A.; Mortele, K.J.; Barish, M.A.; Zou, K.H.; Thibodeau, S.; Tempany, C.M. Three-dimensional fast-recovery fast spin- echo MRCP: Comparison with two-dimensional single-shot fast spin-echo techniques. *Radiology* **2006**, *238*, 459–549.
22. Karakas HM, Celik T, Alicioglu B. Bile duct anatomy of the Anatolian Caucasian population: Huang classification revisited. Surg Radiol Anat 2008;30(7):539-45. https://doi.org/10.1007/s00276-0080365-y