Original Article — The Eurasian Journal of Medicine — EAJM 2011; 43: 67-72

Six Rare Biliary Tract Anatomic Variations: Implications for Liver Surgery

Altı Nadir Safra Yolları Anatomik Varyasyonu: Karaciğer Cerrahisi Sonuçları

Daniel V. Kostov[1], Georgi L. Kobakov[2]

[1]Department of Surgery, Naval Hospital of Varna, Varna, Bulgaria
[2]Division of Surgery, Marko Markov Interregional Dispensary and Hospital of Oncological Diseases of Varna, Varna, Bulgaria

Abstract

Objective: The variations in the anatomy of the biliary tract need to be recognized in modern liver surgery. The purpose of this clinical and anatomical study is to describe several novel biliary tract variations and to outline their practical importance for liver resections and transplantations.

Materials and Methods: Over the previous 10 years, the anatomic variations of the bile ducts were examined during 600 intraoperative cholangiographies, 104 segmentectomies and 54 hemihepatectomies in patients with liver diseases. The intraoperative anatomies of the right and left hepatic ducts and the common hepatic duct confluence were analyzed.

Results: Twenty-two variations occurred in 59.5% of the patients. Six variations were described for the first time: an accessory right hepatic duct in which a cystic duct drained; a tetrafurcation from the right anterior hepatic duct, right posterior hepatic duct and bile ducts for Segments 2 and 3 with aberrant bile drainage from Segment 4 into the bile duct for Segment 8; an aberrant bile drainage from Segments 6 and 7 into the common hepatic duct; an accessory bile duct for Segment 6 that drained into the bile duct for Segment 3; a tetrafurcation from the right anterior hepatic duct and the bile ducts for Segments 6, 3 and 2 with bile from Segment 7 draining into the bile duct for Segment 2; and an accessory bile duct for the left hemiliver that drained bile from the Type 4 small accessory hepatic lobe (according to Caygill & Gatenby) into the common hepatic duct.

Conclusion: These newly described biliary tract variations should be recognized by liver surgeons to avoid unwanted postoperative complications.

Key Words: Bile ducts, Biliary tract variations, Cholangiography, Hepatectomy, Liver segments

Özet

Amaç: Safra yolları anatomisi içinde farklılıkların, modern karaciğer cerrahisinde tanınması gerekir. Bu klinik ve anatomik çalışmanın amacı, birkaç yeni safra yolları değişimini tanımlamak ve karaciğer rezeksiyonları ve nakli için pratik öneminin altını çizmektir.

Gereç ve Yöntem: Bundan önceki on yılda, safra kanallarının anatomik varyasyonlu karaciğer hastalığı olanlarda 600 intraoperatif kolanjiografi, 104 segmentektomi ve 54 hemihepatektomi incelendi. Sağ ve sol hepatik kanalların intraoperatif anatomileri ve ortak hepatik kanal kavşakları analiz edildi.

Bulgular: Hastaların %59.5'da yirmi iki kanal varyasyonu gözlemlenmiştir. Altı varyasyon ilk kez tarif edilmiştir: bir sistik kanala drene olan bir aksesuar sağ hepatik kanal; Segment 4 anormal safra drenajı ile 2 ve 3 segmentleri için sağ anterior hepatik kanal, sağ posterior hepatik kanal ve safra yolları bir tetrafurkasyon içine segment 8 safra kanalı; segment 6 ve 7'den ortak hepatik kanal içine bir anormal safra drenajı; segment 3 safra kanalı içine drene olan segment 6 için bir aksesuar safra kanalı, sağ anterior hepatik kanal bir tetrafurkasyon ve safra segmentleri 6, 3 ve segment 2 safra kanalına drene segment 7 ile 2 safra kanalları ve sol hemiliver için bir aksesuar safra kanalına drene safra bu Tip 4 küçük aksesuar karaciğer lobu (Caygill & Gatenby'a göre) içine ortak hepatik kanal.

Sonuç: Bu yeni tanımlanan safra yolları varyasyonları istenmeyen ameliyat sonrası komplikasyonları önlemek için karaciğer cerrahları tarafından göz önünde bulundurulmalıdır.

Anahtar Kelimeler: Hepatektomi, Karaciğer segmenti, Kolanjiyografi, Safra yolları varyasyonları

Introduction

Smajda and Blumgart's classification [1] of the biliary tract anatomic variations is the most commonly used classification in contemporary liver surgery [2]. This classification includes six main anatomic types. Recently, more modern and comprehensive biliary tract classifications were suggested [3]. Numerous bile duct anatomic variations have been encountered in 50% of the population [1, 4]. The anatomic variations of the right hepatic duct (RHD), the left hepatic duct (LHD) and the common hepatic duct (CHD) confluence (CHDC) have been extensively studied, whereas little is known about the

Received: April 03, 2011 / **Accepted:** July 05, 2011

Correspondence to: Daniel V. Kostov, Department of Surgery, Naval Hospital of Varna, BG-9010 Varna, 3 Hristo Smirnenski Street, Bulgaria
Phone: +359 888 954 829 Fax: +359 52 302650 e-mail: danielkostov@abv.bg

doi:10.5152/eajm.2011.16

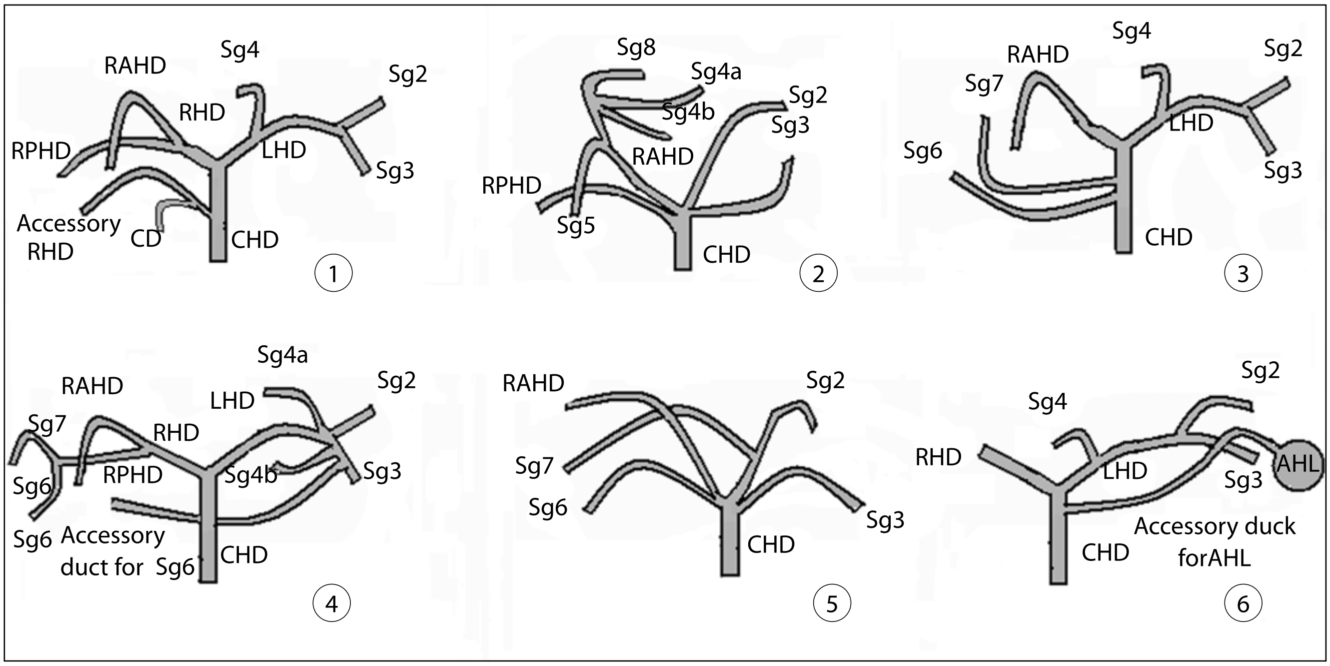

Figure 1. *Six rare anatomic bile duct variations. Accessory hepatic lobe (AHL).*

details of the bile drainage of Segment 4 (Sg4) [2, 5-7]. Sg3 bile drainage has been described as well [8]. A detailed analysis of Sg4 bile drainage has depicted three main types and ten derivative anatomic variations [9]. However, the number of bile duct variations is consistently increasing, and therefore, sufficient knowledge of these variations is important for performing liver resections and transplantations.

Our objective was to present several newly detected variations of the biliary tract and to outline the practical importance of their recognition by liver surgeons.

Materials and Methods

The examinations of the biliary tract anatomic variations were based on 600 intraoperative cholangiographies, 104 segmentectomies and 54 hemihepatectomies performed in patients with liver diseases who were hospitalized in the Department of Surgery, Naval Hospital of Varna, Bulgaria between January 1, 2001 and December 31, 2010. We focused on the intraoperative anatomy of the RHD, LHD and CHDC.

Results

We observed 32 biliary tract anatomic variations, whereas more than 50 have already been reported in other studies. The incidence rate of these variations reached 59.5% of our cases. We described the following six variations with incidence rates below 0.2% for the first time (Figure 1): an accessory RHD in which a cystic duct (CD) drained (Figure 2) [10]; a tetrafurcation from the anterior RHD (RAHD), posterior RHD (RPHD), and the bile ducts for Sg2 and Sg3 with aberrant bile drainage from Sg4 into the duct for Sg8 (Figure 3a) [11]; an aberrant bile drainage from Sg6 and Sg7 into the CHD (Figure 3b) [11]; an accessory bile duct for Sg6 that drained into the bile duct for Sg3 (Figure 4a); a tetrafurcation from the RAHD with bile ducts for Sg6, Sg3 and Sg2 with Sg7 draining into the bile duct for Sg2 (Figure 4b); and an accessory bile duct for the left hemiliver that drained bile from the Type 4 small

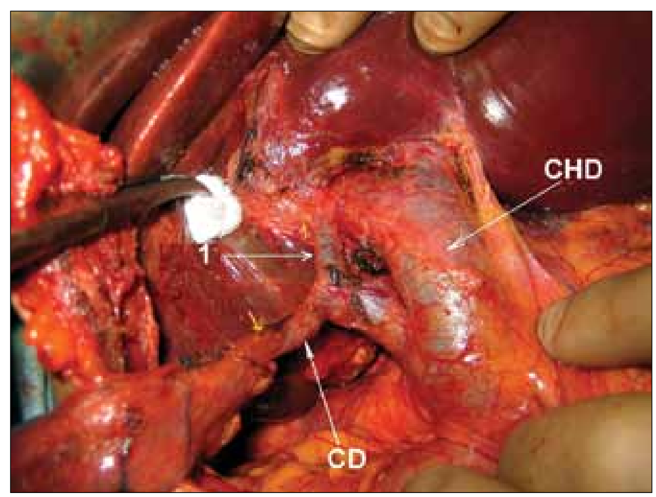

Figure 2. *Accessory RHD (1) in which a CD drains. Both the RHD and LHD form the CHD.*

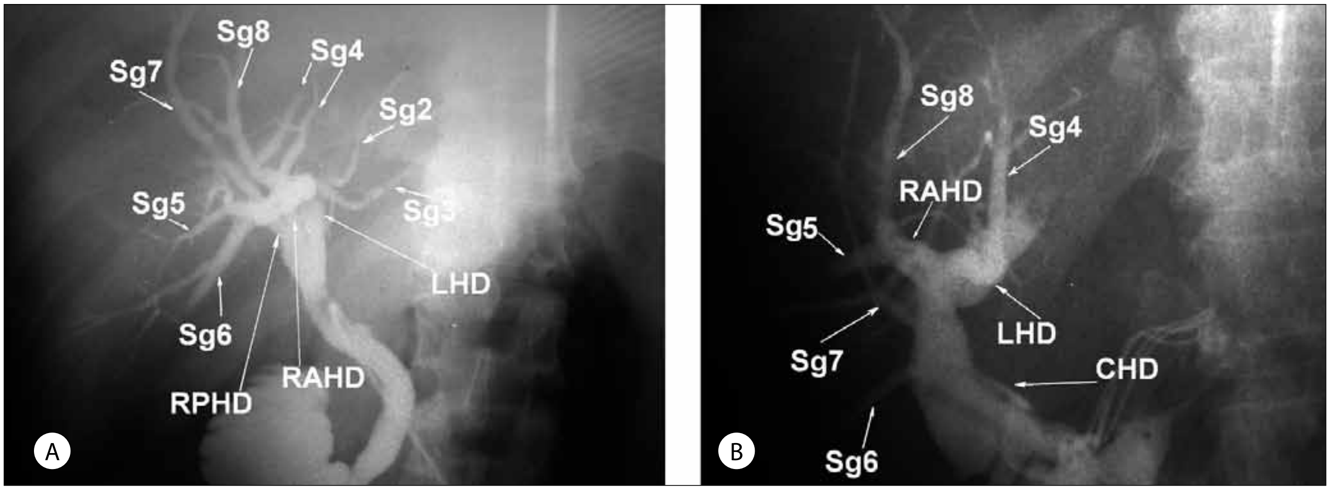

Figure 3. A) *Tetrafurcation formed by the RAHD, RPHD, and biliary ducts for Sg2 and Sg3 with aberrant bile drainage from Sg4 into the biliary duct for Sg8.* ***B)*** *Aberrant bile drainage from Sg6 and Sg7 into the CHD.*

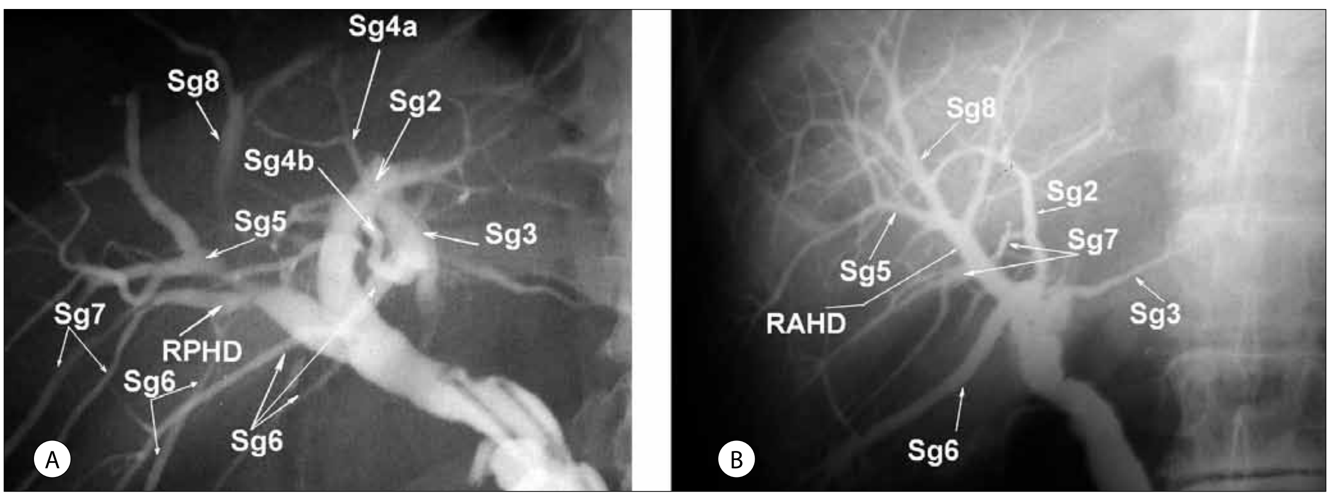

Figure 4. A) *Accessory bile duct for Sg6 that drains into the bile duct for Sg3.* ***B)*** *Tetrafurcation formed by the RAHD and bile ducts for Sg6, Sg3 and Sg2 with bile from Sg7 draining into the bile duct for Sg2.*

accessory hepatic lobe (according to Caygill & Gatenby) [12] into the CHD (Figure 5a, b) [11].

Discussion

The actual number of biliary tract anatomic variations is difficult to estimate. In our study, the occurrence rate reached 59.6% (n=358), which is similar to the rate of common hepatic artery variations of 55% that is described in the literature [1, 13].

RHD features

The RHD is formed through merging of the bile ducts for the right anterior and posterior sectors because the duct for the right posterior sector is epiportal. This variation is considered 'typical' by most authors and occurs in 57-77.5% of cases [2-7, 13-18].

Anatomical variations of the RHD differing from the 'typical' variations were observed in 27.8% of our cases (n=166), whereas the frequency reported in the literature was 22.5-43% [2-6, 13-15,18]. The bile duct for the right posterior sector ran hypoportally in 16.5% of our cases (n=99), which has been shown in 2.5-13% of cases in other studies [2, 4]. Solitary bile ducts for the right anterior and posterior sectors were absent in 4.3% of our cases (n=26). In these cases, the ducts for Sg5, Sg6, Sg7 and Sg8 drained independently into the RHD. This anatomic variation occurred in 2.5% of the cases in previous studies [2]. The danger of cessation of the bile ducts of the intact right segments during right mono-, bi- and

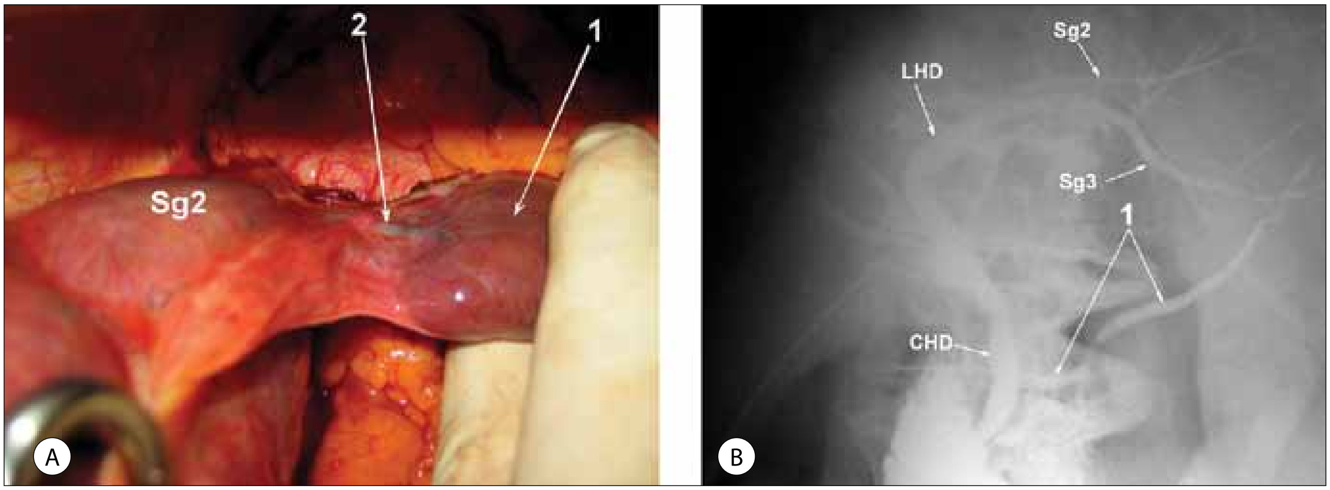

Figure 5. A) *Small accessory hepatic lobe (1) attached to the main liver by a mesentery (2).* ***B)*** *Accessory bile duct (1) for the left hemiliver that drains the small accessory hepatic lobe.*

multisegmentectomies is not commonly considered. There was no solitary bile duct for the right anterior sector in 4.3% of our cases (n=26). The bile ducts for Sg5 and Sg8 drained separately into the RHD in 10-20% of cases in previous studies [2, 3]. The practical significance of this anatomic aberration is the danger of interruption of the bile duct for the right posterior sector during a monosegmentectomy 5 or during a right anterior sectionectomy.

There was an accessory RHD in 0.3% of our patients (n=2), which exited from the *porta hepatis* and entered the CHD. In one case, the CD drained into it. No previous studies have reported this variation. Because of its proximity to the cystohepatic angle formed by the CD and the gallbladder below, the right hepatic lobe above, and the CHD medially, this accessory duct may be accidentally transected or ligated during cholecystectomy, and therefore, complications, such as the formation of a biliary fistula, biloma, sepsis, pain and repetitive episodes of cholangitis, may occur [19]. If a large volume of parenchyma is drained by the ligated duct, biliary atrophy with resultant jaundice may occur. An accessory bile duct for Sg6, which drains into the bile duct for Sg3, was observed for the first time in this study (n=1). The presence of this variation may increase the risk of partial transection of the bile drainage from Sg6 and cholestatic enzyme elevation during a left hepatectomy, left lateral sectionectomy or independent segmentectomy 3. A separate bile drainage from Sg6 and Sg7 into the CHD was observed in this study for the first time as well (n=1). There is a potential risk of interruption of these two bile ducts during a cholecystectomy and CHD resection. An aberrant bile drainage from Sg7 into the bile duct for Sg2 was also observed and has not been previously reported (n=1). The presence of this variation increases the risk of potential cessation of the bile drainage from Sg7 and cholestatic enzyme elevation in left hepatectomies, left lateral sectionectomies and monosegmentectomies 2.

CHDC features

The CHDC was formed from the RHD and LHD in 66.3% of our cases (n=398) and in up to 57% of cases reported elsewhere [1, 6, 13]. There was a triple confluence in 11.8% of our cases (n=71) and between 5% [3, 5, 20] and 16% of patients in other studies [1]. Usually, this confluence was formed from the LHD and the bile ducts for the right anterior and posterior sectors and occurred in 3.5% of our cases (n=21), whereas its frequency ranged from 5-12% in previous studies [1, 3, 6, 15]. During a left hepatectomy, there is an increased risk of damage to the bile drainage of the right segments because of this variation. The bile duct for the right posterior sector drained into the LHD in 14.3% of our cases (n=86), which was the second highest frequency observed in our study, and in 5-19% of cases in previous studies [3-6, 14]. This alteration can cause biliary stasis and relapsing cholangitis [4]. As a result of this variation, the bile drainage from Sg6 and Sg7 can be interrupted during a left hepatectomy, mesohepatectomy, bisegmentectomy 1,4, left trisectionectomy and sometimes during a left lateral sectionectomy. We observed an aberrant bile drainage of the right anterior sector into the LHD in 2% of our cases (n=12) and in 1% of cases in previous studies [2, 3, 6, 13, 16]. The presence of this alteration may increase the risk of cessation of the bile drainage for Sg5 and Sg8 during a left hepatectomy and bisegmentectomy 1,4. Bile drained abnormally from the right posterior sector into the CHD or the CD in 0.83% of our patients (n=5) and in 4.5-16% of cases in previous studies [1-4, 6, 13, 21]. The risk of interruption of the bile drainage from Sg6 and Sg7 during CHD resection or after a cholecystectomy in patients with this alteration may be increased. We detected three variations of a four-fold confluence without a solitary LDH in 1.6% of our patients (n=6). For the first variation, this confluence was formed by merging of the bile ducts for the right posterior and anterior sectors, Sg2 and Sg3; the second variation was formed by merging of the RHD and the bile ducts for Sg4, Sg3, and Sg2; and the third variation was formed by merging of the bile ducts for the right posterior and anterior sectors, Sg2 and Sg3, and the bile from Sg4 drained into the bile duct for Sg8. The third variation has not been previously reported in the available literature.

Although there were previously reported anatomic variations that were not observed in our study group, these variations are extraordinarily rare and involve the presence of aberrant or accessory bile ducts or the absence of a confluence. The existing 'cysticohepatic duct' is essential when performing a laparoscopic cholecystectomy. In 3% of previous cases, the duct for the right posterior sector or the whole RHD drained into the CD [15]. We failed to detect this variation in our study or when performing more than 1000 laparoscopic cholecystectomies. The RHD joined the CHD below the normal confluence in up to 25% of cases in a previous study (9% anterior and 16% posterior) [20] to form a self-confluence ("convergence étagée") [2]. Accessory bile ducts occurred in 2-10% of cases in previous studies [2, 15] and drain small portions of the liver. If unnoticed, these ducts could cause post-operative bilirhagia during a parenchymal transection [22].

LHD features

The anatomic variations of the biliary tract for the left hemiliver were primarily associated with the number and localization of the bile ducts for Sg4. Intrahepatically, all of the bile ducts except for Sg4 are covered by Glisson's capsule [23]. Sg4 was often solitary and drained centrally into the LHD. This variation is usually considered to be 'typical' with a frequency of 15.6-82% in previous studies [1, 9, 13, 24-27], whereas it occurred in 41.5% of our cases (n=249). In the remaining 58.5% of our cases, 8 anatomic variations were observed. In 64.3% of our cases, the bile duct for Sg4 drained centrally, but in 38.6% of our cases, it drained peripherally. In the remaining 3.9% of our cases, there was mixed drainage. In the presence of central drainage, preservation of the bile duct for Sg4 after a left lateral sectionectomy is mandatory. If this bile duct is ligated, elevation of cholestatic enzymes may occur. In 36.3% of our cases, the confluence between the bile ducts for Sg2 and Sg3 was located to the left of the attachment site of *lig. teres hepatis* to the left portal vein branch, in 27.5% of our cases, it was located behind this site, and in the remaining 36.2% of our cases, it was located to the right of this site. Our results are similar to previously published studies in which the bile duct for Sg4 drained to the left of this site in 41.7% of cases, behind this site in 36.2% of cases, and to the right in 15.6% of cases [9]. The localization of the bile duct confluence for Sg2 and Sg3 is important in split-liver transplantation involving hepatic division into two parts along the *fissurae umbilicales*. The difficulty of this procedure is lowered if the confluence is located to the left or behind this particular attachment site.

The bile drainage of Sg1 varies considerably. The number of bile ducts for Sg1 ranges between one and six [2-4, 18, 28]. There were two bile ducts in 80% of cases in previous studies [2, 5] and in 66.6% of our cases. Depending on the size and localization of the caudate lobe, these ducts drain into the CHDC, LHD, or RHD. The bile ducts for *proc. caudatus* and Spiegel's lobe merge into one duct and drain into the CHDC in 26% of the population [18] and in 33.5% (n=201) of our cases.

In conclusion, detailed knowledge of biliary tract anatomic variations is important for safe and effective liver resection surgery and transplantation. Currently, the frequency of these variations is difficult to estimate. There is no original report in the literature that describes all of the variations that have been observed worldwide. Our study contributes six newly described biliary tract anatomic variations to the literature; however, the occurrence rates and optimal surgical management techniques for these variations remains open for future interdisciplinary research.

Conflict of interest statement: The authors declare that they have no conflict of interest to the publication of this article.

References

1. Smadja C, Blumgart LH. The biliary tract and the anatomy of biliary exposure. In: Blumgart LH, ed. Surgery of the Liver and Biliary Tract. Vol. 1. 3rd Edn. Churchill Livingstone, Edinburgh, 2000: 19.
2. Castaing D. Surgical anatomy of the biliary tract. HPB 2008; 10: 72-6. [CrossRef]
3. Vakili K, Pomfret E. Biliary anatomy and embryology. Surg Clin N Am 2008; 88: 1159-74. [CrossRef]
4. Ohkubo M, Nagino M, Kamiya J, et al. Surgical anatomy of the bile ducts at the hepatic hilum as applied to living donor liver transplantation. Ann Surg 2004; 239: 82-6. [CrossRef]
5. Couinaud C. Liver anatomy: portal (and suprahepatic) or biliary segmentation. Dig Surg 1999; 16: 459-67. [CrossRef]
6. Bismuth H. Surgical anatomy and anatomical surgery of the liver. World J Surg 1982; 6: 3-9. [CrossRef]
7. Radtke A, Sgourakis G, Sotiropoulos GC, et al. Vascular and biliary anatomy of the right hilar window: its impact on recipient morbidity and mortality for right graft live donor liver transplantation. World J Surg 2009; 33: 1941-51. [CrossRef]
8. Ozden I, Kamiya J, Nagino M, Uesaka K, Sano T, Nimura Y. Clinicoanatomical study on the infraportal bile ducts of segment 3. World J Surg 2002; 26: 1441-5. [CrossRef]
9. Onishi H, Kawarada Y, Das B, et al. Surgical anatomy of the medial segment (S 4) of the liver with special reference to bile ducts and vessels. Hepatogastroenterology 2000; 47: 143-50. [CrossRef]

10. Kostov DV, Kobakov GL. Accessory right hepatic duct in which a cystic duct drains. HPB 2011; 13: 364. **[CrossRef]**
11. Kostov DV, Kobakov GL. Rare anatomical variants of bile ducts. In: Kostov DV, Kobakov GL. A Colour Atlas of Liver Resections. Marko Markov Interregional Dispensary and Hospital of Oncological Diseases of Varna, Varna, 2010; pp 107-12.
12. Caygill CP, Gatenby PA. Ectopic liver and hepatocarcinogenesis. Eur J Gastroenterol Hepatol 2004; 16: 727-9. **[CrossRef]**
13. Deshpande RR, Heaton ND, Rela M. Surgical anatomy of segmental liver transplantation. Br J Surg 2002; 89: 1078-88. **[CrossRef]**
14. Alibrahim E, Gibson RN, Vincent J, Speer T, Collier N, Jardine C. Spiral computed tomography-intravenous cholangiography with three-dimensional reconstructions for imaging the biliary tree. Australas Radiol 2006; 50: 136-42. **[CrossRef]**
15. Choi JW, Kyoung KT, Kyoung WK, 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: 83-90. **[CrossRef]**
16. Crossingham J, Jenkinsin J, Woolridge N, Gallinger S, Tait G, Moulton CA. Interpreting three-dimensional structures from two-dimensional images: a web-based interactive 3D teaching model of surgical liver anatomy. HPB 2009; 11: 523-8. **[CrossRef]**
17. Düşünceli E, Erden A, Erden I. Anatomic variations of the bile ducts: MRCP findings. Tani Girisim Radyol 2004; 10: 296-303.
18. Healey JE Jr, Schroy PC. Anatomy of the biliary ducts within the human liver; analysis of the prevailing pattern of branchings and the major variations of the biliary ducts. AMA Arch Surg 1953; 66: 599-616.
19. Catalano OA, Singh AH, Uppot RN, et al. Vascular and biliary variants in the liver: implications for liver surgery. Radiographics 2008; 28: 359-78. **[CrossRef]**
20. Hribernik M, Gadzijev EM, Mlakar B, Ravnik D. Variations of intrahepatic and proximal extrahepatic bile ducts. Hepatogastroenterology 2003; 50: 342-8. **[CrossRef]**
21. Chaib E. Ribeiro M, Saad W, Gama-Rodrigues J. The main hepatic anatomic variations for the purpose of split-liver transplantation. Transplant Proc 2005; 37: 1063-6. **[CrossRef]**
22. Nery JR, Fragulidis GP, Scagnelli T, et al. Donor biliary variation: an overlooked problem? Clin Transplant 1997; 11: 582-7. **[CrossRef]**
23. Kawarada Y, Das BC, Taoka H. Anatomy of the hepatic hilar area: the plate system. J Hepatobiliary Pancreat Surg 2000; 7: 580-6. **[CrossRef]**
24. Broering DC, Sterneck M, Rogiers X. Living donor liver transplantation. J Hepatol 2003; 38: 119-35. **[CrossRef]**
25. Cho A, Ryu M, Kinoshita T, et al. Radiological anatomy of the medial segmental bile duct of the liver assessed by CT cholangiography. Hepatogastroenterology 2003; 50: 945-8.
26. Mortele KJ, Ros PR. Anatomic variants of the biliary tree: MR cholangiographic findings and clinical applications. Am J Roentgenol 2001; 177: 389-94.
27. Leelaudomlipi S, Sugawara Y, Kaneko J, Matsui Y, Ohkubo T, Makuuchi M. Volumetric analysis of liver segments in 155 living donors. Liver Transplant 2002; 8: 612-4. **[CrossRef]**
28. Kitami M, Murakami G, Ko S, et al. Spiegel's lobe bile ducts often drain into the right hepatic duct or its branches: study using drip-infusion cholangiography-computed tomography in 179 consecutive patients. World J Surg 2004; 28: 1001-6. **[CrossRef]**