

Frequency of bile duct confluence variations in subjects with pancreas divisum: an analysis of MRCP findings

Ayşegül Gürsoy Çoruh 

Başak Gülpınar 

Hakan Baş 

Ayşe Erden 

PURPOSE

We aimed to evaluate the frequency of bile duct branching pattern variations at the hepatic confluence in patients with pancreas divisum (PD).

METHODS

A search was performed through the hospital database using the keyword “pancreas divisum” to identify patients. The magnetic resonance cholangiopancreatography (MRCP) images of 137 patients who were diagnosed with PD between August 2011 and November 2016 were retrospectively analyzed for the presence of bile duct variations. A control group of 137 patients without PD was established among patients investigated during the same period. Variations of the biliary tract were grouped into seven types according to the McSweeney et al. classification.

RESULTS

Biliary tract variations were detected in 103 of a total of 274 patients. Fifty-eight PD patients (42.3%) and 45 control patients (32.8%) had bile duct variation at the hepatic confluence level. The patients with PD were more likely to have biliary tract variation compared with the control group; however, it was not statistically significant ($P = 0.105$). The most common variation in PD patients was type 3a variation (16.8%).

CONCLUSION

MRCP studies showed atypical bile duct confluence pattern in nearly half of both PD patients and controls. There was no statistically significant difference in the frequency of anatomic variations at bile duct confluence in patients with PD versus those without PD. Derivation of these structures from different outpouchings in early embryological life may explain this insignificant difference.

Congenital anomalies of the pancreatic duct may remain undiagnosed until adulthood and they are often diagnosed incidentally. Pancreas divisum (PD) is the most common congenital anomaly of the pancreas which occurs from a failure of ventral and dorsal bud fusion (1, 2). It accounts for about 4%–14% of the population at autopsy series, and approximately 9% are detected using magnetic resonance cholangiopancreatography (MRCP) (3). In PD, the ventral (Wirsung) duct opens into the major papilla without merging with the dorsal (Santorini) duct. The dorsal duct, which opens into the minor papilla, is responsible for the majority of the drainage from the pancreas. The clinical importance of PD is not clear. Most patients are asymptomatic, whereas in some patients, PD may cause recurrent pancreatitis due to lack of adequate drainage into duodenum via minor papilla (3, 4). Of patients with idiopathic recurrent pancreatitis, 12%–26% have PD (5). There are various type of examinations to evaluate the pancreaticobiliary system; however, MRCP has been shown to be an effective noninvasive imaging modality for the visualization of the biliary tree and pancreatic duct. Bret et al. (6) reported an accuracy rate of 100% in the diagnosis of PD using MRCP (6).

Laparoscopic cholecystectomy, transplantation surgery, hepatic resection, and tumor surgery are the most common hepatobiliary surgeries in which complications related to the bile duct variations comprise one of the most common reasons for morbidity and mortality. Since biliary duct variations are seen in approximately 42% of population, a detailed evalu-

From the Department of Radiology (A.G.Ç. ✉ draysegulgursoy@gmail.com), Ankara University School of Medicine, Ankara, Turkey.

Received 8 July 2017; revision requested 16 August 2017; last revision received 25 December 2017; accepted 30 January 2018.

DOI 10.5152/dir.2018.17200

You may cite this article as: Gürsoy Çoruh A, Gülpınar B, Baş H, Erden A. Frequency of bile duct confluence variations in subjects with pancreas divisum: an analysis of MRCP findings. *Diagn Interv Radiol* 2018; 24:72–76.

ation of the biliary anatomy before surgery must be performed to minimize morbidity and mortality (7). In this respect, MRCP is an essential, noninvasive technique. In addition, accurate evaluation of the intrahepatic bile duct branching anatomy is of utmost importance prior to left or right liver harvesting in living donor liver transplantation, as well as segmental or lobar resection. Familiarity with the bile duct branching pattern and its variations can prevent complications which may occur during the surgical, endoscopic, or percutaneous procedures. During laparoscopic cholecystectomy, resection of the accessory sectoral or segmental ducts may cause bile leakage, bilioma, bile peritonitis, and ligation of the aberrant duct may lead to recurrent cholangitis, hepatic abscess, and atrophy of the involved segment (8).

As the most common pancreatic ductal anatomic variant, in the present study, we hypothesized that there might be an association between the PD and the biliary duct variation due to their closely related embryologic origin. We, therefore, aimed to investigate whether the PD was associated with the biliary branching variations more frequently and to document the prevalence of each type of anatomic variations at the hepatic confluence using MRCP.

Methods

This retrospective study was approved by the institutional review board and a written informed consent was obtained from each

participant. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The Radiology Information System/Picture Archiving and Communication System (RIS/PACS; Centricity 5.0 RIS-i, GE Healthcare) of our institution was utilized to identify patients with PD. The study population was composed of those who underwent MRCP for the presence of clinical pathologies, such as pancreatitis, cholangitis, biliary stricture and those who were screened for live liver donation. The patients were identified with the search in the PACS system using the keyword of "pancreas divisum". We retrospectively evaluated the MRCP images of a total of 145 patients who were incidentally diagnosed as having the variation PD on MRCP performed between August 2011 and November 2016 for the presence of bile duct anomalies. Drainage of the dorsal pancreatic duct via minor papilla, noncommunicated dorsal and ventral ducts, and dominant dorsal duct was defined as PD on MRCP images. Due to the poor image quality eight patients were excluded from the study, leaving a sample size of 137 patients with PD. The control group was composed of 137 patients

without PD who were evaluated during the same period. Control sample consisted of patients closely resembling the PD group in terms of demographic variables and was selected from the list of patients evaluated using MRCP either for potential liver donation or for the presence of diverse pancreaticobiliary disorders. Fig. 1 shows the flow diagram of the study population.

At our institution, MRCP examinations were performed using 1.0 T (Signa LX Horizon, GE Healthcare), 1.5 T (Optima 450w, GE Healthcare), 3.0 T (MAGNETOM Verio, Siemens) magnetic resonance imaging (MRI) scanners with an 8-channel torso phased-array body coil. A total of 89 patients were examined at 1.0 T, 126 patients at 1.5 T, and 59 patients at 3.0 T MRI scanner. The patients fasted for 6 hours prior to examination. No intravenous or oral contrast agent was administered. T2-weighted axial single-shot turbo spin-echo, T1-weighted axial gradient echo (dual echo), three-dimensional respiratory-triggered heavily T2-weighted fast spin-echo (coronal and axial plane), and heavily T2-weighted thick slab images were achieved. Besides the heavily T2-weighted thick slab images,

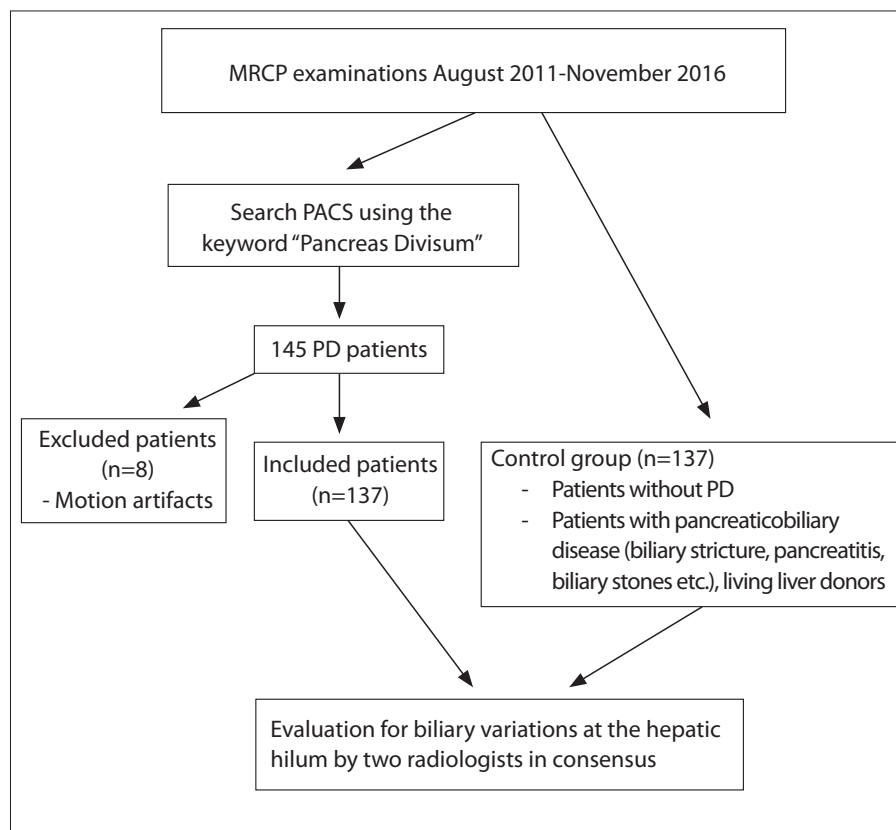


Figure 1. Flow diagram of study population. MRCP, magnetic resonance cholangiopancreatography; PD, pancreas divisum.

Main points

- Biliary branching variations at the hepatic hilum were observed frequently in both pancreas divisum (PD) patients and normal population by magnetic resonance cholangiopancreatography (MRCP).
- Different outpouchings in the early embryologic life may explain the absence of statistically significant difference in the frequency of bile duct variations between PD patients and those with a normal pancreatic duct.
- The most common variation in patients with PD and without PD was abnormal drainage of right posterior hepatic duct into the left hepatic duct.
- Awareness of bile duct variations may help to tailor the therapeutic medications in PD patients with recurrent pancreatitis, cholangitis, and intrahepatic bile duct stones which are thought to occur due to abnormal drainage of the bile duct system.

the axial and coronal heavily T2-weighted source images and the maximum intensity projection (MIP) images were analyzed together for the possible anatomic variations.

All MRCP images were reviewed by two reviewers in consensus at the PACS Workstation. Variations of the biliary tract were categorized into seven groups according to the classification of McSweeney et al. (9). In their classification, the branching pattern of the biliary system at the hepatic confluence is grouped as follows:

Type 1: Normal anatomy; right hepatic duct and left hepatic duct (LHD) merge to form the common hepatic duct (CHD).

Type 2: Triple confluence; right posterior (RP)-right anterior (RA) hepatic ducts and LHD merge to form CHD.

Type 3: Abnormal drainage of RP duct (Type 3a, RP duct drains into the LHD; Type 3b, RP duct drains into the CHD; Type 3c, RP duct drains into the cystic duct).

Type 4: Right hepatic duct drains into the cystic duct.

Type 5: Accessory right segmental intrahepatic duct drains directly into the CHD.

Type 6: Segment 2 and 3 ducts merge separately the right hepatic duct to develop CHD.

Type 7: Complicated anatomy (other than the types indicated above).

Statistical analysis

Statistical analysis was performed using SPSS 11.5 (SPSS Inc.). The descriptive statistics were expressed as mean and standard deviation for metric variables, frequency and percent for categorical variables. The Student's t test and chi-square test were used to compare independent groups in terms of metric and categorical variables, respectively. A *P* value of less than 0.05 was considered statistically significant.

Results

The MRCP images of a total of 274 patients (167 women [60.9%] and 107 men [39.1%]) were evaluated. The PD group consisted of 59 men (43%) and 78 women (57%), with a mean age of 54.7±13.9 years (range, 16–81 years). According to the hospital records, 14 (10%) of the patients with PD had a previous acute pancreatitis episode. The control group consisted of 48 men (35%) and 89 women (65%), with a mean age of 55.6±15.6 years (range, 17–83 years). There were no statistical differences between the groups in terms of age and gender (*P* = 0.129, *P* = 0.173, respectively). Demographic and clinical data of the study population are represented in Table 1.

Table 1. Demographic and clinical data of study population

	Control	PD	<i>P</i>
Age (years), mean±SD (min–max)	55.6±15.6 (17–83)	54.7±13.9 (16–81)	0.129 ^a
Gender, n (%)			
Male	48 (35.0)	59 (43.1)	0.173 ^b
Female	89 (65.0)	78 (56.9)	
Pancreaticobiliary disease, n (%) (e.g., pancreatitis, cholangitis, biliary stricture, biliary stone)	118 (86.2)	125 (91.2)	
Living liver donors	19 (13.8)	8 (5.8)	

^aStudent t test, ^bChi-square test. PD, pancreas divisum.

Table 2. The frequency of the biliary tract variations with respect to the classification proposed by McSweeney et al. (9)

	Type 1	Type 2	Type 3a	Type 3b	Type 3c	Type 4	Type 5	Type 6	Type 7
Control	92 (67.2)	7 (5.1)	28 (20.4)	6 (4.4)	2 (1.5)	0 (0.0)	1 (0.7)	1 (0.7)	0 (0.0)
PD	79 (57.7)	19 (13.9)	23 (16.8)	3 (2.2)	1 (0.7)	1 (0.7)	4 (2.2)	3 (2.2)	5 (3.6)
Total	171 (62.4)	26 (9.5)	51 (18.6)	9 (3.3)	3 (1.1)	1 (0.4)	5 (1.8)	4 (1.5)	5 (1.8)

Data are presented as n (%). PD, pancreas divisum.

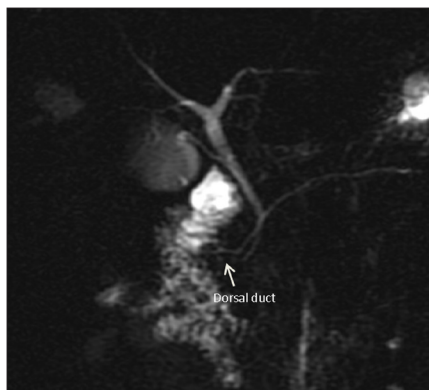


Figure 2. A 26-year-old male patient with autoimmune pancreatitis. Oblique coronal thick slab MRCP image shows type 1 anatomy and PD with dorsal duct (arrow) opening into the minor papilla.

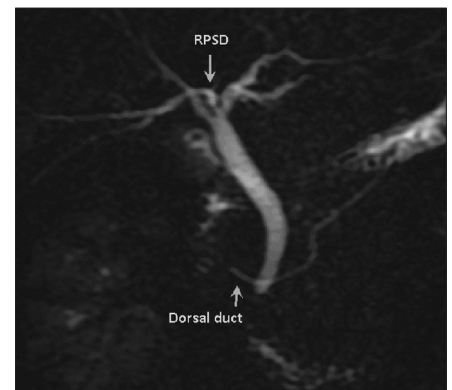


Figure 3. A 55-year-old patient with recurrent pancreatitis. Oblique coronal thick slab MRCP image shows RP segmental duct (arrow) opening into the LHD (type 3a variation). Note the main pancreatic duct continuous with the dorsal duct (arrow).

Of 137 patients with PD, 58 patients (42.3%) had bile duct variations at the level of hepatic confluence. In the control group, 45 patients (32.8%) had branching pattern variations at the hepatic hilum. The patients with PD seem to have more biliary tract variations at the hepatic hilum, compared with the control group; however, it did not reach statistical significance (*P* = 0.105). Table 2 shows the frequency of biliary tract variations for each group.

In this study, classical branching pattern (type 1) was present in 79 PD patients

(57.7%; Fig. 2) and 92 control subjects (67.2%). Drainage of the RP hepatic duct into the LHD (type 3a) was the most common anatomic variant in both the PD group (n=23, 16.8%; Fig. 3) and the control group (n=28, 20.4%; Fig. 4). The second most common variant was triple confluence (type 2) in both groups (13.9% in PD group, 5.1% in the control group), in which the RP-RA hepatic ducts and LHD drain into the CHD. Type 3b variation was observed in 3 PD patients (2.2%; Fig. 5) and 6 control subjects (4.4%). One patient with PD had drainage

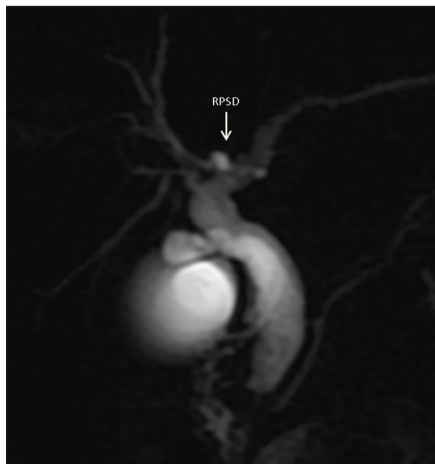


Figure 4. A 67-year-old male with jaundice from the control group. Oblique coronal thick slab MRCP image shows RP segmental duct (*arrow*) opening into the LHD (type 3a variation) and dilatation of intrahepatic ducts and common bile duct. Note that the main pancreatic duct continues with ventral duct. Dorsal duct is also visible.

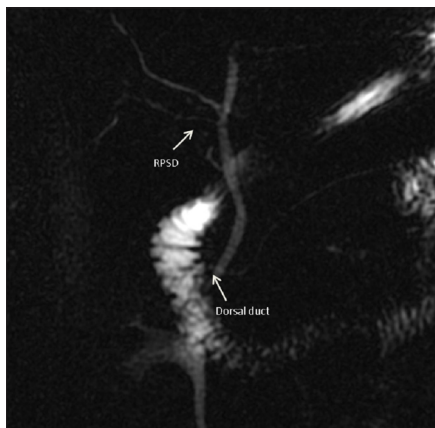


Figure 5. A 33-year-old female patient with elevated liver enzymes. Oblique coronal thick slab MRCP image shows RP segmental duct (*arrow*) draining into the CHD (type 3b) and the main pancreatic duct entering the minor papilla (*arrow*).

of the RP duct into the cystic duct (type 4); 3 PD patients (2.2%) had type 5 anatomical variation. The opening of Segment 2 and 3 duct separately to the right hepatic duct to form CHD (type 6) was observed in 3 PD patients (2.2%; Fig. 6). An undefined/complex anatomy (type 7) was observed in 5 patients (3.6%) with PD. In one patient, Segment 2 and 3 merged with the CHD separately and the RP segmental duct (RPSD) joined to the Segment 2 duct. In the second patient, the RPSD joined to the Segment 2 duct, forming a short duct which drained into the distal end of the Segment 3 duct (Fig. 7). In the third patient, the Segment 3 duct drained into CHD separately and Segment 2 and Segment 4 ducts joined to the RPSD. The

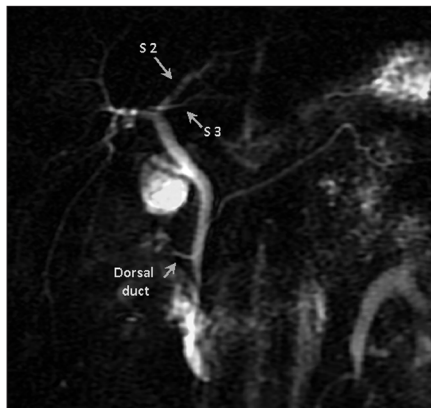


Figure 6. A 72-year-old patient with hyperbilirubinemia. Oblique coronal thick slab MRCP image shows segment 2 (S2) and segment 3 (S3) ducts separately draining into the RHD (type 6) and dorsal duct (*arrow*) opening into the minor papilla (compatible with PD).

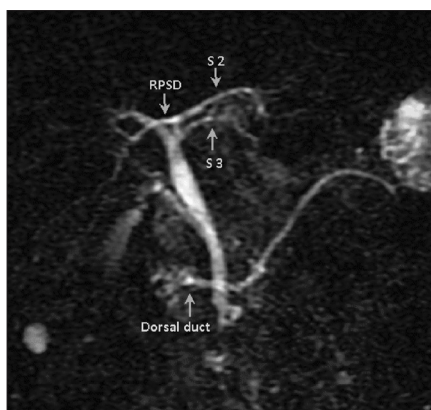


Figure 7. A 42-year-old woman with jaundice. Oblique coronal thick slab MRCP image shows right posterior segment duct (RPSD) and segment 2 (S2) duct join and form a short common duct that drains into distal end of segment 3 (S3) duct (type 7). Note also PD with the dorsal pancreatic duct (*arrow*) crossing the common bile duct to drain into the expected location of the minor papilla.

fourth patient had drainage of the Segment 3 duct to the RA segment duct. Finally, the fifth patient had an accessory duct from the right lobe, draining into the Segment 3 duct. In this study, the accessory right segmental duct was observed in 6 (2.1%) of a total of 274 patients: in four patients, it drained into the CHD, while in one patient, it drained into the Segment 3 duct.

Discussion

To the best of our knowledge, bile duct variations have not been previously investigated for the PD patients. In this study, 42.3% of PD patients and 32.8% of controls had biliary duct variation at the hepatic confluence level. PD patients appeared to

have more biliary tract variations compared with the control group; however, it did not reach statistical significance.

In the human embryo, by the fourth week of gestation, the ventral and dorsal diverticula grow at the junction of the foregut and midgut. The dorsal diverticulum develops into the dorsal portion of the pancreas, while the ventral diverticulum (hepatic diverticulum) develops into the liver, gall-bladder, bile ducts, and ventral pancreas (10–13). During the fifth week, a rapid endodermal proliferation occurs in the dilated funnel-shaped structure above the cystic duct. This proliferation gives rise to several folds, which result in numerous channels at the porta hepatis (12, 13). The existence of several normal variants in the configuration of the right and left hepatic ducts at the hepatic confluence level can be partially explained by this remodeling. The “normal” Y-shaped junction of the right and left hepatic ducts with the CHD is found in about 57% to 72% of adults (12, 14, 15).

The ventral pancreas merges with the dorsal pancreas at approximately the seventh week of gestation (10). PD is caused by the failure to fuse ventral and dorsal pancreas (1–4). The ventral pancreatic duct and the common bile duct are linked by their embryonic origins (both originate from the ventral outpouching), which results in the adult configuration of their common entrance into the duodenum at the major papilla (11). On the other hand, although the dorsal pancreatic duct and biliary system are derived from closely related structures in the early embryologic life, they originate from different outpouchings (10–13). This embryologic difference may explain our observation that the frequency of the bile duct variations in patients with PD was not statistically different from those with a normal pancreatic duct.

According to the literature, the frequency of bile duct variations (except the typical pattern), varies between 28% and 43% (7, 14–19). Our results are comparable with previously reported data: anatomic variation at the hepatic hilum was observed in 32.8% of the control group and 42.3% of the PD patients. Among seven types of anatomic variants, type 3a with drainage of the RP duct into the LHD was the most common, followed by type 2 (trifurcation), which were present in 16.8% and 13.9% of PD patients, respectively. These rates for control group were 20.4% and 5.1%, respectively, and were compatible with those reported in previous studies (8, 14, 20–22).

The most common complications after hepatobiliary surgeries are related to the iatrogenic injuries of bile ducts. Therefore, accurate evaluation of the biliary system is critical, before hepatic surgery. Since the most common variant is type 3a, in a patient with RPSD draining into LHD, ligation of the right posterior branch during left hepatectomy can cause biliary cirrhotic changes at Segments 6 and 7 (18). In addition, documentation of the ductal variations is important to prevent bilioma, bile peritonitis, biliary stricture, cholangitis, and abscess, which may occur due to biliary injuries (19).

In the present study, type 4 and type 3c patterns were the least common variants in PD patients (0.7% for both), and type 4 pattern was not observed in the control group. Sarawagi et al. (8) reported similar findings in their study. Since ligation or resection of the aberrant duct may lead to complications such as bile leakage, biliary bilioma, and bile peritonitis, knowledge of variations of the right hepatic duct draining into the cystic duct (type 4) is critical. If not treated, mortality rates as high as 44% have been reported for this condition (23).

In the literature, it has been reported that 2% of donors have accessory hepatic ducts which may originate from either the left or right ductal system. Similarly, in this study, the accessory right segmental duct was observed in 6 patients (2.1%). For liver transplantation or hepatic resection, the accessory duct must be recognized, as electrocautery may seal an accessory duct during surgery. By applying an appropriate surgical technique, complications such as bile leakage, bilioma, or bile peritonitis can be prevented (15).

Furthermore, it has been assumed that recurrent pancreatitis occurs more frequently in patients with PD (3, 4). Pancreatitis is caused by stenosis of the dorsal duct at the minor papilla and impaired drainage of pancreatic enzymes into duodenum (3, 4). According to the electronic records of the hospital information system, 14 patients with PD (10%) previously experienced mild episodic acute pancreatitis in our study. Of 14 PD patients with a history of pancreatitis, 6 patients had bile duct variations at the hepatic hilum. Three of these patients had type 3a, one patient had type 2, and one patient had type 3b bile duct variation. In addition, as in PD, biliary variation is one of the important etiologic factors for recurrent pancreatitis, as well as recurrent cholangitis

and hepatolithiasis. This is caused by stasis of bile drainage which is usually seen in type 3a branching pattern due to the acute angle between RP and LHD (14).

There are some limitations to this study. First, the number of the patients included in the study was limited. With a larger population, a significant difference may have been detected. Second, we were unable to compare the results with any other modality such as endoscopic retrograde cholangiopancreatography. However, this is the first study to assess the association of PD and biliary duct variations in the literature.

In conclusion, our data did not demonstrate a statistically significant difference in the frequency of anatomic variations at bile duct confluence in patients with PD versus those without PD. MRCP showed atypical bile duct confluence pattern in nearly half of both PD patients and controls. The most common variant was RP duct draining into the LHD in both groups.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

- Borghesi P, Sokhandon F, Shirkhoda A, Morgan DE. Anomalies, anatomic variants, and sources of diagnostic pitfalls in pancreatic imaging. *Radiology* 2013; 266:28–36. [CrossRef]
- Griffin N, Charles-Edwards G, Grant LA. Magnetic resonance cholangiopancreatography: the ABC of MRCP. *Insights Imaging* 2012; 3:11–21. [CrossRef]
- Yu J, Turner MA, Fulcher AS, Halvorsen RA. Congenital anomalies and normal variants of the pancreaticobiliary tract and the pancreas in adults: part 2, pancreatic duct and pancreas. *AJR Am J Roentgenol* 2006; 187:1544–1553. [CrossRef]
- Türkvatan A, Erden A, Türkoğlu MA, Yener Ö. Congenital variants and anomalies of the pancreas and pancreatic duct: imaging by magnetic resonance cholangiopancreatography and multidetector computed tomography. *Korean J Radiol* 2013;14:905–913. [CrossRef]
- Morgan DE, Logan K, Baron TH, Koehler RE, Smith JK. Pancreas divisum: implications for diagnostic and therapeutic pancreatography. *AJR Am J Roentgenol* 1999; 173:193–198. [CrossRef]
- Bret PM, Reinhold C, Taourel P, Guibaud L, Atri M, Barkun AN. Pancreas divisum: evaluation with MR cholangiopancreatography. *Radiology* 1996; 199:99–103. [CrossRef]
- Mortele KJ, Ros PR. Anatomic variants of the biliary tree: MR cholangiographic findings and clinical applications. *AJR Am J Roentgenol* 2001; 177:389–394. [CrossRef]
- 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; 261:250–255. [CrossRef]

- McSweeney SE, Kim TK, Jang HJ, Khalili K. Biliary anatomy in potential right hepatic lobe living donor liver transplantation (LDLT): the utility of CT cholangiography in the setting of inconclusive MRCP. *Eur J Radiol* 2012; 81:6–12. [CrossRef]
- Roskams T, Desmet V. Embryology of extra- and intrahepatic bile ducts, the ductal plate. *Anat Rec (Hoboken)* 2008; 291:628–635. [CrossRef]
- Tadokoro H, Takase M, Nobukawa B. Development and congenital anomalies of the pancreas. *Anat Res Int* 2011; 351217. [CrossRef]
- Tan CE, Moscoso GJ. The developing human biliary system at the porta hepatis level between 29 days and 8 weeks of gestation: a way to understanding biliary atresia. Part 1. *Pathol Int* 1994; 44:587–599. [CrossRef]
- Tan CE, Moscoso GJ. The developing human biliary system at the porta hepatis level between 11 and 25 weeks of gestation: a way to understanding biliary atresia. Part 2. *Pathol Int* 1994; 44:600–610. [CrossRef]
- 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; 239:82–86. [CrossRef]
- Choi JW, Kim TK, Kim KW, 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. [CrossRef]
- 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; 28:1669–1670.
- Lee CM, Chen HC, Leung TK, Chen YY. Magnetic resonance cholangiopancreatography of anatomic variants of the biliary tree in Taiwanese. *J Formos Med Assoc* 2004; 103:155–159.
- Puente SG, Bannura GC. Radiological anatomy of the biliary tract: variations and congenital abnormalities. *World J Surg* 1983; 7:271–276. [CrossRef]
- Minutoli F, Naso S, Visalli C, et al. A new variant of cholecystohepatic duct: MR cholangiography demonstration. *Surg Radiol Anat* 2015; 37:539–541. [CrossRef]
- Sharma V, Saraswat VA, Baijal SS, Choudhuri G. Anatomic variations in intrahepatic bile ducts in a north Indian population. *J Gastroenterol Hepatol* 2008; 23:58–62. [CrossRef]
- 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. [CrossRef]
- 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; 22:489–494. [CrossRef]
- Chandio A, Javid A, Mustafa S, Naqvi S, Aftab F. Biliary tract variations and its correlation with clinical presentations. *Surgery Curr Res* 2014; 4:6–11.