

RESEARCH ARTICLE

Imaging Spectrum of Donor Biliary Complications After Living Liver Donation: An MRCP-Based Analysis

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Abstract

Introduction: To evaluate the imaging spectrum of biliary complications in living liver donors using magnetic resonance cholangiopancreatography (MRCP) and to investigate the relationship between postoperative biliary complications and biliary anatomy.

Methods: In this retrospective single-center study, adult living liver donors who underwent transplantation between January 2017 and January 2025 were reviewed. Donors were followed clinically and with imaging according to institutional protocols, and MRCP was performed when biliary complications were suspected. Preoperative MRCP examinations were analyzed to classify biliary anatomy and obtain morphometric measurements. Imaging characteristics were compared between donors with and without biliary complications.

Results: A total of 181 donors were included, and radiologic biliary complications were identified in 16 donors (8.8%). Early bile leakage and biloma formation constituted the predominant imaging phenotype (68.8%), whereas biliary strictures were less frequent, presenting as common hepatic duct narrowing within the first month in three donors and as later strictures detected at 5.5 and 8 months in two donors. Variant biliary anatomy appeared numerically more frequent among donors with complications but was not significantly associated with complication development ($p=0.282$). Hepatocyte-specific contrast-enhanced MRI confirmed active bile leakage in selected cases. Three donors demonstrated biochemical cholestasis despite normal MRCP findings, highlighting the role of imaging in avoiding unnecessary invasive procedures.

Conclusion: MRCP provides a comprehensive, noninvasive framework for detecting biliary complications in living liver donors. Early imaging should focus on bile leak, while later surveillance is important for identifying biliary strictures, supporting a time-oriented radiologic approach to donor follow-up.

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Introduction

Biliary complications represent an important source of postoperative morbidity following living donor liver transplantation and require accurate radiologic evaluation for timely diagnosis and management.¹ In living donors, who constitute an otherwise healthy population, familiarity with the radiologic spectrum of donor-specific biliary alterations and accurate interpretation of postoperative biliary findings are particularly important for avoiding unnecessary interventions while ensuring timely detection of clinically relevant complications.²

Radiologic imaging, particularly magnetic resonance cholangiopancreatography (MRCP), plays a central role in the evaluation of the biliary tree in transplant settings: preoperatively, to delineate biliary anatomy and identify anatomic variants that may influence surgical planning and potential postoperative risks, and postoperatively, to assess suspected biliary complications following living donor hepatectomy.²⁻⁴ Despite the established role of MRCP in both pre- and postoperative assessment, biliary complications in living liver donors have been comparatively less explored from a radiologic perspective than those in recipients, underscoring the need for dedicated imaging-based studies to enhance radiologic awareness in this population.⁵⁻⁷

The primary aim of this study was to investigate the imaging features of biliary complications and their relationship with biliary tree anatomic variants in living liver donors. As a secondary objective, we briefly describe the observed incidence of biliary complications and the frequency of biliary interventions based on the experience of a tertiary referral center.

Material and Methods

This retrospective imaging study was conducted at a tertiary referral center after institutional ethics committee approval was obtained (Approval number: I01-105-26). Adult living liver donors who underwent liver transplantation between January 2017 and January 2025 were retrospectively reviewed.

Definition and Imaging Criteria for Biliary Complications

Following living donor liver transplantation, donors were routinely followed with clinical assessment, laboratory testing including liver function parameters, and ultrasonography according to the institutional follow-up protocol. Additional imaging

studies were performed when biliary complication was clinically suspected based on biochemical cholestasis, persistent abdominal symptoms, or abnormal ultrasonographic findings.

Biliary complications were defined as bile leakage with or without biloma formation and biliary stricture detected on postoperative imaging. Donors without imaging evidence of these findings, who had at least one year of clinical and radiologic follow-up, were classified as the non-complication group. Donors lacking adequate follow-up data or those with vascular complications were excluded from the study.

In donors demonstrating perihepatic fluid collections suspicious for bile leakage with or without biloma formation on ultrasonography and/or computed tomography, the diagnosis was established when bile-containing fluid exceeding 100 mL/day was detected from surgically placed drains or when percutaneous aspiration confirmed the presence of bile. On magnetic resonance imaging (MRI), perihepatic collections appearing hypointense on T1-weighted and hyperintense on T2-weighted sequences, particularly when communication with the biliary tree was demonstrated on MRCP, were considered compatible with biloma (Figure 1). In addition, hepatobiliary phase MR imaging with hepatocyte-specific contrast agents was evaluated, and delayed-phase contrast extravasation into adjacent collections was regarded as indicative of active biliary leakage (Figures 2-3).

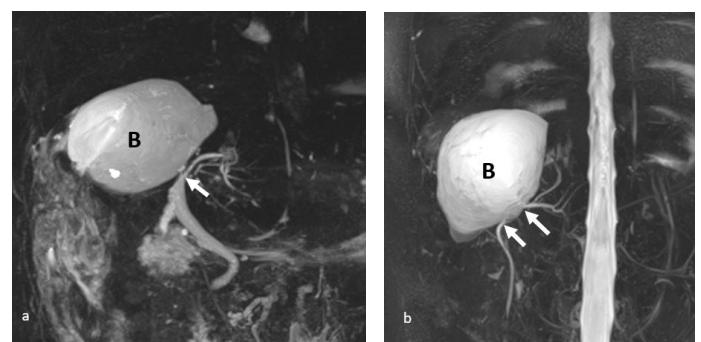


Figure 1. Coronal maximum-intensity-projection MRCP images obtained in two different donors (a, b) demonstrate well-demarcated perihepatic fluid collections compatible with biloma (B), showing direct communication with the biliary tree (arrows).

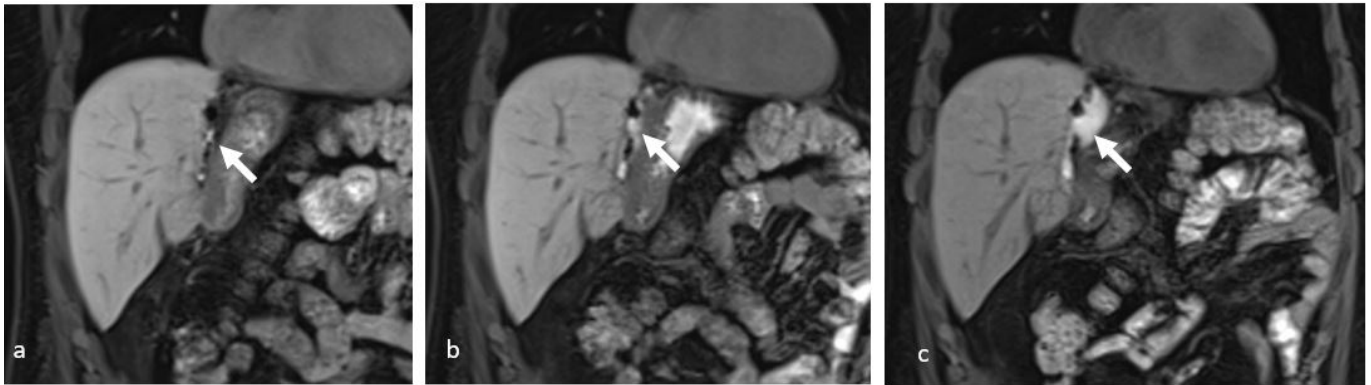


Figure 2. Coronal T1-weighted MR images in a left-lobe donor demonstrate progressive contrast extravasation along the hepatic resection margin on delayed imaging at 30 minutes (a), 60 minutes (b), and 6 hours (c) after administration of a hepatocyte-specific contrast agent, compatible with active biliary leakage (arrows).

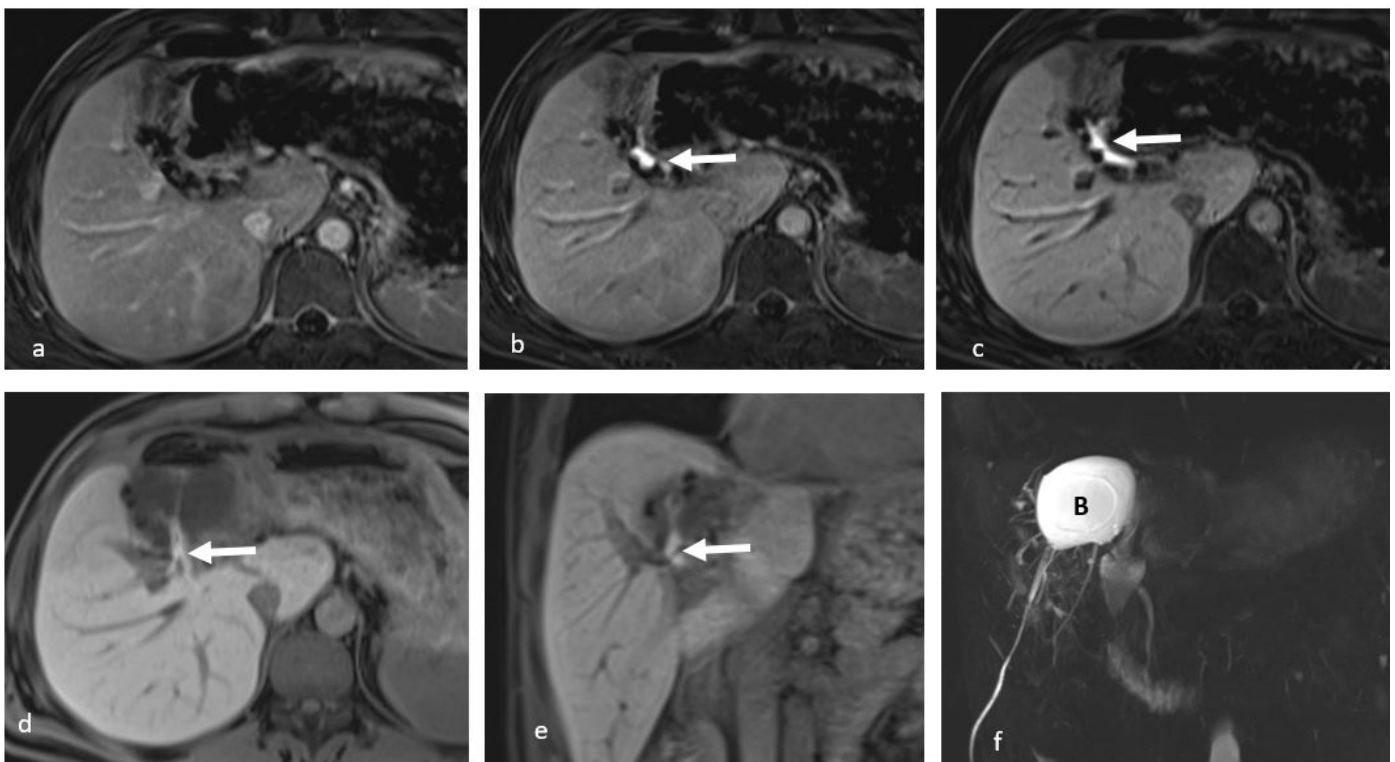


Figure 3. T1-weighted MR images obtained after administration of a hepatocyte-specific contrast agent in a left-lobe donor demonstrate progressive contrast extravasation compatible with active biliary leakage. (a) Equilibrium phase image, (b) 10-minute hepatobiliary phase image, and (c) 30-minute hepatobiliary phase image show increasing contrast accumulation (arrows) adjacent to the hepatic resection margin. (d) Axial and (e) coronal extended delayed hepatobiliary phase images at 120 minutes further confirm contrast leakage (arrows). (f) Coronal maximum-intensity-projection MRCP image demonstrates the corresponding biloma (B) formation and leakage site.

Biliary stricture was defined on MRCP as a focal or segmental luminal narrowing in bile duct caliber associated with upstream ductal dilatation or caliber change (Figure 4). MRCP evaluation also included assessment of concomitant intrahepatic bile duct dilatation.

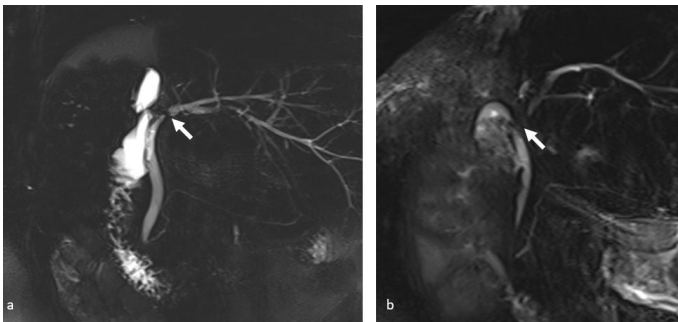


Figure 4. Coronal thick-slab MRCP images obtained in two different right-lobe donors (a, b) demonstrate focal luminal signal loss at the hepatic confluence (arrows), compatible with biliary stricture, accompanied by upstream intrahepatic biliary dilatation.

Medical records were retrospectively reviewed to obtain demographic data, graft type, postoperative clinical course, time interval between transplantation and detection of biliary complications, and information regarding endoscopic or percutaneous interventions. These biliary interventions were documented for descriptive purposes only, as the primary aim of the study was radiologic characterization of biliary complications in living liver donors rather than assessment of treatment outcomes.

Preoperative MRCP-Based Evaluation of Biliary Anatomy

All MRCP examinations were retrospectively reviewed in consensus by two radiologists, one with more than 10 years of experience in abdominal radiology and the other with 6 years of experience in general radiology. Image analysis focused on postoperative biliary findings as well as the anatomic configuration of the biliary tree. Biliary anatomy was classified according to established MRCP-based branching patterns.⁸ In type 1 (classic anatomy), the right posterior hepatic duct joins the right anterior hepatic duct to form the right hepatic duct, which subsequently merges with the left hepatic duct to create the common hepatic duct. Type 2 anatomy represents trifurcation of the right anterior, right posterior, and left hepatic ducts.

In type 3a, the right posterior hepatic duct drains into the left hepatic duct, whereas in type 3b it drains directly into the common hepatic duct below the biliary bifurcation. Type 3c describes drainage of the right posterior hepatic duct into the cystic duct, type 4 refers to aberrant drainage of right hepatic duct into the cystic duct, and type 5 anatomy refers to the presence of an accessory hepatic duct draining into the right hepatic duct. In addition, the distance between the right posterior hepatic duct and the biliary bifurcation was measured on thick-slab coronal-oblique MRCP images for morphometric analysis.

MRCP Acquisition

MR imaging was performed on 1.5-T (Optima 450w; GE Healthcare, Milwaukee, WI) and 3.0-T (MAGNETOM® Verio; Siemens Healthineers, Erlangen, Germany) systems using phased-array body coils, with patients positioned supine. Baseline imaging included heavily T2-weighted single-shot MR cholangiographic sequences, respiratory-triggered axial T2-weighted fast spin-echo acquisitions, and fat-suppressed three-dimensional gradient-echo T1-weighted sequences obtained before and after contrast administration. Detailed evaluation of the biliary tree primarily relied on heavily T2-weighted MRCP images, including thick-slab coronal-oblique projections and three-dimensional thin-slice acquisitions. Dynamic contrast-enhanced imaging with the hepatocyte-specific contrast agent gadoteric acid disodium (Gd-EOB-DTPA, Primovist) was performed following intravenous administration of 0.1–0.2 mmol/kg at an injection rate of 2–3 mL/s. Dynamic images including pre-contrast, arterial, portal venous, and equilibrium phases were acquired in the axial plane, followed by hepatobiliary phase imaging at approximately 10–30 minutes in axial and coronal planes. If biliary opacification was insufficient on hepatobiliary phase images, additional delayed acquisitions at approximately 120–150 minutes were obtained using the same pulse sequence. In cases with persistent clinical or biochemical suspicion of bile leakage despite negative initial hepatobiliary phase findings, further delayed imaging at extended intervals was performed to improve detection of contrast extravasation. Imaging was terminated when bile leakage was demonstrated or when adequate biliary excretion was achieved without evidence of leakage.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Comparisons were performed between donors with and without biliary complications based on demographic characteristics, graft type, biliary anatomy, and MRCP-derived measurements. Normality of data distribution was assessed using the Shapiro–Wilk test. Continuous variables were expressed as mean \pm standard deviation or median (range), as appropriate. The independent samples t-test was used for normally distributed variables, whereas the Mann–Whitney U test was applied for non-normally distributed variables. Categorical variables were compared using the chi-square test or Fisher’s exact test, as appropriate. A two-sided p value of < 0.05 was considered statistically significant.

Results

Donor Demographics and MRCP Findings Across Groups

A total of 181 living liver donors were included in the study. Of these, 77 donors (42.5%) were female and 104 (57.5%) were male. Right-lobe grafts were used in 124 donors (68.5%), while 57 donors (31.5%) donated a left-lobe graft. The mean donor age was 32.99 ± 8.82 years. During postoperative follow-up, 19 donors underwent MRCP due to suspected biliary complications. Radiologic biliary complications were identified in 16 donors (8.8%), whereas 3 donors demonstrated biochemical cholestasis despite normal MRCP findings.

Donor age was comparable between the biliary complication and non-complication groups (32.38 ± 8.69 vs. 33.05 ± 8.86 years, $p = 0.708$). Male donors were more frequent in both the biliary complication and non-complication groups, accounting for 12 of 16 donors (75.0%) and 92 of 165 donors (55.8%), respectively, with no significant difference in sex distribution between groups ($p = 0.137$). Similarly, right-lobe graft donation predominated in both groups, observed in 12 of 16 donors (75.0%) with complications and in 112 of 165 donors (67.9%) in the non-complication group, showing no statistically significant difference ($p = 0.558$).

Type 1 anatomy was the most common biliary configuration, observed in 69.6% of donors, followed by the type 3a variant in 15.5%. Type 2 and type 3b variants accounted for 5.5% and 5.0% of donors, res-

pectively, whereas type 5 and type 3c variants were identified in 3.9% and 0.6% of cases. When stratified by complication status, type 1 anatomy was present in 9 of 16 donors (56.3%) with biliary complications and in 117 of 165 donors (70.9%) without complications. Variant biliary anatomies appeared relatively more frequent among donors with complications, including type 2 anatomy in 4 donors (25.0%), type 3a in 2 donors (12.5%), and type 3b in 1 donor (6.3%), while no type 5 or type 3c variants were observed in this group. Despite these distributional differences, biliary anatomy variants were not significantly associated with biliary complications ($p = 0.282$) (Table 1).

Table 1. Baseline demographic and preoperative MRCP imaging parameters in donors

	Biliary complication (+) (n=16)	Biliary complication (-) (n=165)	Total (n=181)	p value
Age (years)	32.38 ± 8.69 31 (21–55)	33.05 ± 8.86 32 (17–59)	32.99 ± 8.82 32 (17–59)	0.708
Sex	4 female (25.0%) 12 male (75.0%)	73 female (44.2%) 92 male (55.8%)	77 female (42.5%) 104 male (57.5%)	0.137
Graft type	12 right (75.0%) 4 left (25.0%)	112 right (67.9%) 53 left (32.1%)	124 right (68.5%) 57 left (31.5%)	0.558
Bile duct anatomy variants				0.282
Type 1	9 (56.3%)	117 (70.9%)	126 (69.6%)	
Type 2	4 (25%)	6 (3.6%)	10 (5.5%)	
Type 3a	2 (12.5%)	26 (15.8%)	28 (15.5%)	
Type 3b	1 (6.3%)	8 (4.8%)	9 (5%)	
Type 3c	0 (0%)	1 (0.6%)	1 (0.6%)	
Type 5	0 (0%)	7 (4.2%)	7 (3.9%)	
Right posterior duct–biliary bifurcation distance (mm)	9.06 ± 5.79 7.1 (3.6–22.0)	7.23 ± 5.30 5.2 (1.5–23.3)	7.63 ± 5.41 5.4 (1.5–23.3)	0.154

Continuous variables are presented as mean \pm standard deviation and median (range).

Percentages are calculated within each biliary complication group.

The median distance from the right posterior sectoral duct to the biliary bifurcation was 7.1 mm (range, 3.6–22.0) in donors with biliary complications and 5.2 mm (range, 1.5–23.3) in donors without complications, and this parameter did not differ significantly between groups ($p = 0.154$).

Spectrum of Postoperative Biliary Complications and Interventions

Bile leakage and biloma formation were the most frequent imaging findings, observed in 11 of 16 donors (68.8%), predominantly during the early postoperative period. Imaging typically demonstrated fluid collections adjacent to the hepatic resection margin, consistent with biloma, and in two donors active biliary leakage was demonstrated on delayed hepatobiliary phase imaging performed with hepatocyte-specific contrast agents (Figures 2-3). Intrahepatic bile duct dilatation was observed in three patients, all of whom required interventional management: two were treated with ultrasound-guided percutaneous drainage, and one underwent combined percutaneous drainage and ERCP with biliary stent placement. In one patient, regional parenchymal perfusional changes were noted on imaging in association with biloma formation. Overall, six patients were managed conservatively, four underwent ultrasound-guided percutaneous drainage (including one patient who required repeated drainage), and one patient required combined percutaneous drainage and ERCP with biliary stent placement after bile leakage was confirmed.

Overall, biliary stricture developed in five donors during follow-up. Within the first postoperative month, three donors developed biliary narrowing at the level of the common hepatic duct with upstream bile duct dilatation, occasionally accompanied by perfusional alterations. Only one patient required combined percutaneous transhepatic biliary drainage and ERCP with stent placement, whereas the remaining two patients were managed conservatively without intervention. During later follow-up, two additional donors developed biliary strictures detected at 5.5 and 8 months postoperatively, respectively. Imaging demonstrated biliary narrowing with associated ductal dilatation. One patient underwent ERCP with sphincterotomy, while the other was managed conservatively (Table 2).

Three donors presented with elevated liver function tests and cholestatic parameters at 6 months, 14 months, and 2 years after transplantation. In all three cases, MRCP demonstrated normal biliary anatomy without evidence of stricture, dilatation, or bile leakage (Figure 5).

Table 2. Postoperative MRCP findings and management of biliary complications in living liver donors

Imaging finding / Complication type	No. of donors (%)	Typical MRCP findings	Timing after transplantation	Management
Bile leak ± biloma	11 (68.8%)	Perihepatic fluid collections adjacent to the resection margin; intrahepatic bile duct dilatation in 3 patients; regional perfusional change in 1 patient	Postoperative 1 week–1.5 months	Conservative follow-up (n=6); US-guided drainage (n=4, including 1 repeated); Percutaneous drainage and ERCP-assisted biliary stenting (n=1)
Biliary stricture	5 (31.2%)	Focal and segmental luminal narrowing of the bile duct with upstream dilatation	Postoperative 1 week–1 month (n = 3); later follow-up at 5.5 and 8 months (n = 2)	Combined percutaneous transhepatic biliary drainage and ERCP-guided stent placement (n = 1); ERCP-guided sphincterotomy (n=1); conservative follow-up (n = 3).
Biochemical cholestasis with normal MRCP	3	Normal biliary anatomy without stricture, dilatation, or bile leak	6 months, 14 months, and 2 years	Clinical follow-up

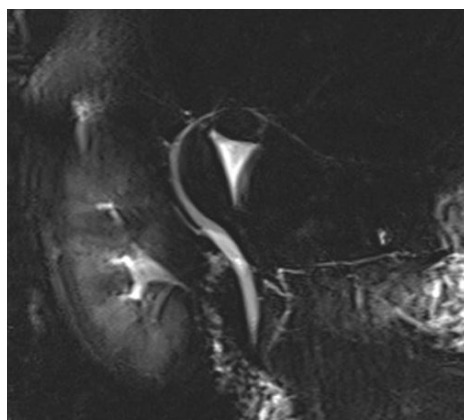


Figure 5. Coronal thick-slab MRCP image obtained in a right-lobe donor demonstrates normal biliary anatomy without evidence of bile leakage, biliary stricture, or intrahepatic duct dilatation despite clinical and laboratory findings suggestive despite biochemical cholestasis prompting MRCP evaluation.

Discussion

In this MRCP-based donor cohort, radiologic biliary complications were detected in 8.8% of living liver donors, with bile leakage and biloma formation constituting the predominant imaging phenotype (68.8%), whereas biliary strictures were less frequent, occurring as early biliary narrowing within the first postoperative month in three donors and as later-developing strictures in two donors during follow-up. Neither MRCP-defined biliary branching patterns nor MRCP-derived morphometric parameters demonstrated a statistically significant association with postoperative biliary complications. A small subgroup demonstrated biochemical cholestasis despite a normal MRCP, emphasizing that abnormal liver enzymes are not synonymous with structural biliary pathology in donors and that imaging–laboratory discordance is clinically relevant for avoiding over-intervention.

From a radiologic perspective, the predominance of bile leak/biloma aligns with the expected imaging spectrum after donor hepatectomy, where peripheral ductal injury at the transection plane results in perihepatic fluid collections. Importantly, our experience supports the incremental value of hepatocyte-specific contrast-enhanced delayed imaging in selected cases—when conventional MRCP is non-diagnostic yet clinical suspicion persists—because demonstration of contrast extravasation into a collection upgrades “postoperative fluid” into active bile leak with actionable implications.^{5,9} For biliary strictures, early biliary narrowing with upstream dilatation may be observed in association with intraoperative technical factors, whereas later strictures may reflect evolving fibrotic or ischemia-related changes; however, definitive etiologic attribution remains limited.¹⁰ MRCP continues to serve as a key noninvasive modality for evaluating duct caliber changes and biliary dilatation patterns. The lack of association between branching variants and complications suggests that, in the modern era of high-resolution MRCP and meticulous surgical planning, radiologic anatomy alone may not represent a strong predictor of donor morbidity, consistent with the existing literature.^{11,12}

Our observed donor biliary-complication rate of 8.8% falls within the broad spectrum reported in living donor hepatectomy literature, where incidences vary widely depending on study design, definitions, and follow-up strategies, generally ranging from approximately 2% to 18%.^{1,9,13,14} Large donor series have reported lower bile-leak rates with minimal or

absent strictures, whereas right-lobe–dominant cohorts tend to demonstrate slightly higher complication frequencies, likely reflecting increased technical complexity at ductal transection.^{1,12,15} Across studies, bile leakage consistently represents the most common early postoperative event, while strictures emerge later during follow-up, mirroring the temporal imaging pattern observed in our MRCP cohort.^{15,16} Emerging evidence also suggests that surgical factors such as the number of bile duct orifices may better explain leakage risk than classical MRCP-based branching classifications alone, highlighting the limitations of relying solely on morphologic anatomy for radiologic risk stratification.^{15,17} Within this context, donor biliary complication rates appear heterogeneous yet broadly consistent with our findings, supporting a radiologic paradigm in which MRCP primarily functions as a problem-solving and triage tool—guiding timely intervention while avoiding unnecessary invasive procedures in an otherwise low-risk donor population.

From a clinical imaging perspective, our findings highlight several practical implications for radiologists involved in donor follow-up. Consistent with prior reports, our experience underscores the added value of hepatocyte-specific contrast-enhanced MRI in differentiating true bile leakage from nonspecific postoperative collections. In the early postoperative period, perihepatic fluid is common and may mimic biloma on conventional sequences; however, visualization of delayed hepatobiliary phase contrast extravasation enables functional confirmation of active leakage, thereby reducing both overdiagnosis and delayed intervention.^{5,18} The temporal distribution of complications observed in our cohort further supports a phase-oriented imaging strategy: early imaging should focus on detection of bile leakage, whereas later surveillance should prioritize identification of biliary strictures. This time-dependent imaging pattern reinforces the importance of adapting radiologic interpretation to the postoperative interval rather than applying a uniform diagnostic framework across all time points. Finally, our results reinforce that MRCP should be considered not only an anatomic modality but also a clinical decision-support tool. In donors presenting with cholestatic laboratory abnormalities but normal MRCP findings, clear radiologic reporting is essential to avoid unnecessary invasive procedures by emphasizing the absence of imaging evidence for leak or stricture and suggesting alternative, non-biliary causes for biochemical alterations.

This study has several limitations that should be acknowledged. First, its retrospective single-center design and the relatively small number of biliary complications may have limited statistical power to detect subtle associations between MRCP-derived anatomic features and clinical outcomes. Second, MRCP examinations were performed based on clinical suspicion rather than standardized postoperative surveillance, which may have introduced selection bias and variability in imaging timing. In addition, imaging findings could not be systematically correlated with detailed operative parameters or interventional outcomes, such as duct division technique or the number of bile duct orifices, which may represent stronger determinants of leakage risk than morphologic anatomy alone. Future research should therefore focus on larger, multidisciplinary prospective studies integrating radiologic, surgical, and interventional datasets with longitudinal outcome tracking to better define imaging-based risk stratification and optimize postoperative management strategies in living liver donors.

Conclusion

In conclusion, MRCP-based evaluation demonstrated that biliary complications in living liver donors occur infrequently, with early leak/biloma as the dominant imaging phenotype and a smaller burden of biliary strictures. Preoperative MRCP-defined biliary branching variants were not significantly associated with donor biliary complications, suggesting that modern imaging-based anatomic characterization alone may not adequately stratify donor risk. For radiologists, MRCP — particularly when combined with hepatocyte-specific delayed imaging — provides a comprehensive, noninvasive framework for accurately detecting clinically relevant complications, guiding time-adapted surveillance, and preventing unnecessary invasive interventions in this low-risk donor population.

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