Anatomical Variants of Biliary Tree in a Tertiary Care Teaching Hospital of Nepal

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ABSTRACT

Background

Anatomical variations of the biliary tree are common and have significant clinical implications, particularly during hepatobiliary surgeries such as cholecystectomy, liver resection, and liver transplantation. This study was conducted to identify the different hepatobiliary variants among the Nepalese population. It was also conducted to look for any specific pathological condition associated with a specific pattern and to determine whether any accessory ducts were present in the study population.

Objective

To identify the anatomical variants of the intrahepatic biliary tree in the Nepalese population using the Huang classification.

Method

This retrospective cross-sectional study was conducted in the Department of Radiology at Dhulikhel Hospital. A total of 100 patients who underwent magnetic resonance cholangiopancreatography (MRCP) were included. Magnetic resonance cholangiopancreatography images were reviewed to identify the type of intrahepatic biliary duct and were classified according to the Huang classification.

Result

Among the 100 participants, 62 (62%) were female, and 38 (38%) were male, with a mean age of 45.65 years (range: 6–88 years). According to the Huang classification, 67 (67%) were Type A1, 16 (16%) were Type A2, 13 (13%) were Type A3, 4 (4%) were Type A4, and 0 (0%) were Type A5.

Conclusion

Huang classification Type A1 was the most common type of intrahepatic bile duct observed in this study.

KEY WORDS

Anatomical variation, Biliary tree, Huang classification, Intrahepatic bile duct

INTRODUCTION

The hepatobiliary system has a complex anatomy due to the existence of a wide range of anatomical variants.[1] The right posterior hepatic duct (RPHD) joining the right anterior hepatic duct is the most common variant.[2] Trifurcation of the common hepatic duct (CHD), RPHD joining the CHD, and RPHD joining the cystic duct are other common variants of the intrahepatic ductal system. Other rarer variants also exist.[3] Exact knowledge of these anatomic variations is of significant clinical relevance with the growing trend in interventional radiological methods and surgical techniques, such as image-guided interventional biliary drainage procedures, laparoscopic cholecystectomy, tumor surgery, and liver resection alongside liver transplantation, as perioperative biliary complications, such as postoperative strictures, comprise one of the most commonly encountered causes of morbidity and mortality.[2,4,5]

It is the responsibility of the operating team to precisely identify the type of hepatobiliary variant in each case preoperatively to decrease the chances of iatrogenic injury, which could decrease the mortality and morbidity. Among various imaging modalities, MRCP, one of the evolving techniques that visualizes the bile duct and pancreatic duct with great accuracy, is preferred because of its non-invasiveness and the absence of severe complications such as pancreatitis, hemorrhage, bowel perforation, as well as its lack of radiation and superior soft tissue contrast.[6,7] This study aims to find the anatomical variation of hepatobilliary system in the Nepalese population.

METHODS

This retrospective, cross-sectional study was conducted in the Department of Radiology at Dhulikhel Hospital from December 2023 to February 2024. A total of 100 patients who underwent magnetic resonance cholangiopancreatography (MRCP) for various clinical indications were selected on a simple random basis. Patients who met the inclusion criteria were enrolled in the study, while incomplete scans or non-evaluable biliary anatomy were excluded.

The study protocol was reviewed and approved by the Institutional Review Committee (IRC) of Kathmandu University School of Medical Sciences (KUSMS). Informed consent was waived due to the retrospective nature of the study. Patients who underwent MRCP at Dhulikhel Hospital during the study period and had complete MRCP examinations with evaluable intrahepatic biliary anatomy were included in the study. MRCP examinations with incomplete imaging, poor image quality, or non-evaluable biliary anatomy due to severe pathology, motion artifacts, or technical limitations were excluded. For patients with multiple MRCP examinations, only the first eligible examination was included.

Patients fasted for four hours and were administered 100 mL of pineapple juice 15 minutes before image acquisition to minimize gastrointestinal fluid signal. MRCP was performed using a 1.5T MRI system (Philips Ingenia) in the supine position with a dedicated body coil over the abdomen and respiratory gating placed over the right hemidiaphragm. The imaging protocol included low-resolution T2-weighted three-plane localizers (axial, coronal, sagittal), T2-HASTE fat-saturated coronal, T2-TSE transverse, BTFE transverse (GRE sequence), T2-SPACE 3D coronal, and T2-HASTE (single-shot) breath-hold coronal oblique (radial) sequences.

Anatomical classification of the intrahepatic biliary tree was evaluated on a workstation by a radiologist with three years of experience using the Huang classification system.

Statistical analysis was performed using SPSS version 25. Categorical data were presented as frequencies and percentages. The Chi-square test was applied to compare the prevalence between male and female participants. A p-value of ≤ 0.05 was considered statistically significant.

Magnetic Resonance Cholangiopancreatography (MRCP) Protocol and Imaging Acquisition

MRCP was performed using a 1.5T MRI system (Philips Ingenia). Standard imaging sequences included low-resolution T2-weighted three-plane localizers, T2-HASTE fat-saturated coronal, T2-TSE transverse, and BTFE transverse sequences. Non-invasive evaluation and mapping of the intrahepatic biliary tree were primarily conducted using respiratory-gated coronal 3D T2-SPACE (TR/TE = 1180/600 ms, slice thickness 1 mm) and breath-hold single-shot coronal oblique radial T2-HASTE (TR/TE = 8000/800 ms) sequences.

Image Analysis

Anatomical variations of the intrahepatic biliary tree were classified using the Huang classification system based on the drainage site of the right posterior hepatic duct (RPHD):

Images were analyzed on a workstation, and the images were interpreted by a radiologist with three years of experience. Data on different biliary tree variants, along with demographic details, were recorded. SPSS version 25 was used for statistical analysis. Descriptive statistics, including frequencies and percentages, were calculated for demographic characteristics and anatomical variant types. The Chi-square test was applied to assess differences in variant distribution between male and female participants.

RESULTS

A total of 100 cases were taken into account for the study. Out of the participants, 62 (62%) were female, 38 (38%) were male, and the male-to-female ratio was 0.61:1. The ages of the participants ranged from 6 to 88 years, with a mean age of 45.65 years. This, in itself, shows the range of variability among the participants involved in the study.

We used the Huang classification method to identify the variants. Overall, 67 participants (67%) were categorized as Huang Type A1, 16 (16%) as Type A2, 13 (13%) as Type A3, and 4 (4%) as Type A4. No cases of Type A5 were identified.

Anatomic variants were more frequent in females overall, corresponding to their higher representation in the study cohort. However, Type A2 was observed in a higher proportion of males than females (9 males, 23.7% vs. 7 females, 11.3%). Detailed gender-wise distributions are presented in table 1.

Table 1. Structural classification system for intrahepatic biliary duct variations according to the Huang anatomical criteria

Variant type	Site of opening of right posterior hepatic duct (RPHD)
Huang A1	The right anterior hepatic duct (RAHD)
Huang A2	The hepatic confluence (trifurcation)
Huang A3	The left hepatic duct (LHD)
Huang A4	The main hepatic duct (MHD)
Huang A5	The cystic duct

Figures 1–5 show the anatomical variants of the patients included in the study, ranging from Huang Type A1 to A4.

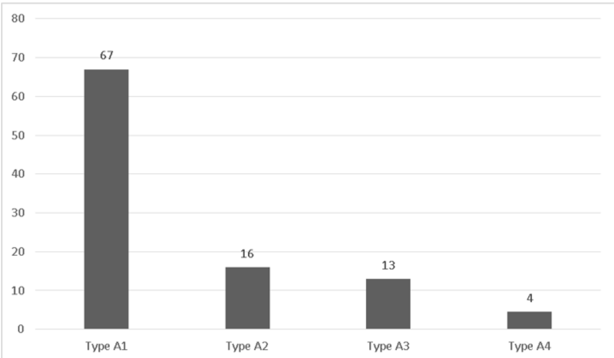

Figure 1. Percentage distribution of intrahepatic biliary duct variants according to the Huang classification system (n=100)

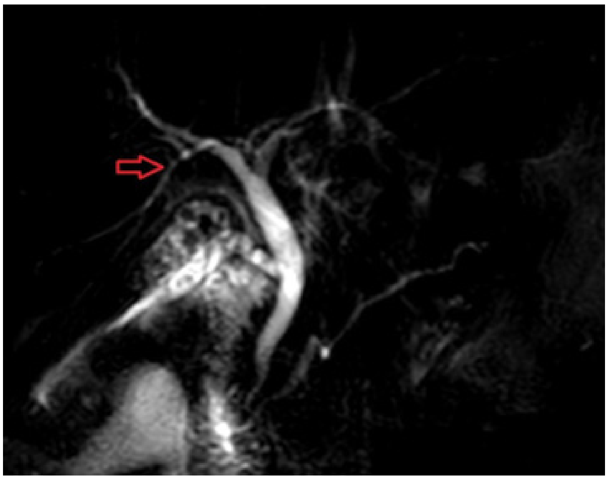

Figure 2. Huang type A1 - Coronal 3D MR cholangiopancreatography showing right posterior hepatic duct(red arrow) draining into the right anterior hepatic duct and joining the left hepatic duct to form the common bile duct.

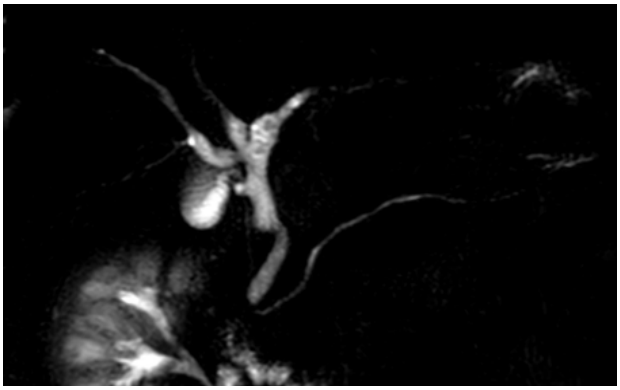

Figure 3. Huang type A2 (trifurcation): Coronal 3D MR cholangiopancreatography showing trifurcation pattern formed by the right posterior hepatic duct, right anterior hepatic duct, and left hepatic duct to form the CHD.

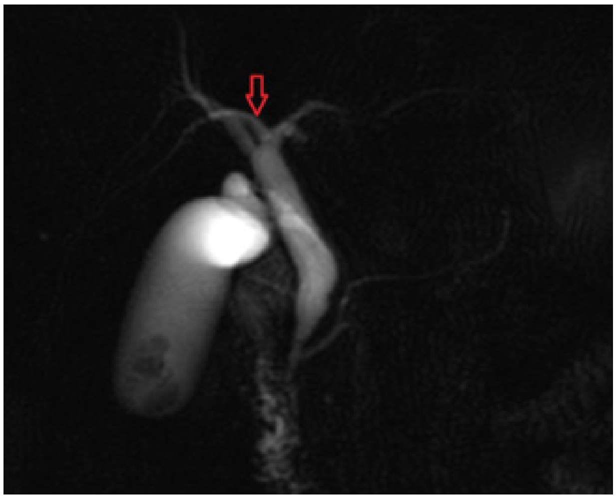

Figure 4. Huang type A3 - Coronal 3D MR cholangiopancreatography showing the right posterior hepatic duct(red arrow) draining into the left hepatic duct and then joining the right anterior hepatic duct to form the CHD.

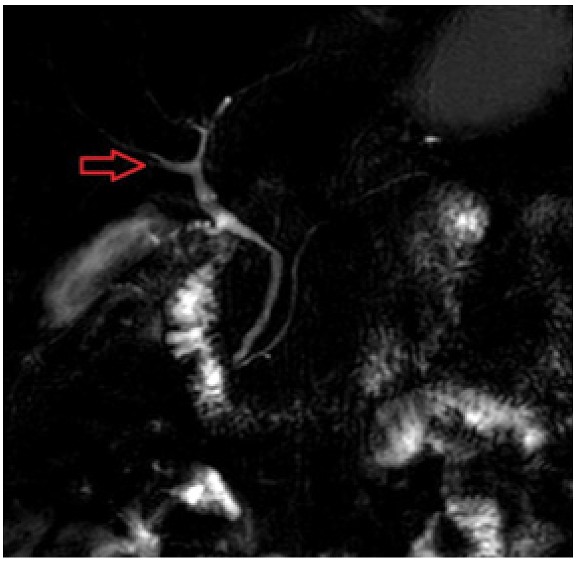

Figure 5. Huang type A4 - Coronal 3D MR cholangiopancreatography showing the right posterior hepatic duct (red arrow) draining directly into the CHD.

Table 2. Gender wise differentiation of various types of biliary tree variants

	Type A1	A2	A3	A4	Total
Females	43	7	8	4	62
Males	24	9	5	0	38
Total	67	16	13	4	100

DISCUSSIONS

Anatomical variations in the intrahepatic biliary architecture create significant surgical and interventional challenges.[2]

Preoperative identification of these variants is required to minimize iatrogenic biliary injuries during procedures such as laparoscopic cholecystectomy and liver transplantation.[2]

MRCP (magnetic resonance cholangiopancreatography) is the non-invasive imaging modality of choice for biliary evaluation, providing high-resolution images without exposing patients to ionizing radiation.[1]

In 100 patients evaluated in our study, the typical anatomical arrangement (Huang Type A1), characterized by the right posterior hepatic duct (RPHD) draining into the right anterior hepatic duct (RAHD), was observed in 67 (67%) cases. This intrahepatic biliary structure with classic anatomy remains the most frequent finding across diverse ethnic populations.[3] In similar studies, the prevalence of classic Type 1 anatomy was 63% in an Indian population, 63.2% in the Egyptian population, and 71.7% in the Caribbean population.[8-10]

Notable patterns have been identified across different study populations. In our study, the second most common pattern was the trifurcation variant (Type A2), seen in 16 (16%) cases. This finding is comparable to the Indian study, where there was an 18% prevalence, 19.1% in the Caribbean population, and 10.4% reported in the Egyptian population.[8-10] The anomalous drainage of the RPHD directly into the left hepatic duct (Type A3) in our study was seen in 13 (13%) cases, which is similar to the Caribbean population, where it was 4.61%, and comparable to the 17% reported in the Egyptian population and 14.7% in Uganda.[9-11]

Aberrant RPHD drainage directly into the common hepatic duct was found in 4 (4%) cases, which is comparable to the study conducted in the Indian population, showing a 3% prevalence, and 3.6% in the Iranian population.[8,12] Interestingly, no cases of RPHD draining directly to the cystic duct (Type A5) were observed in our population. The Huang classification Type A5 variant is considered the rarest variant, and its absence has been reported in many studies, including those by Taghavi et al. in Iran, Cawich et al. in the Caribbean, and Yason et al. in Uganda, all of which recorded a 0% prevalence for this specific variant.[10-12]

Embryologically, the biliary tree develops from the hepatic diverticulum during early gestation, and minor deviations in ductal recanalization or regression can lead to distinct anatomical configurations.[13] In our centre, non-invasive imaging utilizing breath-hold 3D T2-SPACE sequences enabled detailed multi-planar evaluation, minimizing diagnostic ambiguity.

Recognizing these anatomical variants preoperatively carries substantial clinical significance.[1] For example, a low-joining aberrant RPHD (such as Types A3 or A4) increases the vulnerability of the duct to accidental ligation, transection, or stricture formation during cholecystectomy.[2,6] In living donor liver transplantation, failure to identify a trifurcation (Type A2) or aberrant RPHD drainage preoperatively can lead to inadvertent biliary leakage or compromised graft vascularization and drainage.[2,3] Therefore, systematic reporting of intrahepatic biliary variants using standard criteria such as the Huang classification provides surgeons with crucial spatial roadmaps, ultimately reducing postoperative morbidity.[2,3]

This study has several limitations that should be acknowledged. First, its retrospective design and hospital-based setting at a single tertiary center limit the generalizability of these findings to the broader Nepalese population. Second, its sample size of 100 participants, while adequate for common variants, may underrepresent exceptionally rare anomalies such as Type A5. Third, intraoperative correlation or direct cholangiography confirmation was not available for all cases to validate the MRCP observations.

Future multicenter prospective studies with larger cohorts are warranted to establish comprehensive epidemiological baseline data on biliary variants in the region.

Table 3. Comparison of Biliary tree anatomical variants across different populations

Study	Year	Country	Total cases	Imaging techniques	Type A1	Type A2	Type A3	Type A4	Type A5	Others
Khanduja et al.8	2016	India	100	MR abdomen + MRCP	63%	18%	9%	8%	0%	2%
Tawab et al.9	2012	Egypt	106	MRCP	63.2%	10.4%	17%	7.5%	1.9%	0%
Taghavi et al.12	2017	Iran	362	MRCP	45%	21.5%	13.3%	3.6%	0%	16.6%
Cawich et al.10	2021	Eastern carrib ean	152	MRCP	71.7%	19.1%	4.61%	3.95%	0%	0%
Liamond et al.14	2004	United states	27	MRCP	19%	5%	2%	1%	0%	0%

CONCLUSION

Variations in biliary ductal anatomy are common, with Huang Type A1 being the most common variant, consistent with most of the available literature. Three-dimensional magnetic resonance cholangiopancreatography (3D-MRCP) sequences can accurately depict these ductal variations. As a non-invasive and radiation-free imaging modality, MRCP is considered the gold standard for detecting hepatobiliary anatomical variations.

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