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Identification of Variation in the Extrahepatic Arterial System of Thai Cadavers

Identificación de la Variación en el Sistema Arterial Extrahepático de Cadáveres Tailandeses

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SUMMARY: Liver transplantation (LT) is the treatment of choice for decompensated liver cirrhosis. In the LT procedure, an adequate arterial supply is required for anastomosis to prevent postoperative necrosis and maintain hepatic parenchymal functions. The extrahepatic arterial system is primarily responsible for carrying oxygenated blood from the heart, 25 % of total cardiac output. Normally, the celiac trunk gives off the common hepatic artery. The common hepatic artery branches into the hepatic artery proper and supplies blood to the hepatic parenchyma. Recognizing the anatomical variations of the hepatic artery proper is essential for the planning and implementation of LT. The extrahepatic arterial variations are hard to study in live humans because of the limitations of human rights. Studying cadavers can solve this problem. This study investigates the distribution of normal, accessory, and replaced hepatic arteries proper by dissecting Thai cadavers (n = 152; males = 82 and females = 70) in the Gross Anatomy Laboratory at the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University. The cadavers were preserved in a 10 % formaldehyde solution. The exclusion criteria for liver specimens were cirrhosis, liver carcinoma, including hepatocellular carcinoma and cholangiocarcinoma, and other liver masses. Accordingly, the extrahepatic arterial system was conventionally dissected and identified at the porta hepatis. The extrahepatic arterial system was identified and documented in terms of features of normal distribution and variations, such as accessory or replaced hepatic arteries. There were 75 % normal type, 18.42 % accessory left hepatic arteries (aLHA), 1.32 % replaced left hepatic arteries (rLHA), 0.66 % accessory right hepatic arteries (aRHA), 1.32 % of replaced right hepatic arteries (rRHA), 1.97 % of aLHA and aRHA, and 1.32 % aortic type. The identification of variations in the hepatic artery system is essential to detection of distribution patterns. This knowledge is crucial for promoting LT.

KEY WORDS: Liver; Anatomy; Extrahepatic arterial system. Thai individuals.

INTRODUCTION

The liver is a reddish-brown organ that is shaped somewhat like a wedge. It is located in the right hypochondriac region, the epigastric region, and the left hypochondriac region. The liver is found inferior to the diaphragm, superior to the stomach and duodenum, and anterior to the lesser omentum. The liver is the body's largest visceral organ, accounting for approximately 2 %–3 % of total body weight. Although the liver is responsible for numerous functions, its most important role that sets it apart from other organs is its detoxification ability (Abdel-Misih & Bloomston, 2010). Hepatocytes play an important role in protecting an organism against from potential toxic chemical insults. They do this through their capacity to convert toxic substances into water-soluble metabolites, which can then be efficiently eliminated from the body (Braet & Wisse, 2002). When the liver is repeatedly pushed to process toxins or is subject to a prolonged viral attack, it can result in chronic hepatocyte destruction and inflammation. Cirrhosis is the last stage of chronic liver disease that results in significant changes in the liver structure (Schuppan & Afdhal, 2008). Currently, pharmacological treatments that can slow or stop the progression of decompensated cirrhosis are still being developed, making liver transplantation (LT) the only curative option for cirrhosis and end-stage liver disease.

The main vascular anastomoses that are performed during LT are on the hepatic portal vein, hepatic artery proper, and common bile duct (Blumgart *et al*., 2007). In order for LT to prevent postoperative necrosis and sustain liver parenchymal functions, a sufficient arterial supply is necessary for anastomosis. Thus, it is critical to recognize anatomic variations of the extrahepatic artery in patients undergoing

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liver transplantation. As a result, recognizing extrahepatic arterial variations is important for surgical planning. Normally, the common hepatic artery arises from the celiac axis, and the proper hepatic artery is the continuation, which shortly divides into the right and left hepatic arteries. However, because the embryological development of the celiac axis, the superior mesenteric artery, and the aorta are fairly complex, there are wide variations in the arterial supply of the liver. The classification of extrahepatic arterial variations has been proposed by Michels (1966) and Hiatt *et al*. (1994). This study used Hiatt's devised version of Michels's classification, which reduces Michels's original 10 groupings to 5 major types with subgroups and a particularly rare 6th type.

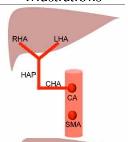
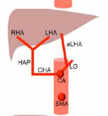
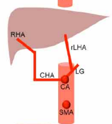
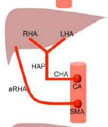
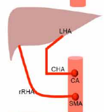
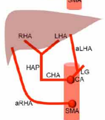
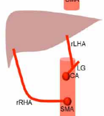
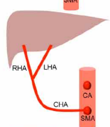
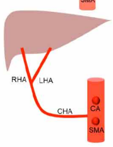
Because of human rights restrictions, it is difficult to examine extrahepatic arterial variations in living humans. This hindrance can be avoided by using a cadaveric study, which permits an attempt to investigate the variations in the vessel branching pattern. The many variants of the extrahepatic arterial system can be identified through dissection. Hence, dissection of the porta hepatis at the hepatoduodenal ligament in Thai cadavers allows the identification of numerous variations of the extrahepatic arterial system.

MATERIAL AND METHOD

Between 2019 and 2020, one-hundred fifty-two cadavers were dissected at the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University. They were fixed with a 10 % solution of formaldehyde. The cadavers were divided into two groups: males (n = 82) and females (n = 70). The age range is 40-101 years. All cadavers were obtained through body donation and signed informed consent forms by themselves for medical education at Mahidol University's Department of Anatomy, Faculty of Medicine Siriraj Hospital. The voluntary donors declared for themselves that the remains would be donated as materials for medical study and research. Research permission was approved by the Ethical Commission of the Siriraj Institutional Review Board under Protocol Number 462 Exemption. Conventional dissection of the cadavers was performed in the gross anatomy laboratory room. Liver specimens with cirrhosis or cancer, including hepatocellular carcinoma and cholangiocarcinoma, or other masses, were exclude. Anatomic variations of the hepatic artery were classified according to a modified Michels's classification as represented in Table I (Michels, 1966; Hiatt *et al*., 1994).

The dissection procedures included, first, making five skin incisions radiating from the umbilicus. Then cut the falciform ligament to detach the liver from the anterior abdominal wall. Once the liver was free from its attachment, access was gained to the inferior surface of the liver, and inspection of the free edge of the lesser omentum was possible. The subject of our interest was the hepatic artery proper. Following that, the celiac axis and its branches, common hepatic artery, left and right gastric arteries, hepatic artery proper, and right

Table I. Classification criteria of the extrahepatic arterial system: a modification of Michel's classification (Michels, 1966 and Hiatt *et al*., 1994).

Types	Definitions	Illustrations
Type 1	Normal type	
Type 2a	Accessory left hepatic artery (aLHA)	
	Replaced left hepatic artery (rLHA)	
Type 3a	Accessory right hepatic artery (aRHA)	
Type 3b	Replaced right hepatic artery (rRHA)	
Type 4a	Accessory left hepatic artery and accessory right hepatic artery (aLHA and aRHA)	
Type 4b	Replaced left hepatic artery and replaced right hepatic artery (rLHA and rRHA)	
Type 5	CHA from Superior mesenteric artery (SMA)	
Type 6	CHA from others e.g., aorta	

CA: celiac artery; SMA: superior mesenteric artery; CHA: common hepatic artery; HAP: hepatic artery proper; LHA: left hepatic artery; RHA: right hepatic artery; LG: left gastric artery; aLHA: accessory left hepatic artery; rLHA: replaced left hepatic artery; aRHA: accessory right hepatic artery; rRHA: replaced right hepatic artery.

and left hepatic arteries were cleaned and identified. Next, swing the small intestine to the right and remove the peritoneum that was attached to it. This was to grant access to the superior mesenteric artery and clean this vessel. When all of the preceding steps were completed, the type of variation could be determined by referring to the classification criteria. Moreover, other types of procedures, such as those performed on the abdominal aorta, were clarified.

RESULTS

The variations in the extrahepatic arteries of 152 cadavers were classified into one of six types. The mean age of the male Thai cadavers (n = 82) was 69.62 years (maximum: 92 years, minimum: 41 years, age range: 41-92 years) and that of the females Thai cadavers (n = 70) was 71.68 years (maximum: 101 years, minimum: 40 years, age range: 40-101 years). The cumulative mean of the group was 70.65 years (maximum: 101 years, minimum: 40 years).

Table II represents the variations of the extrahepatic arterial system in Thai cadavers. After the variation was identified, 75 % of cases were of the normal type (type 1) (n = 114), indicating that the left and right hepatic arteries arose from the hepatic artery proper branch of the common hepatic artery. The common

Table II. Variations of the extrahepatic arterial system in Thai cadavers.

Types	Number and percentage (%)		
	Total	Males	Females
	(n = 152)	(n = 82)	(n = 70)
Type 1	114	66	48
	75.00%	57.89%	42.11%
Type 2a	28	12	16
	18.42%	42.86%	57.14%
Type 2b	2	2	0
	1.32%	100.00%	0.00%
Type 3a	1	0	1
	0.66%	0.00%	100.00%
Type 3b	2	1	1
	1.32%	50.00%	50.00%
Type 4a	3	2	1
	1.97%	66.67%	33.33%
Type 4b	0	0	0
	0.00%	0.00%	0.00%
Type 5	0	0	0
	0.00%	0.00%	0.00%
Type 6	2	1	1
	1.32%	50.00%	50.00%

hepatic artery emerged from the celiac axis to form the gastroduodenal and proper hepatic arteries (Figs. 1A-B).

There were 28 cadavers with type 2a, in which the accessory left hepatic artery arose from the left gastric artery, accounting for 18.42 % of all cases. Surprisingly, there were no hepatic arteries proper. As shown in Figures 2A-B, both the right

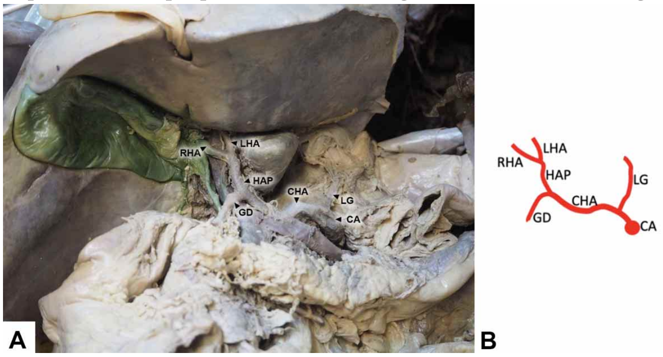


Fig. 1. A. A photo illustration of type 1 or normal type. B. A diagram showing the distribution of celiac artery. CA: celiac artery; LG: left gastric artery; CHA: common hepatic artery; HAP: hepatic artery proper; LHA: left hepatic artery; RHA: right hepatic artery; GD: gastroduodenal artery.

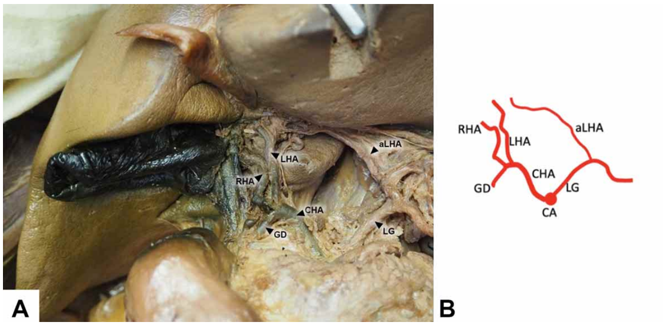


Fig. 2. A. A photo illustration of type 2a without hepatic artery proper. B. A diagram showing the distribution of celiac artery. CA: celiac artery; LG: left gastric artery; aLHA: accessory left hepatic artery; CHA: common hepatic artery; RHA: right hepatic artery; LHA: left hepatic artery; GD: gastroduodenal artery.

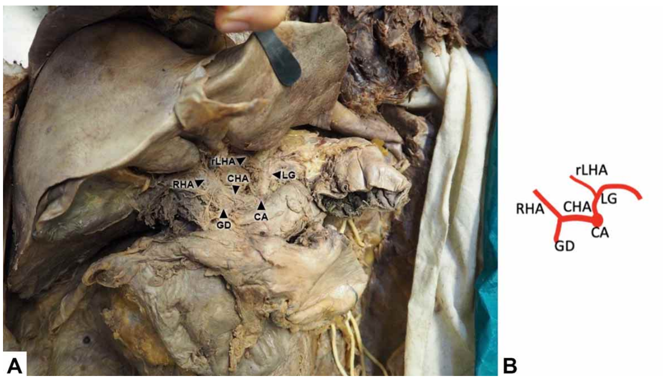


Fig. 3. A. A photo illustration of type 2b. B. A diagram showing the distribution of celiac artery. CA: celiac artery; LG: left gastric artery; rLHA: replaced left hepatic artery; CHA: common hepatic artery; RHA: right hepatic artery; GD: gastroduodenal artery.

and left hepatic arteries were formed directly from the common hepatic artery, and the accessory left hepatic artery was formed from the left gastric artery. Only 2 cases (1.32 %) were classified as type 2b, in which the replaced left hepatic artery arising from the left gastric artery (Figs. 3A-B).

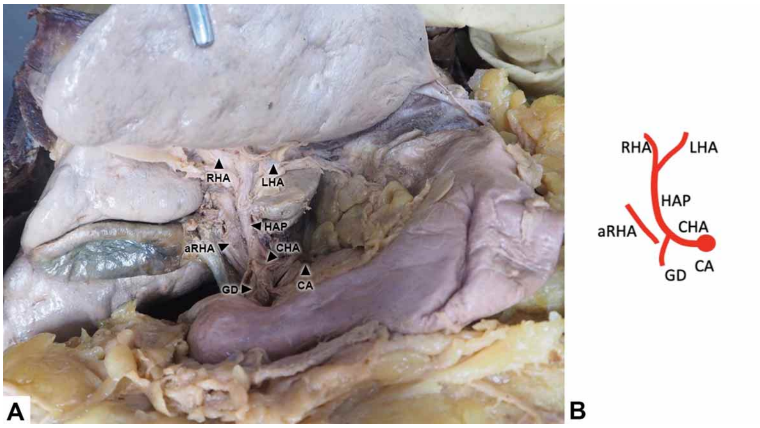


Fig. 4. A. A photo illustration of type 3a. B. A diagram showing the distribution of celiac artery. CA: celiac artery; CHA: common hepatic artery; GD: gastroduodenal artery; HAP: hepatic artery proper; LHA: left hepatic artery; RHA: right hepatic artery; aRHA: accessory right hepatic artery.

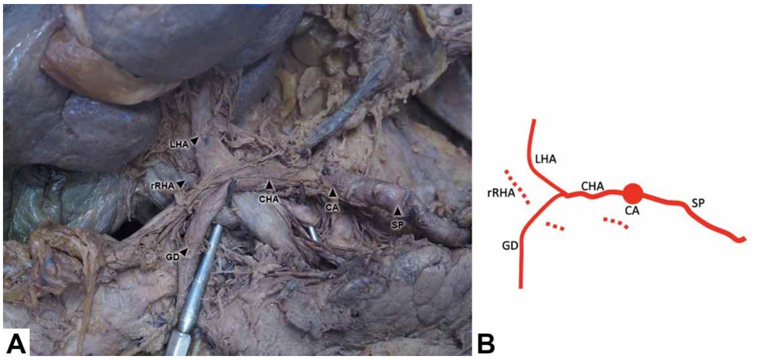


Fig. 5. A. A photo illustration of type 3b. B. A diagram showing the distribution of celiac artery. SP: splenic artery; CA: celiac artery; CHA: common hepatic artery; LHA: left hepatic artery; GD: gastroduodenal artery; rRHA: replaced right hepatic artery.

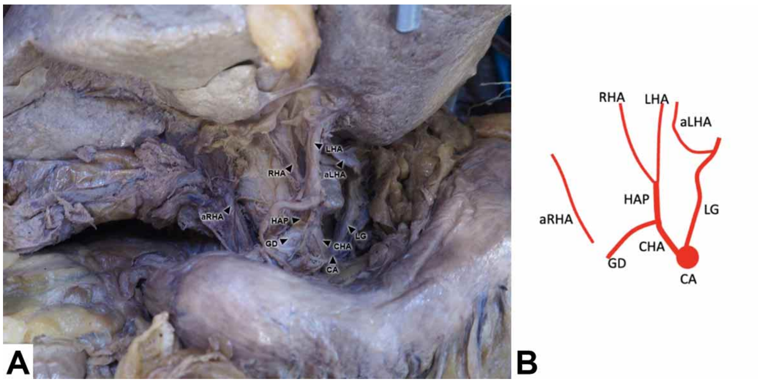


Fig. 6. A. A photo illustration of type 4a. B. A diagram showing the distribution of celiac artery. CA: celiac artery; LG: left gastric artery; aLHA: accessory left hepatic artery; CHA: common hepatic artery; GD: gastroduodenal artery; HAP: hepatic artery proper; LHA: left hepatic artery; RHA: right hepatic artery; aRHA: accessory right hepatic artery.

Only 1 case (0.66 %) was Type 3a, which was defined as the accessory right hepatic artery being developed directly from the superior mesenteric artery, as shown in Figures 4A-B. Only 2 cases (1.32 %) were classified as Type 3b, in which the right hepatic artery arises from the superior mesenteric artery as the replacement vessel (Figs. 5A-B).

A double accessory of the hepatic artery, or type 4a (Figs. 6A-B), was found in 3 cases (1.97 %). The left accessory hepatic artery emerges from the left gastric artery, while the right accessory hepatic artery emerges from the superior mesenteric artery. Types 4b and 5 were not found in any of the cadavers that were dissected and examined in this study. However, type 6, an uncommon aberration in which the common hepatic artery derives directly from the aorta, was observed in two of the cases.

DISCUSSION

In this study, Thai human cadavers were dissected to collect information on extrahepatic arterial variation in the Thai population based on a modified Michels's classification by Hiatt *et al*. (1994). This was done with the intention of expanding the database for surgeons performing procedures around the porta hepatis to prevent damage to vascular structures. The most prevalent type of anatomic variation of the extrahepatic arterial system that was observed in this study was type 1 or the normal type. Type 1 occurred in 66 male and 48 female cadavers, accounting for 75 % of cases (n = 114). This finding was consistent with previous studies by Michels (1966), Hiatt *et al*. (1994), and Gruttadauria *et al*. (2001), in which type 1 found to be the most prevalent. These case studies revealed that among all the types, type 1 had an incidence ranging from 55.0 % to 75.7 %. Out of 152 cadavers evaluated, the hepatic artery was aberrant in 25 % of cases (n = 38). When comparing Michels's data to those in this study, it was shown that the patients examined in Michels's study exhibited a greater incidence of variant patterns (43 %) (Michels, 1966). The incidence of a Type 3 anatomy was 18 % in Michels (1966) report and 10.6 % in Hiatt *et al*. (1994) report, both of which are significantly higher than the 1.98 % found in this study. It is worth mentioning that types 4b and 5 were not found in this study. Interestingly, some types of hepatic artery variation were less common than others, and not all variants were seen in every study. This is possibly attributed to the fact that, while variations in the extrahepatic arterial system are typical, the configurations and combinations of these branches are not predictable.

Michels (1966) and Hiatt *et al*. (1994) established the standard for all future contributions in this area with their classic classification of anatomic variations in the extrahepatic arterial system. The variations were classified according to the origin of the hepatic artery and its branching pattern. The cause of a variable branching pattern can be traced back to embryonic development. In the early stage, before the fusion of the dorsal aorta, it gave rise to several vitelline branches. During embryogenesis, the celiac artery develops from the splanchnic arteries as one of the ventral branches along with the superior and inferior mesenteric arteries (Rosen & Bordoni, 2022). Many of these arteries regress after fusion, and only the ventral branches (celiac and superior and inferior mesenteric arteries) remain in adults. The embryonic left hepatic artery, middle hepatic artery, and right hepatic artery originate from the left gastric artery, celiac axis, and superior mesenteric artery, respectively. During fetal development, the embryonic left and right hepatic arteries regress, whereas the middle hepatic artery remains the proper hepatic artery in adulthood. The proper hepatic artery branches into the right and left hepatic arteries near the left end of the liver's hilum. When these arteries fail to regress, vascular anomalies or variations may occur. The persistence of the ventral splanchnic branch of the dorsal aorta may lead to anomalous branches of the celiac trunk (Rejendran *et al*., 2011).

Variations in the artery pattern are prevalent, as different studies have demonstrated. The existence of these aberrant arteries may make surgical treatments in the hepatic region more difficult. Each variation is distinct, and failure to recognize them may pose a significant risk, of fatal consequences. General surgeons must understand the potential variations of the extrahepatic vascular anatomy in order to achieve successful liver transplantation (Michels *et al*., 1966; Noussios *et al*., 2017). These arterial patterns are important in the planning and performance of all surgical and radiological procedures involving the upper abdomen. For instance, in patients with anatomic variations involving the accessory vessels, both the major and the accessory arteries will need to be identified. According to Abdullah *et al*. (2006), accessory vessels do not always need to be preserved for arterial reconstruction if intrahepatic anastomoses result in sufficient backflow. However, reconstruction of several vessels may be necessary due to the small diameters of accessory arteries.

Consequently, it may increase the risk of hepatic artery thrombosis. Although this circumstance is unusual, it should not be regarded as a contraindication to a living donor liver transplant. However, it will still be a contributing factor for the determination of the best arterial reconstruction method (Hardy & Jones, 1994; Varotti *et al*., 2004; Herrero *et al*., 2017).

Data from previous studies, as well as this one, suggest that the anatomic patterns of the hepatic artery vary greatly. Recent investigations have documented a variation type that has not yet been recognized in the well-known studies performed over the last decades. That is why it is important to have new studies to contribute to the existing data pool. To support the success of future liver transplants or other liver-related surgeries, this study intends to shed light on potential variances of the hepatic artery in Thai people.

CONCLUSION

Variations in the extrahepatic arterial system are frequent. It is important to identify variations in the hepatic arterial system so as to ascertain their distribution patterns. Doing so facilitate the planning and implementation of LT surgeries, thus surgeons need to be aware of them.

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PHONGSRI, R.; SRICHAROENVEJ, S.; LANLUA, P. & BAIMAI, S. Identificación de la variación en el sistema arterial extrahepático de cadáveres tailandeses. *Int. J. Morphol., 41(3)*:758-763, 2023.

RESUMEN: El trasplante hepático (TH) es el tratamiento de elección para la cirrosis hepática descompensada. En el procedimiento de TH, se requiere un suministro arterial adecuado para la anastomosis para prevenir la necrosis postoperatoria y mantener las funciones del parénquima hepático. El sistema arterial extrahepático es el principal responsable de transportar sangre oxigenada desde el corazón, el 25 % del gasto cardíaco total. Normalmente, el tronco celíaco da origen a la arteria hepática común. La arteria hepática común se ramifica en la arteria hepática propia y suministra sangre al parénquima hepático. Reconocer las variaciones anatómicas de la arteria hepática es fundamental para la planificación e implementación del TH. Las variaciones arteriales extrahepáticas son difíciles de estudiar en humanos vivos debido a las limitaciones de los derechos humanos. El estudio de cadáveres puede resolver este problema. Este estudio investiga la distribución de las arterias hepáticas normales, accesorias y aberrantes mediante la disección de cadáveres tailandeses (n = 152; hombres = 82 y mujeres = 70) en el Laboratorio de Anatomía Macroscópica del Departamento de Anatomía, Facultad de Medicina del Hospital Siriraj, Mahidol. Los cadáveres se conservaron en una solución de formaldehído al 10 %. Los criterios de exclusión para las muestras de hígado fueron cirrosis, carcinoma hepático, incluidos el carcinoma hepatocelular y el colangiocarcinoma, y otras masas hepáticas. En consecuencia, el sistema arterial extrahepático se diseccionó e identificó convencionalmente en el hilio hepático. El sistema arterial extrahepático se identificó y documentó en términos de características de distribución normal y variaciones, como arterias hepáticas accesorias. Hubo 75 % tipo normal, 18,42 % arterias hepáticas izquierdas accesorias (aLHA), 1,32 % arterias hepáticas izquierdas aberrantes (LHAr), 0,66 % arterias hepáticas derechas accesorias (aRHA), 1,32 % arterias hepáticas derechas aberrantes (ARHr), 1,97 % de aLHA y aRHA, y 1,32 % de tipo aórtico. La identificación de variaciones en el sistema de la arteria hepática es esencial para la detección de patrones de distribución. Este conocimiento es crucial para promover LT.

PALABRAS CLAVE: Hígado; Anatomía; Sistema arterial extrahepático; Individuos tailandeses.

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