Retrospective Analysis of Aberrant Hepatic Artery in 1250 Patients with Hepatocellular Carcinoma Undergoing Transarterial Chemoembolization

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AIM: Aberrant hepatic artery is particularly common, and its diversity and complexity play a critical role in surgery. The aim of this study was to describe the incidence and type of aberrant hepatic artery, and to compare differences in transarterial chemoembolization (TACE) in patients with hepatocellular carcinoma (HCC) with vs without aberrant hepatic artery.
METHODS: This was a retrospective study of patients with HCC who received TACE at the same intervention center between March 15, 2020 and December 31, 2022. All patients who met inclusion criteria were divided into two groups based on whether or not they had aberrant hepatic artery. The aberrant hepatic artery was systematically classified according to variations in origin. We compared differences in baseline characteristics, operation duration, and postoperative hospitalization between the two groups. Postoperative adverse events and laboratory data were also compared.
RESULTS: A total of 1250 patients hospitalized with HCC were included in the study (mean age, 58 ± 10 years, 1019 [81.5%] males). A high incidence of aberrant hepatic artery was found during TACE (21.3%, 266 of 1250), mainly involving a single variation of the aberrant left hepatic artery (aLHA) (6.1%, 76 of 1250) or aberrant right hepatic artery (aRHA) (10.9%, 136 of 1250) origin, as well as complex variations of the aLHA and aRHA origin (2.4%, 30 of 1250). When comparing patients with vs without aberrant hepatic artery, the TACE operation duration was significantly different ($p < 0.001$), and tended to be greater for patients with aberrant hepatic artery. In addition, differences between aberrant and normal hepatic artery groups in postoperative nausea and vomiting were statistically significant (40.2% vs 30.8%, respectively, $p = 0.004$). Postoperative laboratory examinations revealed significant differences in aspartate aminotransferase, alanine aminotransferase, and neutrophil percentage between the two groups ($p < 0.05$).
CONCLUSIONS: The incidence of aberrant hepatic artery is extremely high, and the condition is characterized by complex variations. Moreover, aberrant hepatic artery may have a critical impact on the course of TACE treatment.

Keywords: transarterial chemoembolization; digital subtraction angiography; aberrant hepatic artery; hepatocellular carcinoma

Introduction

Hepatocellular carcinoma (HCC) is the sixth most common malignancy in the world and the fourth leading cause of malignancy death [1,2]. Furthermore, HCC is characterized by clear etiology and high incidence, and is often diagnosed at the intermediate and advanced stages. Patients with HCC frequently require a combination of treatments, including surgical resection, liver transplantation, and percutaneous radiofrequency ablation, as well as transarterial chemoembolization (TACE) and systemic treatment [3,4]. TACE was first proposed in 1977 to treat HCC through the hepatic artery. Since then, TACE has been recognized as the standard treatment for patients with intermediate-stage HCC, including patients with large or multinodular tumors and well-tolerated liver function [5]. It is well known that TACE is the preferred non-surgical treatment and that it plays a pivotal role in the comprehensive treatment of HCC. TACE mainly blocks tumor blood supply by embolizing tumor arteries, leading to tumor ischemia and hypoxia. Concurrently, high-concentration chemotherapy drugs that can contact with tumor cells are delivered to inhibit tumor growth and promote tumor cell necrosis and apoptosis.

Michels [6] first proposed the I-XI classification of the hepatic arterial system by dissecting 200 cadavers in 1966. On this basis, Hiatt *et al*. [7] modified the classification and proposed types I–VI in the analysis of 1000 patients with liver transplantation. It is apparent that aberrant hepatic artery is particularly common and varied, with reported incidence ranging from 19.7% to 48.7% [6,7,8,9]. As early as 1989, Brown *et al*. [10] reported a surgical case that demonstrated the clinical relevance of aberrant hepatic artery in interventional therapy. Subsequently, an increasing number of studies have discovered new variations and have suggested implications for clinical treatment. Moreover, dur-

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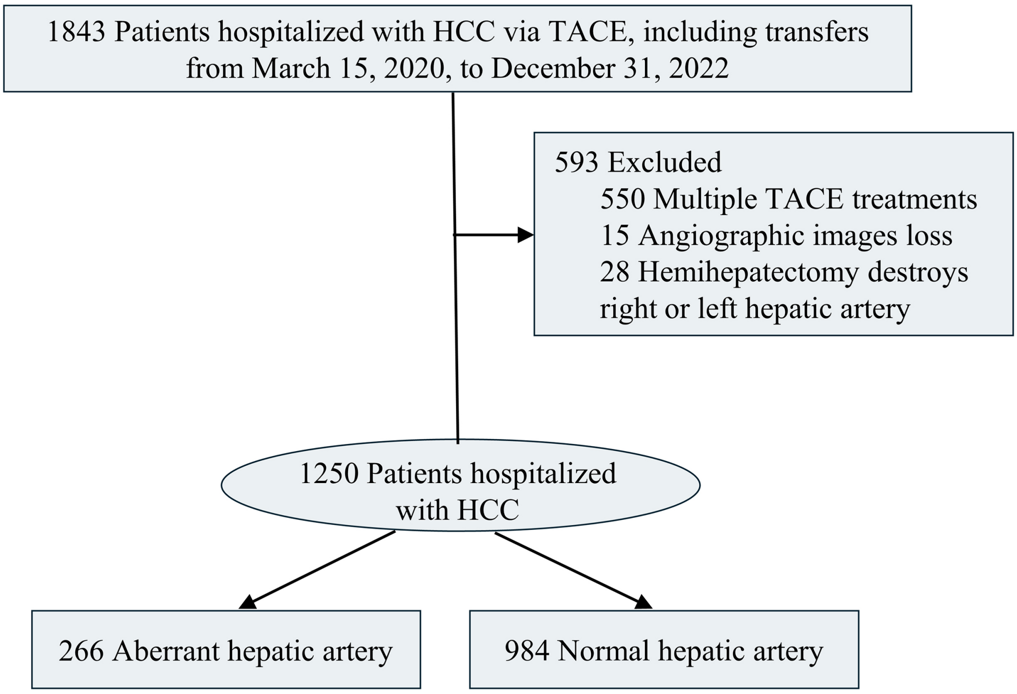

Fig. 1. Flow chart. HCC, hepatocellular carcinoma; TACE, transarterial chemoembolization.

ing TACE therapy, it is often found that aberrant hepatic arteries supply blood to the tumor, thus increasing the difficulty of interventional treatment. To date, the effects of aberrant hepatic artery on interventional therapy have not been quantified in patients with HCC undergoing TACE.

In order to better understand the surgical implications of aberrant hepatic artery, we studied patients during the TACE process and postoperative hospitalization period. The effects of aberrant versus normal hepatic arteries in patients with HCC undergoing TACE was retrospectively studied.

Materials and Methods

Study Population

This study was approved by the Institutional Review Board of the institution. A retrospective study was conducted on patients who were hospitalized with HCC undergoing TACE between March 15, 2020 and December 31, 2022. Specifically, the inclusion criteria were: (1) diagnosis of HCC by clinical imaging or histopathological evaluation; (2) well-preserved liver function and Child-Pugh class A or B [11]; (3) dynamic diagram of the first TACE. Exclusion criteria for patients were: (1) hemihepatectomy, resulting in the absence of left or right hepatic artery; (2) incomplete angiographic images; (3) vascular invasion or extrahepatic spread [12]; (4) presence of other malignant tumors [13]; (5) severe liver dysfunction or Child-Pugh class C, including jaundice, hepatic encephalopathy, and refractory ascites. A total of 1250 patients with HCC for the first TACE were eligible based on the study criteria. Data of hospitalized patients with vs without aberrant hepatic artery, including individual age, sex, clinical history, laboratory results, imaging data, surgical records, nursing records, length of stay, and postembolization syndrome, were collected. The exclusion criteria are shown in Fig. 1 using Adobe Photoshop Version 20.0 software (Adobe Corp, SAN Jose, CA, USA).

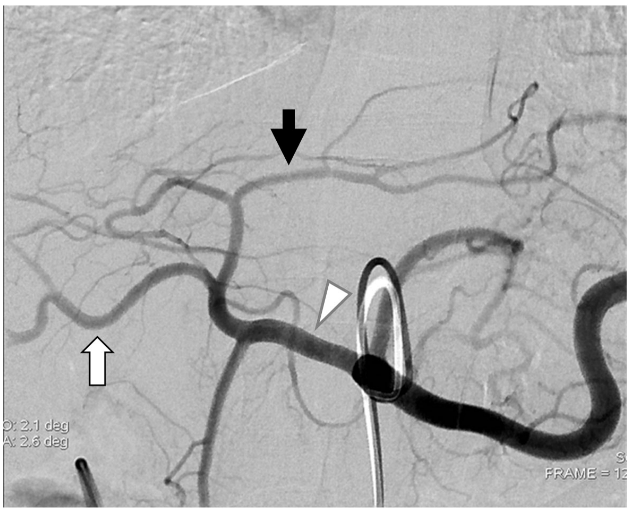

Fig. 2. Normal hepatic artery. The celiac axis divides into the left gastric artery (LGA), Splenic artery, and common hepatic artery (CHA) (white triangle). After the gastroduodenal artery (GDA), the CHA becomes the proper hepatic artery (PHA). Then the PHA bifurcates into the right hepatic artery (RHA) (white arrow) and left hepatic artery (LHA) (black arrow).

Table 1. Baseline characteristics.

Characteristic	Total (n = 1250)	With variation (n = 266)	Without variation (n = 984)	χ^2/Z/T	*p* value
Age, years, mean ± SD	58.1 ± 9.8	58.3 ± 10.2	58.1 ± 9.7	–0.276	0.783
Male	1019 (81.5)	207 (77.8)	812 (82.5)	3.071	0.080
Smoking	730 (58.4)	148 (55.6)	582 (59.1)	1.060	0.303
Drinking	825 (66.0)	181 (68.0)	644 (65.4)	0.630	0.427
Hepatitis	1154 (92.3)	242 (91.0)	912 (92.7)	0.859	0.354
Liver cirrhosis	1122 (89.8)	232 (87.2)	890 (90.4)	2.375	0.123
Child-Pugh stage (A)	1152 (92.2)	251 (94.4)	901 (91.6)	2.265	0.132
Tumour number				0.368	0.544
1	741 (59.3)	162 (60.9)	579 (58.8)		
>1	509 (40.7)	104 (39.1)	405 (41.2)		
Largest tumor diameter, cm	5.7 (3.3–9.8)	5.5 (3.7–8.7)	5.8 (3.8–10.0)	–0.237	0.812
AFP, ng/mL				0.241	0.623
<400	726 (58.1)	158 (59.4)	568 (57.7)		
≥400	524 (41.9)	108 (40.6)	416 (42.3)		
WBC, 10^9/L	4.9 (4.0–5.8)	4.6 (4.1–5.8)	5.0 (4.0–5.8)	–0.126	0.899
Neutrophil percentage	63.1 (56.6–68.3)	60.8(54.4–70.1)	63.3 (57.2–68.1)	–0.834	0.404
Lymphocyte percentage	25.4 (20.9–31.9)	27.9 (21.1–32.3)	24.8 (20.8–31.8)	–1.378	0.168
AST, U/L	38.5 (29.0–59.0)	37.5 (31.0–66.0)	39.5 (28.0–59.0)	–0.364	0.716
ALT, U/L	29.0 (22.0–46.0)	28.0 (22.5–45.0)	30.0 (22.0–50.0)	–0.746	0.422
ALB, g/L	38.6 (35.5–41.6)	39.3 (36.7–41.3)	38.3 (35.4–41.9)	–1.209	0.227
TBIL, µmol/L	16.9 (13.5–22.8)	16.4 (11.7–23.5)	17.0 (13.7–22.7)	–1.174	0.247
Creatinine, µmol/L	60.3 (53.8–68.3)	59.9 (53.1–67.1)	60.3 (53.8–68.7)	–0.870	0.384

Values are expressed as n (%) or median (IQR) unless otherwise specified.

SD, standard deviation; AFP, alpha-fetoprotein; WBC, white blood cell; AST, aspartate aminotransferase; ALT, alanine aminotransferase; ALB, albumin; TBIL, total bilirubin.

TACE Procedure

Using the Seldinger technique for puncture, we usually select the patient's right femoral artery for insertion of the catheter sheath under local anesthesia (manufactured by Terumo Corporation; approval No.: RS*A50N25AQ, specification: 5F; Tokyo, Japan), followed by selective catheter insertion (manufactured by Terumo Corporation, Progreat approval No.: MC-PE27131, specification: 2.0F; Tokyo, Japan). Fig. 2 shows an angiographic image that reveals the overall shape of the celiac axis. The TACE procedure was performed by two interventional hepatobiliary surgeons (Z.Z. and X. W.) with more than 8 years of interventional experience and more than 10 years of hepatobiliary surgery experience. In some patients with HCC, careful reading of hepatic arteriography images showed that vessels were not displayed in some liver areas, that is, incomplete hepatic arteriography, indicating the presence of aberrant hepatic artery. In this case, the superior mesenteric artery (SMA), left gastric artery, aorta, or even the splenic artery would be selected instead. If necessary, the abdominal aorta would be re-selected for angiography to observe the presence of the aberrant hepatic artery. All patients with HCC underwent SMA imaging, which was performed together with abdominal angiography.

Clinical Outcome

After TACE surgery, an operative record of the procedure was made. In addition to tumor size and blood supply, intraoperative hepatic artery shape and distribution were also recorded in detail. We initially recorded the patients' basic information and hepatic artery condition by reviewing the surgical records. Then, we obtained intraoperative angiographic images of all patients, and these were reviewed by two hepatobiliary surgeons (Z.Z. and X. W.) to confirm the origin, shape, and distribution of the hepatic arteries. According to the above results, the sample was divided and the operation time was recorded simultaneously. Likewise, the length of hospital stay after surgery was available from the discharge records.

Adverse Events

All patients were observed during a short period of 1–3 days after TACE surgery. We compared the two groups based on preoperative and postoperative laboratory examinations, including liver function analysis (alanine aminotransferase, aspartate aminotransferase, albumin, total bilirubin), kidney function analysis (serum creatinine), and routine blood examination (white blood cell count, lymphocyte percent-

Table 2. Origin variations of single hepatic artery (n = 236).

Origin	Patients, No. (%)		
	Right hepatic artery (n = 136)	Left hepatic artery (n = 76)	Common hepatic artery (n = 24)
Superior mesenteric artery	102 (75)	1 (1.3)	20 (83.3)
Left gastric artery	0 (0)	70 (92.1)	1 (4.2)
Gastroduodenal artery	3 (2.2)	1 (1.3)	NA
Celiac axis	10 (7.4)	3 (4.0)	NA
Aorta	2 (1.5)	1 (1.3)	3 (12.5)
Splenic artery	1 (0.7)	NA	NA
Common hepatic artery	18 (13.2)	NA	NA

NA, not applicable.

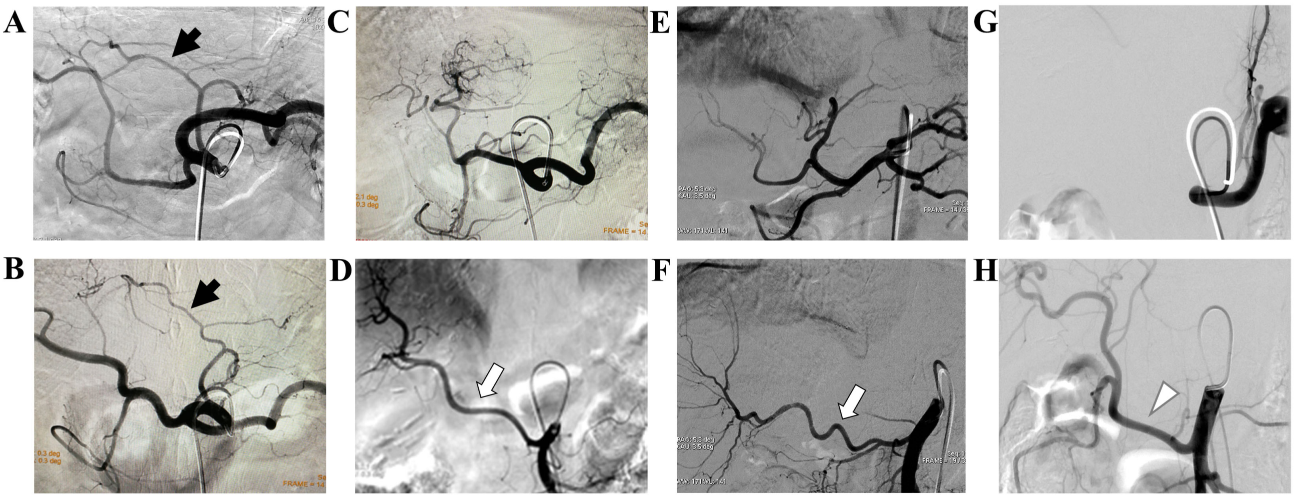

Fig. 3. Origin variations of single hepatic artery. (A,B) Aberrant left hepatic artery (aLHA) (black arrow) originating from the left gastric artery (LGA). (A) Replacement left hepatic artery originating from the LGA. (B) Accessory left hepatic artery originating from the LGA. (C–F) Aberrant right hepatic artery aberrant right hepatic artery (aRHA) (white arrow) originating from the superior mesenteric artery (SMA). (C,D) Replacement right hepatic artery originating from the SMA. (E,F) Accessory right hepatic artery originating from the SMA. (G,H) Aberrant common hepatic artery (aCHA) (white triangle) originating from the SMA in a 57-year-old male patient with hepatocellular carcinoma.

age, neutrophil percentage). Postembolization syndrome is characterized by nausea, vomiting, abdominal pain, and fever. We made detailed records and grouped statistics through nursing checklists, medical order records and postoperative course records.

Statistical Analysis

Continuous variables that were normally distributed are presented as the mean and SD, and group differences were assessed using *T* tests. Those that were not normally distributed are expressed as the median and interquartile range, and differences were assessed using the Mann-Whitney U test. Associations between categorical variables were assessed using the χ^2 test. All analyses were conducted using SPSS Version 25.0 software (IBM Corp, Chicago, IL, USA) and 2-sided p values < 0.05 were considered statistically significant.

Results

Patient Characteristics

After applying the exclusion criteria, a total of 1250 patients out of 1843 hospitalized with HCC were eligible for the study. There was no significant difference in age between patients with vs without aberrant hepatic artery (58.3 $\pm$ 10.2 years vs 58.1 $\pm$ 9.7 years, respectively, p = 0.783). Although there was no significant difference in sex between the two groups, a larger percentage of patients in the group without aberrant hepatic artery were male (77.8%, 207 of 266 vs 82.5%, 812 of 984 male, p = 0.080). There were no significant group differences according to medical history, which included smoking, drinking, and hepatitis. However, hepatitis affected more than 90 percent of HCC patients with or without aberrant hepatic artery (91.0% vs 92.7%, respectively, p = 0.354). In addition, there were no significant differences in cirrhosis and Child-Pugh stage. Because all patients with Child-Pugh class C were excluded as contraindications to surgery, we

Table 3. Origin variations of multiple hepatic artery (n = 30).

Origin	Patients, No. (%)				
	Aberrant left hepatic artery				
	LGA	SMA	GDA	Celiac axis	Aorta
Aberrant right hepatic artery					
SMA	22 (73.3)	1 (3.3)	1 (3.3)	0 (0)	0 (0)
GDA	1 (3.3)	0 (0)	0 (0)	0 (0)	0 (0)
Celiac axis	1 (3.3)	0 (0)	0 (0)	0 (0)	0 (0)
Aorta	1 (3.3)	0 (0)	0 (0)	0 (0)	0 (0)
Splenic artery	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
CHA	2 (6.7)	0 (0)	0 (0)	0 (0)	0 (0)
Aberrant CHA					
SMA	1 (3.3)	0 (0)	NA	NA	0 (0)

SMA, superior mesenteric artery; GDA, gastroduodenal artery; CHA, common hepatic artery; NA, not applicable.

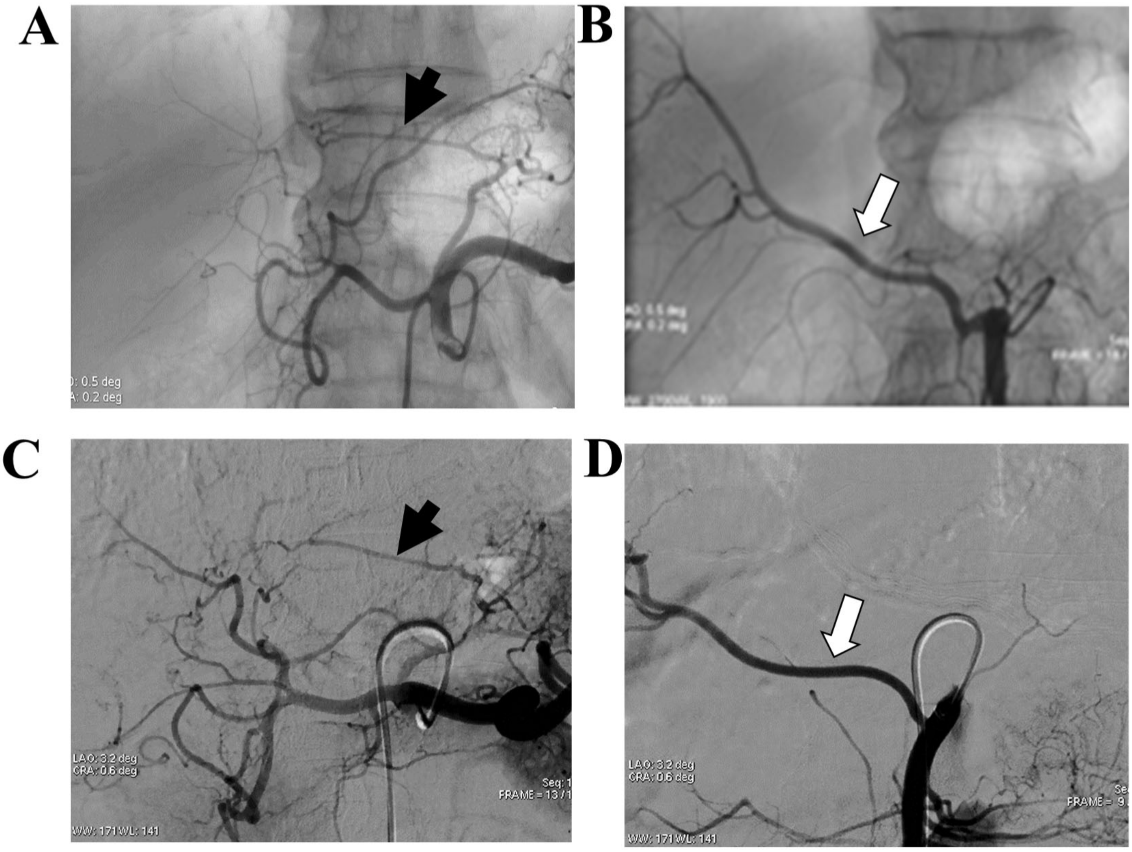

Fig. 4. aLHA (black arrow) originating from the LGA + aRHA (white arrow) originating from the SMA. (A,B) Replaced the left hepatic artery originating from the left gastric artery; Replaced right hepatic artery originating from the superior mesenteric artery in a 60-year-old male patient with hepatocellular carcinoma (HCC). (C,D) Accessory left hepatic artery originating from the left gastric artery; Accessory right hepatic artery originating from the superior mesenteric artery in a 56-year-old male patient with HCC. aLHA, aberrant left hepatic artery; LGA, left gastric artery; aRHA, aberrant right hepatic artery.

only compared class A (94.4% vs 91.6%, respectively, $p = 0.132$) or class B between the two groups. Moreover, preoperative laboratory tests, including routine blood examination (white blood cell [WBC] count, neutrophil percentage, lymphocyte percentage), liver function analysis (aspartate aminotransferase [AST], alanine aminotransferase [ALT], albumin [ALB], total bilirubin [TBIL]), and serum creatinine, did not differ significantly between groups. Group differences in all other baseline characteristics were nonsignificant ($p > 0.05$). Baseline characteristics of patients with vs without aberrant hepatic artery are summarized in Table 1.

Table 4. Classification and comparison according to the Hiatt classification system.

Classification	Patients, No. (%)						
	I	II	III	IV	V	VI	Others
Present study, 2023, DSA, n = 1250	78.7	5.6	8.2	1.8	1.6	0.2	3.9
Hiatt *et al*. [7], 1994, Surgery, n = 1000	75.7	9.7	10.6	2.3	1.5	0.2	0
Covey *et al*. [8], 2002, DSA, n = 600	61.3	14.5	10.2	4.5	2	2	5.5
Koops *et al*. [9], 2004, DSA, n = 604	79.1	3.0	11.9	1.3	2.8	0.2	1.7
Saba *et al*. [14], 2011, CT, n = 1629	61.4	14.2	17.6	4.0	1.6	NA	1.2
Choi *et al*. [15], 2021, CT+DSA, n = 5625	72.6	11.7	7.0	3.1	NA	NA	5.6

DSA, digital subtraction angiography; CT, computed tomography; NA, not applicable. Others = anatomic variation of hepatic artery was not included in the Hiatt (I–VI) classification.

Table 5. Comparison of operation duration and postoperative hospitalization.

Outcome	Patients, No. (%)		χ^2	*p* value
	With variation	Without variation		
	(n = 266)	(n = 984)		
Operation duration, min			165.789	< 0.001
≤39	21 (7.9)	296 (30.1)		
40–49	74 (27.8)	424 (43.1)		
50–59	120 (45.1)	231 (23.5)		
≥60	51 (19.2)	33 (3.3)		
Postoperative hospitalization, days			1.978	0.160
≤2	224 (84.2)	861 (87.5)		
>2	42 (15.8)	123 (12.5)		

Anatomic Variations of the Hepatic Artery

The incidence of aberrant hepatic artery was 21.3% (266 of 1250). In order to facilitate the description and clinical analysis of aberrant hepatic artery, we divided it into two types: single aberrant hepatic artery and multiple simultaneous aberrant hepatic arteries. The overall prevalence of the single hepatic artery variants was 18.9% (236 of 1250), and the origin and incidence of aberrant left hepatic artery (aLHA) (n = 76), aberrant right hepatic artery (aRHA) (n = 136), and aberrant common hepatic artery (aCHA) (n = 24) are shown in Table 2. The most common variations were the aLHA originating from the left gastric artery (LGA) 92.1% (70/76), the aRHA originating from the SMA 75% (102/136), and the aCHA originating from the SMA 83.3% (20/24), as shown in Fig. 3. The incidence of variations in multiple hepatic arteries was 2.4% (30 of 1250), consisting mainly of the aLHA and aRHA (n = 29), and 1 case of aCHA and aLHA, which is extremely rare, as indicated in Table 3. The most common variant was the aLHA originating from the LGA and the aRHA originating from the SMA 73.3% (22/30), as shown in Fig. 4. The results clearly show that single aberrant hepatic artery was more common than complex variations. We also analyzed variations according to Hiatt's classification system and compared the results with previous studies. These results are presented in Table 4 (Ref. [7,8,9,14,15]).

Rare Variations

Extremely rare variants were observed in this study, accounting for 3.9% (49 of 1250) of unclassified hepatic artery variants. These include the aRHA originating from the aorta (n = 2) or the splenic artery (n = 1), and the aLHA originating from SMA (n = 1), gastroduodenal artery (GDA) (n = 1), or the aorta (n = 1). The aCHA originated in only a single patient with the LHA, the same as Michels type IX, as shown in Table 2. In addition, we found rare patients with variations in the origin of multiple hepatic arteries. These included the aLHA originating from the GDA while the aRHA originated from SMA (n = 1), the aLHA and aRHA arising separately from the SMA (n = 1), and the aCHA originating from the SMA while the aLHA originated from the LGA (n = 1) in Table 3.

Clinical Outcomes

When comparing patients with vs without aberrant hepatic artery, the TACE operation time was significantly different between the two groups ($p < 0.001$). For the aberrant hepatic artery group, the highest incidence was observed for the 50–59 min duration (45.1%); for the normal group, the highest incidence was observed for the 40–49 min duration (43.1%). However, there was no significant difference in hospitalization days after operation ($p = 0.160$) and most of them were ≤2 days, as indicated in Table 5. To further confirm the influence of aberrant hepatic artery on

Table 6. Comparison of postoperative adverse events and laboratory examinations.

Outcome	Patients, No. (%)		χ^2/Z	*p* value
	With variation	Without variation		
	(n = 266)	(n = 984)		
Postembolization syndrome				
Nausea or vomiting	107 (40.2)	303 (30.8)	8.453	0.004
Abdominal pain	108 (40.6)	354 (36.0)	1.923	0.166
Fever	132 (49.6)	525 (53.4)	1.168	0.280
Postoperative laboratory examinations				
WBC, 10^9/L	5.8 (4.0–8.5)	5.7 (4.4–7.9)	–0.958	0.338
Neutrophil percentage	71.5 (66.3–75.1)	69.6 (58.0–78.2)	–1.988	0.043
Lymphocyte percentage	18.5 (14.3–24.2)	20 (12.3–28.1)	–1.664	0.096
AST, U/L	55.0 (45.0–160.0)	58.0 (36.5–113.5)	–2.609	0.009
ALT, U/L	52.0 (40.0–72.0)	48.5 (31.5–79.0)	–2.226	0.026
ALB, g/L	38.2 (35.7–40.6)	38.1 (35.3–40.5)	–0.669	0.504
TBIL, µmol/L	22.5 (16.3–28.3)	20.5 (15.9–26.4)	–1.630	0.103
Creatinine, µmol/L	61.9 (54.1–68.4)	62.1 (54.0–69.7)	–0.718	0.473

AST, aspartate aminotransferase; ALT, alanine aminotransferase; ALB, albumin; TBIL, total bilirubin.

postoperative adverse events, we compared postembolization syndrome and postoperative laboratory tests. Postembolization syndrome includes nausea and vomiting, abdominal pain, and fever. The difference in nausea and vomiting between the aberrant and normal hepatic artery groups (40.2% vs 30.8%, respectively, $p = 0.004$) was statistically significant. There was no significant difference in abdominal pain (40.6% vs 36.0%, $p = 0.166$) or fever (49.6% vs 53.4%, $p = 0.280$) between the two groups. AST, ALT, and neutrophil percentage were significantly different between the two groups ($p < 0.05$). However, WBC, ALB, TBIL and serum creatinine did not differ significantly after TACE ($p > 0.05$), as shown in Table 6. Based on these results, we can conclude that aberrant hepatic artery plays an important role in TACE.

Discussion

In this retrospective study of patients hospitalized with HCC undergoing TACE, the incidence of aberrant hepatic artery was found to be 21.3%, indicating an extremely high prevalence, which is consistent with previous studies [8,9,14,15,16].

As we all know, the most commonly used classification systems are those of Michels [6] and Hiatt *et al.* [7]. Hiatt simplified the classification of Michels into type I–IV, did not distinguish the alternative or accessory hepatic artery, and removed the rare variant Michels type X, instead of Hiatt type VI, which is the CHA originating from the abdominal aorta. We also compared our results with the Hiatt classification. Although that classification is a milestone in the description of hepatic arteries, there are still some limitations. With technological advances, new variations of aberrant hepatic artery are discovered. The incidence of unclassified aberrant hepatic artery in previous studies has been reported to be 1.7% to 18% [8,9,14,15]. Moreover, those studies have analyzed large samples of more than 1000 patients [14,15,16,17,18]. Thus, accumulating evidence has revealed the diversity and complexity of aberrant hepatic artery.

In a recent study, Choi *et al.* [15]. classified aberrant hepatic artery according to the origin of the LHA and RHA. Based on that study, we further studied the variation of the CHA. We used single aberrant hepatic artery and multiple aberrant hepatic arteries for analysis, and identified variations with a high incidence, such as the most common aRHA originating from SMA, aLHA originating from LGA, and aCHA originating from SMA. All of this is consistent with previous reports [14,15,16,17,19,20]. The most common variation in multiple aberrant hepatic arteries is aRHA originating from the SMA and the aLHA originating from the LGA. This detailed classification is more suitable for clinicians to understand and apply, so as to identify variations the first time during the operation, save operation time, and reduce unnecessary radiation. Special attention should be paid to the presence of accessory hepatic arteries, especially those supplying liver tumors. Notably, a recent clinical study by Rastogi *et al.* [21], which analyzed 3035 liver donors, also showed that aberrant hepatic artery has a great impact on clinical treatment. In addition, the discovery of rare variations of aberrant hepatic artery complements existing clinical studies [22,23,24]. Since the incidence of rare aberrant hepatic artery is not low and it is not easy to detect, it will introduce uncertainty to interventional therapy. For radiologists, who need not only precise mechanical assistance during surgery, but also operational skills, understanding variation is equally important [25,26]. In a review study, Favelier *et al.* [25] comprehensively described aberrant hepatic artery in angiography and suggested the guiding significance of variation for interventional therapy.

Another important finding of our study is that aberrant hepatic artery had significantly longer operative times than those without hepatic artery, suggesting that aberrant hepatic arteries play a crucial role in TACE treatment. The TACE operative time exceeding 50 min was the most prevalent for the aberrant group. Specifically, when the hepatic artery is more complex, the operation time is significantly longer. In this case, the operation time can reach 90 min. Although a variety of adverse events may occur, the most common is postembolization syndrome, the main symptoms of which include nausea, vomiting, right upper abdominal pain, and fever, all of which are caused by TACE [27,28]. According to previous studies, the incidence was 36.1–41.0% [29,30,31]. The differences in the incidence of nausea or vomiting between the two groups in the present study may be related to repeated attempts at selective TACE and additional use of contrast media during hepatic arterial variation. When the anatomic variation of the hepatic artery is complex, it may increase the adverse events of nausea and vomiting. In addition, TACE can result in liver cell damage with elevated transaminase levels, sometimes accompanied by hyperbilirubinemia, but usually returns to normal within 10 to 14 days [29,32]. Similar to our study, aminotransferase levels of liver function were significantly higher than before surgery, but creatinine levels of kidney function were not significantly changed. Notably, laboratory tests during the first 3 days after TACE found that aberrant hepatic artery was significantly higher in aminotransferases and neutrophil percentages than those without aberrant hepatic artery. However, comparing the long-term differences between the two groups needs further research. Leung *et al*. [32]. found that postembolization syndrome was one of the main factors for the length of postoperative hospitalization. For patients with mild symptoms or symptom control, discharge is usually within 1–2 days after surgery [29,33], which is similar to what we found.

In previous studies, fewer than 10% of patients have reported serious adverse events, including cholecystitis, gastrointestinal ulcers or bleeding, liver failure, and vascular dissection [31,32,33]. Sometimes this happens when a non-hepatic artery is mistakenly embolized. This procedure requires our individualized and precise treatment to fully treat the blood supply of liver cancer while preserving more normal liver tissue, thus avoiding most complications. Although it seems to be a heavy psychological burden on the patient, the prognosis for treatment is the same. In our study, there were no serious complications compared with aberrant hepatic artery.

On the other hand, it is necessary to accurately treat the aberrant hepatic artery that supplies blood to tumors, reducing the possibility of missing embolization and erroneous embolization. Missing embolization may lead to incomplete tumor treatment, and one should be vigilant regarding blood supply from the accessory hepatic artery. The erroneous embolization can cause significant side effects, especially in non-hepatic arteries (e.g., phrenic artery, cystic artery, intercostal arteries) [34,35]. Therefore, we should minimize complications during and after intervention to increase the safety and effectiveness of treatment.

The incidence of aberrant hepatic artery in patients with HCC undergoing TACE has not been previously reported. Interestingly, we proposed a classification suitable for clinical application, including single and multiple aberrant hepatic arteries. Our findings add to the existing literature on variations in aberrant hepatic artery. Furthermore, this is the first study to investigate the influence of aberrant hepatic artery on TACE treatment, including operation duration, postoperative hospitalization, and postoperative adverse events.

There are some limitations to this study. First, it was a single-center retrospective study which may have unintentional bias in the process of data collection, and the sample size was not large enough. Second, the clinical database was limited to patients with HCC undergoing TACE, which may result in these findings not being applicable to all patients. Third, the study focused on outcomes during hospital stays. The study lacked long-term follow-up results, which are needed to fully understand the safety and anti-tumor effect of patients with HCC. Fourth, there was a lack of data analysis on tumor location, as well as aberrant hepatic artery blood supply to the tumor.

Conclusions

Aberrant hepatic artery, which is complex and diverse, is extremely common. Moreover, aberrant hepatic artery may have a critical impact on TACE in patients with HCC. Therefore, we need a more comprehensive understanding of the consequences of aberrant hepatic artery to achieve personalized and precise treatment for patients.

Availability of Data and Materials

Data for the study can be made available from the corresponding author upon request.

Author Contributions

ZHZ and NSW designed the research study. DDD and MZM performed the research. DDD, ZHZ and XXW analyzed the data. All authors have participated in drafting the manuscript, and NSW revised it critically. All authors read and approved the final version of the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Ethical approval of our study was obtained from the Shandong Provincial Hospital Biomedical Research Ethics Committee on December 30, 2019 (decision number 2019-211). Informed patient consent was obtained for this study in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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