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Aberrant left hepatic artery arising from the left gastric artery: perioperative effects of a risky vascular anomaly in gastrectomy

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ABSTRACT

Aims: The aim of this study was to analyze the results of the choice of cutting and preservation in different surgical methods in the presence of aberrant left hepatic artery (ALHA) during gastric cancer surgery.

Methods: This study was conducted as a single-center, retrospective study between 01/01/2022 and 31/08/2023. Patients who underwent open, laparoscopic and robotic surgery due to gastric cancer were included. The presence of ALHA in preoperative computed tomography scans was screened using the application focusing on vascular anatomy in the radiology automation system. The results of patients with and without ALHA were analyzed.

Results: No statistically significant difference was observed between the groups in terms of duration of surgery, length of hospital stay, history of neoadjuvant therapy, total number of lymph nodes removed, and number of metastatic lymph nodes.

Conclusion: We recommend close postoperative monitoring of liver enzymes and collaboration with an experienced radiologist in patients with suspected ALHA.

Keywords: Aberrant left hepatic artery, gastric cancer, oncological surgery, robotic surgery

INTRODUCTION

Gastric cancer is the fifth most common malignancy and the third leading cause of cancer-related deaths worldwide.[1,2] Notwithstanding the recent advances in multidisciplinary approaches, including adjuvant treatment models, immunotherapy and targeted therapies, surgery with negative margins and adequate lymphadenectomy remains the gold standard curative treatment.[3,4]

It is widely acknowledged that ligating the main vessels at their origin and meticulously dissecting the surrounding tissue, ensuring complete removal of the gastrohepatic ligament, is paramount for achieving oncological and adequate resection.[3] However, vascular variations in the left gastric and hepatic arteries are frequently encountered, impeding procedural efficacy and giving rise to contentious debates. The prevalence of vascular variations in hepatic artery anatomy has been documented to range from 13%-48% in the general population and it has been further reported that 10% to 25% of these variations are classified as aberrant left hepatic artery (ALHA), which originates from the left gastric artery (LGA).[5,6] ALHA can be classified into two main subtypes: accessory LHA (acLHA) and replaced LHA (RLHA), with a ratio of 45% and 55%, respectively.[7] ALHA supplies the left hepatic lobe in part or in full, and is usually explored coincidentally during surgery.[8,9] Although open surgery may ensure the identification of ALHA by palpation of the lesser omentum, this is challenging in laparoscopic surgery or obese patients.[9] Curative gastric cancer surgery with extended lymphadenectomy requires the ligation of LGA at its root for station 7th lymph node and all the tissues forming the lesser omentum, causing the division of ALHA if it is present.[3,10] Despite the existence of reports recommending the preservation of ALHA to prevent fatal liver dysfunction and ischemia, there remains considerable controversy among surgeons regarding the decision to ligate for oncological reasons.[4,11]

Shinohara et al.[10] found that there were no differences in terms of adequacy of lymph node dissection and oncological results

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in patients whether ALHA was preserved or not. However, Oki et al.[12] suggested that ALHA should be preserved when encountered in laparoscopic gastrectomy. In 2022, Tao et al.[13] reported in their systematic review that ligation of ALHA is not always without risk and that measurement of the diameter of the artery may be a useful guide to determining the presence of chronic liver disease.

To date, a consensus on the safety and/or necessity of routine ligation of ALHA during gastric cancer surgery has not been reached. The objective of this study was to ascertain the variations of celiac artery branches and the frequency of ALHA presence by means of a retrospective re-evaluation of the preoperative radiological examinations of patients who underwent gastric cancer surgery. The secondary objective was to evaluate the effects of ALHA-oriented approaches and surgical procedures on liver function tests, perioperative results and oncological surgical principles.

METHODS

Ethics approval and Study Design

Our study was approved by the Başakşehir Çam and Sakura City Hospital Clinical Researches Ethics Committee (Date: 22.11.2023, Decision No: 602). All procedures were performed in accordance with ethical regulations and the tenets of the Declaration of Helsinki, and informed consent was obtained from patients for procedures performed in the clinic and during their hospital stay. This single-center and retrospective study followed the "STrengthening the Reporting of OBservational studies in Epidemiology (STROBE)" guidelines.

Inclusion criteria: To identify patients who underwent surgery for gastric cancer between January 2022, and August 2023, the hospital automation system retrospectively scanned the surgical codes for "subtotal gastrectomy" and "total gastrectomy." Patients who underwent preoperative contrast-enhanced triphasic abdominal computed tomography (CT) were included in the study.

Exclusion criteria: Patients who underwent emergency surgery due to bleeding, obstruction, or perforation, or who underwent palliative surgery without oncological principles, were excluded. Patients who received non-contrast radiological imaging or unavailable images were excluded.

After identifying the cases to be included in the study, the contents of the surgery performed, details with vascular anatomy if indicated, and information on whether or not ALHA was ligated in case of deviation were recorded from the operation notes (Figure 1). Another experienced surgeon and a radiologist not involved in these procedures were asked to assess the celiac vascular anatomy according to the preoperative CT in a blinded manner (without knowledge of the surgical procedures) and to record it according to the presence of ALHA. In case of disagreement regarding vascular anatomy, these cases were evaluated jointly by the researchers and a decision was made. The radiologist's assessment was made using software that allows digital highlighting of the vascular network in the radiology automation system (Figure 2). Computed tomography images were obtained using SCT-

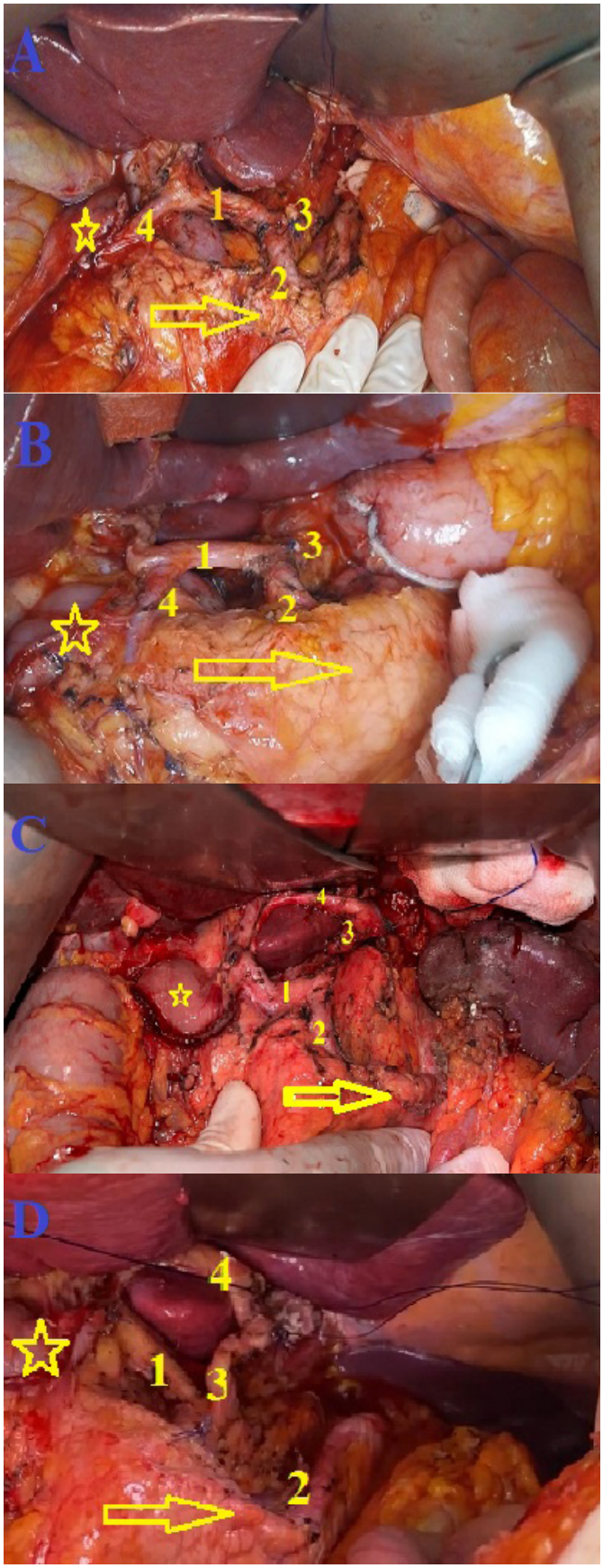


Figure 1. Examples of celiac arterial anatomy in our open surgeries. A) Total gastrectomy normal anatomy, B) Subtotal gastrectomy normal anatomy, C and D) examples of D2 lymph node dissection with preservation of the abbreviated left hepatic artery from different cases

Explanations of numbers and signs on the figure: 1) Common hepatic artery, 2) Splenic artery, 3) Left gastric artery, 4) Gastroduodenal artery in A and B and 4) Aberrant left hepatic artery in C and D

Star: Duodenal stump and Arrow: Pancreas

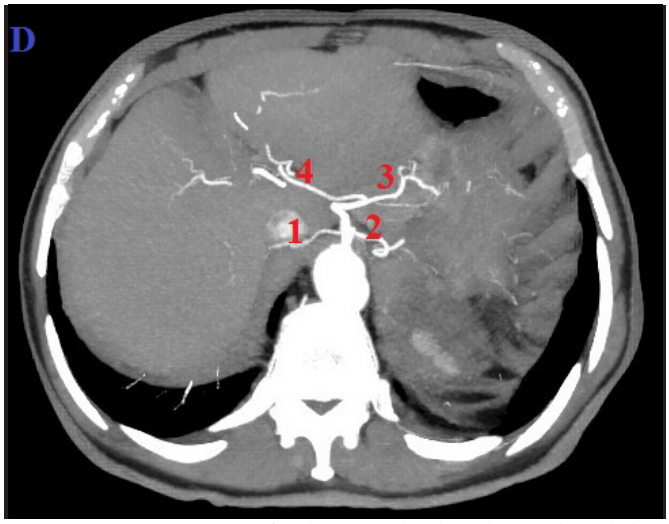


Figure 2. Demonstration of celiac vascular branches with radiology automation of the computerized tomography of the case in Figure 1D

Explanations of numbers on the figure: 1) Right hepatic artery, 2) Splenic artery, 3) Left gastric artery, 4) Aberrant left hepatic artery

7800TC (Shimadzu Corporation, Kyoto, Japan) and analyzed with a three-dimensional reconstruction software integrated into the Picture Archiving and Communication System (PACS) in Digital Imaging and Communications in Medicine (DICOM) format Synapse 3D (Fujifilm Corporation, Tokyo, Japan). Those without vascular variation were divided into two groups as group A and those with ALHA as group B. Group B was then recorded separately according to whether ALHA was cut or not.

Surgical Procedure

All patients are evaluated by a multidisciplinary gastrointestinal oncology surgery council. These councils include gastrointestinal surgeons, radiologists, medical oncologists, radiation oncologists, and pathologists. The council makes decisions regarding the suitability of surgical treatment, neoadjuvant therapy, or post-neoadjuvant surgery based on the clinical stage of gastric cancer. Patients who underwent surgery had a history of previous abdominal surgery, a high ASA (American Society of Anesthesiologists) score, and comorbidities that made laparoscopy/robotic surgery unsuitable for them underwent open surgery. A selection bias was applied to laparoscopic/robotic surgeries, favoring an experienced team. Younger patients, patients with a low body-mass index, early-stage tumors without invasion of surrounding tissues, and surgical experience were the most important determining factors in this regard. In open surgery, a median incision was used, and all anastomoses were performed with staples. In laparoscopic procedures, anastomoses were performed intracorporally. The da Vinci Xi® Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was used as robotic technology.

Data Collection

The neoadjuvant treatment status of the cases, robotic/laparoscopic/open surgery status, total/subtotal gastrectomy status, operation time (minutes), hospital stay (days), total lymph node count and metastatic lymph node count in the pathology report were recorded. In laboratory tests, aspartate aminotransferase (AST, U/L), alanine aminotransferase (ALT, U/L) and total bilirubin (TB, U/L) levels were measured 48-72 hours before surgery and the results were recorded on the first, seventh and 30th postoperative days.

Statistical Analysis

SPSS 25.0 (SPSS Inc, Chicago, IL, USA) was used for statistical analysis of the data. While numerical variables in the data set were summarised by median (minimum-maximum), categorical variables were summarised by number (percentage). The Shapiro-Wilk test was used to test whether the data conformed to a normal distribution. In statistical analyses, the Mann-Whitney U test, the Friedman test and the Yetes-corrected Chi-square test were used, where appropriate, given the distribution of the data. When statistically significant differences were found in the Friedman test, the Wilcoxon signed rank test with Bonferroni correction was used for pairwise comparisons. In statistical analyses, $p<0.05$ was considered significant.

RESULTS

A search of the database revealed that a total of 266 cases were operated on (open: 196, minimally invasive: 70) during the specified period. Of these, 209 cases met the inclusion criteria for the study. There were 173 patients in group A (no ALHA detected) and 36 patients in group B (ALHA detected). Of the total sample, 69 (33%) were female and 140 (67%) were male. The mean age of the sample was 63.7±10.8 (26-86) years. The numbers of total/subtotal gastrectomy by robotic, laparoscopic and open methods were 43(20.5%)/14(6.7%), 14(6.7%)/7(3.3%) and 87(41.6%)/44(21%), respectively. According to celiac vascular anatomy, 173 (82.8%) cases with normal LGA were classified as group A and 36 (17.2%) cases with ALHA were classified as group B. Details of the groups are summarised in Table 1. Standard D2 lymph node dissection was performed

Table 1. Gastrectomy surgery methods and types

Group A (normal anatomy) n (%)						Group B (ALHA) n (%)					
173 (82.8)						36 (17.2)					
Total			**Subtotal**			**Total**			**Subtotal**		
118 (68.2)			55 (31.8)			26 (72.2)			10 (27.8)		
Robotic	**Laparoscopic**	**Open**	**Robotic**	**Laparoscopic**	**Open**	**Robotic**	**Laparoscopic**	**Open**	**Robotic**	**Laparoscopic**	**Open**
35 (29.7)	11 (9.3)	72 (61)	14 (25.5)	7 (12.7)	34 (61.8)	8 (30.8)	3 (11.5)	15 (57.7)	0 (0)	0 (0)	10 (100)

ALHA: Aberrant left hepatic artery

in all cases in group A. D2 lymph node dissection was performed in all open cases in group B with preservation of ALHA (Figure 1), while lymphadenectomies were completed by ligation of the LGA root without preservation of ALHA in all robotic and laparoscopic cases. No statistically significant difference was observed in terms of operative time, days in hospital, history of neoadjuvant treatment, total number of lymph nodes removed and number of metastatic lymph nodes (Table 2).

Table 2. Comparison of surgical parameters of groups

Variables	Group A	Group B	p
	Median (min-max)		
Duration of surgery (minutes)	245(60-755)	242 (125-360)	0.792*
Duration of hospital stay (days)	7(3-41)	7(3-22)	0.673*
Pathology specimen total LN (n)	32(12-87)	32(17-75)	0.537*
Pathology specimen metastatic LN (n)	2(0-36)	3(0-40)	0.869*
Neoadjuvant treatment (yes)	77 (44.50)	21 (58.30)	0.184**

*: Mann-Whitney U test, **: Yatesin corrected Chi-square test, min-max: Minimum-maximum, LN: Lymph node

In both groups, median values of laboratory parameters AST and ALT were elevated on the first postoperative day; however, these values decreased by the seventh postoperative day, approaching preoperative levels by the thirtieth day. Bilirubin levels remained unchanged throughout the postoperative period (Table 3). In both groups, a statistically significant difference was observed in the ALT values on the first, seventh and thirtieth postoperative days compared to the preoperative period ($p<0.05$). However, no significant difference was observed in the AST values of the groups on the thirtieth postoperative day (Table 4). In group B, no significant difference was observed between the postoperative AST and ALT averages in the subgroups with and without ALHA cut-off in terms of surgery duration, number of days of hospitalization, number of lymph nodes removed and number of metastatic lymph nodes (Table 5).

Table 3. Preoperative and postoperative liver function tests of the groups

Variables	Group A	Group B
	Median (min-max)	
ALT(U/L)		
Preoperative	14 (3-75)	12.5 (6-71)
Po1	48 (5-509)	50 (6-820)
Po7	26 (3-275)	21(6-195)
Po30	18 (3-141)	18 (3-374)
AST(U/L)		
Preoperative	20 (6-84)	18 (10-63)
Po1	50 (10-676)	55.5 (12-540)
Po7	26 (8-220)	25 (0.52-84)
Po30	22 (4-227)	20 (9-177)
Total bilirubin (U/L)		
Preoperative	0.33 (0.06-1.71)	0.31 (0.09-1.35)
Po1	0.51 (0.14-1.97)	0.445 (0.21-1.54)
Po7	0.44 (0.12-1.25)	0.41 (0.13-1.37)
Po30	0.38 (0.14-1.5)	0.41 (0.17-9.5)

min-max: Minimum-maximum, ALT: Alanine aminotransferase, AST: Aspartate aminotransferase, Po: Postoperative day

Table 4. Comparison of preoperative and postoperative liver function tests of the groups

	Variable pairs	p-value for pairwise comparisons**	Overall p-value*
Group A	PreO ALT-po1ALT	<0.001	<0.001
	PreO ALT-po7ALT	<0.001	
	PreO ALT-po30ALT	0.002	
Group B	PreO ALT-po1ALT	<0.001	<0.001
	PreO ALT-po7ALT	<0.001	
	PreO ALT-po30ALT	0.018	
Group A	PreO AST-po1AST	<0.001	<0.001
	PreO AST-po7AST	<0.001	
	PreO AST-po30AST	0.106	
Group B	PreO AST-po1AST	<0.001	<0.001
	PreO AST-po7AST	0.407	
	PreO AST-po30AST	0.999	

ALT (U/L): Alanine aminotransferase, AST (U/L): Aspartate aminotransferase, PreO: Preoperative, Po: Postoperative day, *: Friedman test, **: Wilcoxon test with Bonferroni correction

DISCUSSION

In our study, we retrospectively classified gastric cancer patients who underwent surgery into groups with and without ALHA to determine whether or not peroperative ligation of this artery is safe for liver function. Our results showed that 17.2% of the cases had an aberrant artery. Postoperative ALT levels were found to be elevated in both groups with and without ALHA, but no statistical difference was found at 30 days postoperatively. In the ALHA group, ligation or protection of the artery had no significant effect on postoperative AST-ALT levels, operation time, hospital stay, number of lymph nodes removed or number of metastatic lymph nodes.

Today, there is still no widely accepted consensus on ligating an ALHA during gastrectomy, especially if it is found incidentally. The gold standard curative treatment for gastric cancer is known to be total/subtotal gastrectomy with en-bloc lymphadenectomy, and regional lymph nodes circulating the root of the LGA should be dissected.[3] For oncological safety, LGA should be ligated at its origin with en-bloc resection of lymph nodes three and six. However, an unrecognised or sacrificed left hepatic artery can lead to liver dysfunction and even death.

Table 5. Analysis of group B variables

Group B variables	ALHA cuts (n=11)	ALHA protected (n=25)	p-value*
	Mean (±standard deviation)		
Preoparative ALT	11±6.06	13±13.23	0.918
Preoperative AST	22±14.19	17±9.15	0.126
po1 ALT	64±39.20	38±175.57	0.419
po1 AST	74±50.03	46±121.87	0.164
po7 ALT	17±7.63	25±39.00	0.068
po7 AST	19±7.52	26±20.40	0.074
po30 ALT	20±6.84	17±71.97	0.655
po30 AST	18±7.12	21±40.15	0.262
Duration of surgery (minutes)	240±64.15	245±60.38	0.439
Duration of hospital stay (days)	5±2.76	7±5.03	0.194
Pathology specimen total LN (n)	34±13.71	32±14.83	0.327
Pathology specimen metastatic LN (n)	2±2.75	4±11.76	0.058

ALHA: Aberrant left hepatic artery, ALT (U/L): Alanine aminotransferase, AST (U/L): Aspartate aminotransferase, LN: lymph node, Po: Postoperative day, *: Mann-Whitney U test

ALHA is the most common vascular variation encountered in gastric cancer surgery with rates ranging from 6.5% to 34%.[14] Huang et al.[11] found the same anatomical variation with an incidence of 11.5% in their large retrospective analysis of 1173 patients. Essentially, ALHA can be divided into two main subtypes: accessory LHA (acLHA), which is an addition to the normal left hepatic artery, and replaced LHA (RLHA), which can be accepted as a replacement for a normal left hepatic artery.[7] It is usually discovered incidentally during gastric cancer surgery due to the lack of a non-invasive and reliable preoperative imaging method.[14] Liu et al.[15] proposed preoperative three-dimensional CT angiography as a diagnostic imaging modality for the perigastric arterial system, which may not be cost-effective if routinely used in the clinic. In our study, the celiac trunk and its branches were evaluated in detail by clarifying the contrast pattern of triphasic CT and arterial phase images thanks to the simulator on the digital system in radiology automation.

Although there are studies with contrary results, in general, the published literature usually recommends the preservation of ALHA to reduce postoperative complications. In their propensity score matching analysis, Lee et al.[14] suggested that ALHA should be preserved, especially when it is thought to be replaced for postoperative liver function, and sacrificed when it is accessory for oncological safety. When the root of the LGA is ligated during lymphadenectomy for gastric cancer, the blood supply to the ALHA, if present, is also cut off. In this situation, fatal complications such as postoperative hepatic dysfunction, liver failure and left hepatic lobe necrosis due to ALHA ligation have been reported.[16] Conversely, in their study of ligated and protected groups in both accessory and replacement ALHA patients, researchers found no differences in operative time, blood loss, overall complication rate, length of hospital stay and number of lymph nodes removed. It has been shown that if the ALHA diameter is greater than 1.5 mm, a transient increase in AST and ALT is observed on the 2nd postoperative day in ligated cases.[8] Two weeks after surgery, all values recovered completely without the need for medication or intervention, similar to our results at 30 days.

The difference between laparoscopic and open surgery in relation with the presence of ALHA and liver function has been searched, focusing on the use of carbon dioxide to create pneumoperitoneum. Changes in liver function tests may be observed due to the intra-abdominal pressure resulting from pneumoperitoneum. Jeong et al.[17] demonstrated this in their study by finding that AST and ALT levels were significantly higher on the first day after laparoscopic gastrectomy than after open gastrectomy. In addition to comparing open and laparoscopic surgery, the researchers also looked at whether the surgery was total or subtotal. In gastric cancer patients who underwent total or distal subtotal open gastrectomy, postoperative liver segments II and III were examined. The segments were found to have significant volume loss compared to the rest of the liver and the whole liver. This situation was associated with venous ischaemia due to the deterioration of the vessels contributing to the venous circulation of the gastric antrum.[18] In our results, minimally invasive type or resection margins (total/subtotal) did not significantly affect on the results or found related with ALHA ligation.

In their multi-centre and comprehensive analysis, Ang et al. concluded that ALHA ligation is a safe procedure with no adverse outcomes, resulting only in a transient increase in post-operative AST-ALT levels in cases with more than 1.5 mm diameter of aberrant artery.[8] As a result, the investigators suggested that ALHA be preserved in early gastric cancer and sacrificed in advanced cases. Pre-existing liver disease is also seen as a determining factor in the decision to withhold ALHA. Huang et al.[11] reported that it should not be ligated in this patient group to prevent liver dysfunction. Conversely, hepatic necrosis has not been reported even in patients with diagnosed liver disease after ALHA ligation, demonstrating that collateral arterial flow develops after hepatic artery ligation.[10,13,14] Cirocchi et al.[7] reported that collateralisation between phrenic and intrahepatic arteries spares the left lobe of the liver from the first postoperative ten hours after ligation, explaining the transient increase in enzymes. Similarly, Kim et al.[9] found no significant differences in operative time, blood loss, number of lymph nodes harvested or length of hospital stay after ALHA ligation. They also found no lethal complications such as necrosis or extreme increases in liver enzymes. The researchers also hypothesised that large ALHA result from a large LGA and that measuring the diameter of the LGA may be more accurate and easier than analysing ALHA preoperatively with contrast-enhanced CT. Lee et al.[14] reported ALHA of 17% in their series and although the patients with postoperative elevated AST-ALT levels showed longer hospital stay and higher incidence of postoperative complications grade ≥ IIIa, they suggested sacrificing ALHA

as a safe option. Interestingly, they also reported that only 20.8% of patients in the ligation group had a documented diagnosis of ALHA. Sano et al.[16] found that ALHA ligation was a significant independent risk factor for liver enzyme elevation and suggested that ALHA should be preserved in the setting of oncologically standard dissection of the surrounding lymph nodes. In one of the first systematic reviews, Tao et al.[13] analysed the clinical significance of ALHA preservation and recommended that close monitoring of postoperative liver function tests is essential, especially in patients with chronic liver disease or ALHA diameter >1.5 mm. They also found no significant difference in the number of retrieved lymph nodes between groups, similar to our results.

Limitations

The limitations of our study are that it was a single-center, retrospective design, and unlike some similar studies, the aberrant artery diameter was not studied. However, the strengths of our study include the inclusion of two major subgroups, total and subtotal gastrectomy, and the comparison of cases performed with open, laparoscopic and robotic techniques, unlike studies in the literature.

CONCLUSION

In our retrospective analysis, the prevalence of ALHA was 17.2% in patients with gastric cancer. Although we found a transient increase in postoperative liver enzymes in the ligated group, the statistical significance between the groups disappeared on day 30. We recommend close postoperative monitoring of liver enzymes in patients with suspected ALHA and collaboration with an experienced radiologist. Our results may contribute to the point of view that ALHA ligation is a safe intervention in gastric cancer surgery in terms of liver function.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Başakşehir Çam and Sakura City Hospital Clinical Researches Ethics Committee (Date: 22.11.2023, Decision No: 602).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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