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Anatomic variations in the left gastric vein and their clinical significance during laparoscopic gastrectomy

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Abstract

Background Surgeons normally encounter the left gastric vein (LGV) during laparoscopic gastrectomy (LG) for gastric cancer, and the various anatomic variants of this vessel make the procedure difficult. The objective of this study was to classify anatomic variants of the LGV in the laparoscopic operation field and clarify their clinical significance during LG.

Methods In total, 405 patients who underwent LG in 2013–2017 for gastric cancer were enrolled in the study. LGV drainage was classified into six types by the anatomic relation of the LGV to the arteries of the celiac axis: Type Ia [LGV runs anteriorly to the common hepatic artery (CHA)], Type Ip (LGV runs posteriorly to CHA), Type II (LGV runs anteriorly to the left gastric artery), Type IIIa [LGV runs anteriorly to the splenic artery (SA)], Type IIIp (LGV runs posteriorly to SA), and Type IV (LGV runs cranially into the proximal portal vein or liver parenchyma). If the LGV was injured during the operation, the patient was included as a member of the injury group (IG).

Results Most patients ($n=391$, 96.5%) had a single LGV, whereas 14 (3.5%) patients had double LGVs. Type Ip was the most common of the six drainage types ($n=195$, 48.1%). The number of patients in the IG was 49 (13.0%). Types I and III were relatively easily injured when compared with type II ($p=0.025$). Patients in the IG had longer operation times, more blood loss, and more lymph node metastases than the non-IG patients.

Conclusions In most patients, the LGV drains posteriorly to the CHA or anteriorly to the LGA. Gastric surgeons should take great care not to injure the LGV during LG when it is not present on the anterior side of the celiac axis.

Keywords Left gastric vein · Anatomic variants · Laparoscopic gastrectomy

The left gastric vein (LGV), also known as the gastric coronary vein, has an important role in venous drainage of the stomach. The LGV typically drains into the portal vein (PV) or splenic vein [1–3]; therefore, accidental injury to the LGV during an operation can lead to heavy blood loss. However, as the LGV has several anatomic variants, clear identification and safe ligation of the vessel is one of the most challenging procedures in radical gastrectomy for gastric cancer patients.

Laparoscopic gastrectomy (LG) has become a common treatment for gastric cancer worldwide, with several advantages that enhance patient quality of life [4–6]. However, unexpected anatomic variations in the perigastric vascular structure can dramatically increase the difficulty of LG, as these variations complicate navigation of the surgical field with a lack of tactile sense and make it difficult to control vascular injury, especially venous injury [3, 7]. Several studies have sought to identify variations in the LGV by preoperative computed tomography (CT) with three-dimensional (3D) reconstruction [2, 3, 8–10]. However, 3D CT is expensive and requires a substantial amount of contrast medium; therefore, prior studies included very limited numbers of enrolled patients. Moreover, there have been several proposed classification systems for anatomic variations in the LGV, but those systems are complex, and their clinical significance in LG has not been clearly elucidated [11, 12]. Therefore, this study was designed to directly demonstrate and classify the various courses of the LGV in the laparoscopic surgical field and to analyze the clinical utility of this classification with respect to the safety of LG.

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Materials and methods

Patients

From April 2012 to December 2017, 608 patients underwent LG for gastric adenocarcinoma at our center. Of these patients, 10 patients who underwent completion of total gastrectomy, 48 patients whose operation was terminated without the detection of LGV (palliative resection, severe adhesion due to previous operation, open conversion), 145 patients whose operation video could not be reviewed due to technical problems were excluded from the study. Finally, a total of 405 patients were enrolled in the study. The surgeries were performed by a single expert surgeon who had treated more than 500 cases of LG since 2008. Approval was obtained from the Institutional Review Board of the Catholic University of Korea College of Medicine (HC18RESI0001).

Operating procedure

Gastric resections included laparoscopic total and distal gastrectomies, with D1+ to D2 lymph node dissection (LND) performed according to the third Japanese gastric cancer treatment guidelines [13]. All surgical procedures were recorded on a laparoscopic video system; the course of each LGV was reviewed retrospectively by the surgical team and classified into one of six types, as described below. If the LGV was injured during the operation, the patient was included as a member of the injury group (IG) regardless of the injury severity. Patients' clinicopathological characteristics, operation time, and estimated blood loss were assessed from a prospectively collected database.

Classification and nomenclature of variants of the LGV

All surgical procedures were recorded on a laparoscopic video system and retrospectively reviewed. The course of the LGV was classified by its anatomic relationship to the celiac axis (CA), left gastric artery (LGA), common hepatic artery (CHA), and splenic artery (SA) (Fig. 1). From right to left, if the LGV crossed the CHA and drained into the portal venous system, it was classified as type I. If the LGV drained anteriorly to the CA, it was classified as type II. If the LGV crossed the SA and drained, it was classified as type III. Furthermore, types I and III were both subdivided into anteriorly (a) and posteriorly (p) drained groups by their position relative to the CHA or SA. If the LGV drained directly into the liver parenchyma or into the proximal PV near the PV bifurcation, it was classified as type IV. By this nomenclature, the course of LGV was classified into six types: Ia, Ip, II, IIIa, IIIp, and IV. If a patient had double or multiple LGVs, the type of LGV was determined by the course of the largest one.

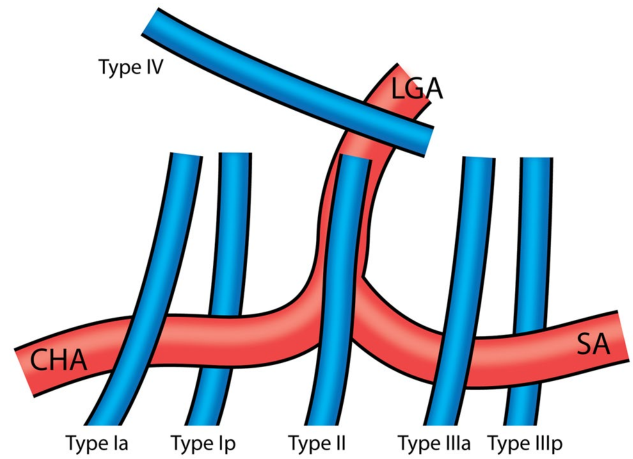

Fig. 1 Course of the LGV classified by anatomic relations to the CHA, LGA, and SA

Statistical analysis

The statistical analyses were performed with SPSS 18.0 (SPSS Inc.; Chicago, IL, USA). The collected data are expressed as median values (range) for non-parametric continuous variables, means ± standard deviations for parametric continuous variables, and frequencies with percentages for nominal variables. The Chi-square test or Fisher's exact test was used for nominal variables. The Mann–Whitney *U* test was used for non-parametric variables, and Student's *t* test was used for parametric continuous variables. Significance was determined using a two-tailed *p* value of 0.05. The variables that were found to be significant ($p < 0.10$) in the univariate analysis were included in the multivariate logistic regression analysis to identify the impact of each variable on LGV injury.

Results

Patients' clinicopathological characteristics and operative data are shown in Table 1. Images of each type are shown in Fig. 2. In 48.1% ($n = 195$) of patients, the LGV drained posteriorly to the CHA (type Ip, Table 2). The next most common type, accounting for 30.0% ($n = 121$) of patients, was type II, in which the LGV drained anteriorly to the LGA. Types Ia, IIIa, IIIp, and IV were observed in 3.0% ($n = 12$), 12.3% ($n = 50$), 5.7% (23%), and 1.0% ($n = 4$) of patients, respectively. Fourteen patients (3.5%) had double LGVs, and the most common types for the larger LGVs were types

Table 1 Clinicopathological characteristics and operative data

Variables	Values ($n=405$)
Age	64 (30–92)
Sex	
Male	259 (64.0%)
Female	146 (36.0%)
BMI (kg/m^2)	24.1 (16.4–37.3)
Type of gastrectomy	
Subtotal gastrectomy	359 (88.6%)
Total gastrectomy	46 (11.4%)
Extent of LN dissection	
D1+	74 (18.3%)
D2	331 (81.7%)
Pathologic stage	
I	277 (68.4%)
II	67 (16.5%)
III	59 (14.6%)
IV	2 (0.5%)
Total retrieved LN	31 (9–83)
Metastasized LN	0 (0–36)[a]
Operation time (min)	160 (90–410)
Estimated blood loss (cc)	52 (5–606)

BMI body mass index, *LN* lymph node

[a]Mean: 1.7

II ($n=8$) and Ip ($n=6$). No patient had more than double LGVs.

In 49 (13.8%) patients, the LGV was injured during LG. The incidence of LGV injury differed among the variation types of LGV drainage (Table 3). Type II LGV was more likely than types I or III to be ligated safely ($p=0.025$). In type II, 5.8% of LGVs were injured during LG, but the injury group included 14.0% and 17.8% of all type I and III patients, respectively. Posteriorly drained LGVs tended to be more frequently injured than anteriorly drained LGVs, although the trend was not significant. Type of gastrectomy, pathological stage, and number of malignant lymph nodes did not significantly differ among types I, II, and III or between anteriorly and posteriorly drained LGVs. In a univariate analysis of risk factors for injury of the LGV, T stage of primary tumor above T1, lymphatic metastasis, and LGV types other than type II were the risk factors for LGV injury (Table 4). In a multivariate analysis, LGV type other than type II was determined to be a risk factor for LGV injury.

When compared to patients whose LGV was not injured during LG, the IG required extended operation times (IG vs. non-IG: 196.9 min vs. 173.0 min, $p=0.012$) and exhibited increased intraoperative blood loss (IG vs. non-IG: 133.0 cc vs. 73.7 cc, $p=0.029$). The IG also had more advanced pathological stages of disease ($p=0.031$) and a higher proportion of patients with pathologically malignant lymph nodes than the uninjured group (IG vs. non-IG: 41.7% vs. 25.1%, $p=0.034$). Furthermore, the mean number of malignant lymph nodes was elevated in the IG (IG vs. non-IG: 4.2 vs. 1.3, $p=0.010$).

Among the 49 IG patients, one patient with type Ip needed a conversion to open surgery due to LGV injury. His bleeding was successfully managed after open conversion, and his pathologic stage of gastric cancer was T4aN3bM0. He was discharged without any postoperative complications on the 11th day after operation. LGV injury in the other 48 IG patients was successfully managed on the laparoscopic field.

Discussion

Several anatomic variations of the LGV are known to exist, and damage to that vessel can lead to massive hemorrhage during gastrectomy because it directly drains to the portal venous system [2, 8, 10]. Therefore, a precise understanding of the courses of its anatomic variants is a prerequisite for safe surgery [14]. However, there has been no research on these conditions, and the present study is, to the best of our knowledge, the first to directly categorize the anatomic variations in the LGV in the laparoscopic field and track the incidence of LGV injury. In addition, we provide a new nomenclature system for LGV anatomic variants. The new classifications are easy to understand because they are defined by the relationship between the LGV and the large arteries of the CA.

The reasons for the different LGV drainage patterns remain unclear despite several anatomical studies [1, 15, 16]. Embryologically [17], the primitive foregut venous plexus (PFVP) courses along the primitive foregut, while the ductus venosus of Arantius anastomoses with the PFVP, resulting in the anastomotic omental veins. During the development of the PFVP, the anastomotic omental veins gradually disappear, with both the right and left gastric veins ending in the main PV. Veins, however, must adapt to changes in the intestinal canal and expansion of the liver, resulting in different LGV drainage patterns, which probably emerged at different times during the course of evolution. In 1950, Douglass classified the LGV by the site of its connection to the portal venous system. In 1993, Roi reported an ultrasound study on the LGV, but the vessel was identified in only 46% of the patients. Since the early twenty-first century, attempts have been made in several studies to identify anatomic variations in perigastric vascular structures by multidetector CT (MDCT) with 3D reconstruction before pancreatectomy or gastrectomy [2, 3, 8–10, 18]. Using MDCT findings from 81 gastric cancer patients, Kawasaki et al. [10] defined five groups of LGV locations and validated them with intraoperative

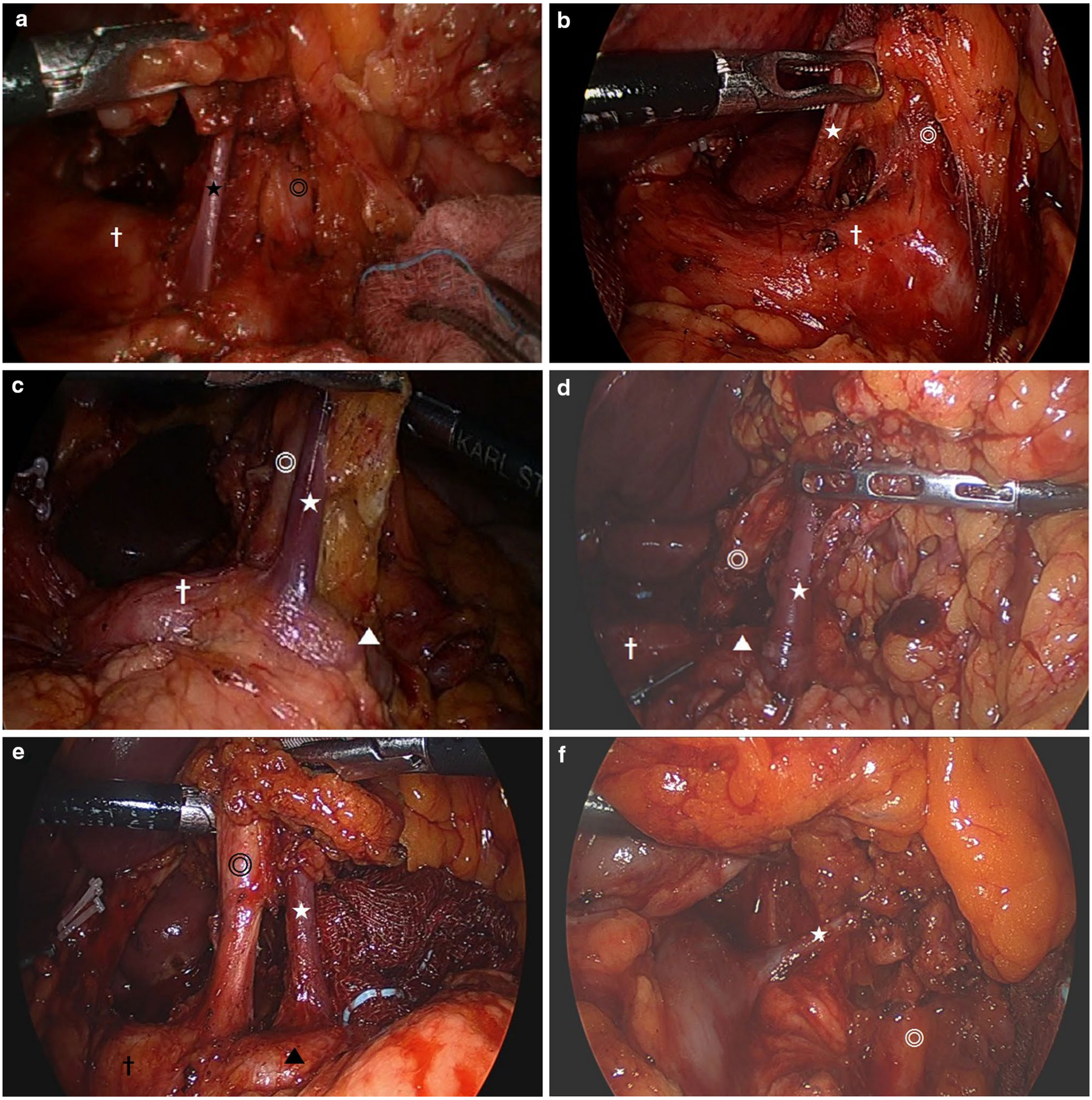

Fig. 2 Various LGV types observed during laparoscopic gastrectomy. **A** Type Ia. **B** Type Ip. **C** Type II. **D** Type IIIa. **E** Type IIIp. **F** Type IV. Filled star, LGV; ◎, LGA; dagger, CHA; filled triangle, SA

observations. Their classification groups were dorsal to the CHA, dorsal to the SA, ventral to the CHA, ventral to the SA, and others. Our classification is largely similar to theirs, but we identified some patients in whom the LGV was attached to the LGA and drained at its anterior side. We classified that variant as type II, and this type exhibited a prevalence of 30.0%. LGV crossing the CHA posteriorly was the most common course found in the present study. The frequency of this type (Ip) was 48.1%, and this result was similar to the values reported in previous studies, which ranged from 36 to 49.8% [9, 10].

The incidence of injury to the LGV during LG was 13.0% in our study. We included all minor injuries during operation, and although these data did not include any information with respect to the severity of LGV injury, to the best of our knowledge, this is the first report about the prevalence of LGV injury during LG. By our new classification, compared to types I and III, type II LGV was found to be relatively safe

Table 2 Anatomic variations in the LGV and their frequencies

Variation type	Description	Frequency
Ia	LGV runs anteriorly to CHA	3.0% ($n=12$)
Ip	LGV runs posteriorly to CHA	48.1% ($n=195$)
II	LGV runs anteriorly to LGA	30.0% ($n=121$)
IIIa	LGV runs anteriorly to SA	12.3% ($n=50$)
IIIp	LGV runs posteriorly to SA	5.7% ($n=23$)
IV	LGV runs cranially into proximal portal vein or liver parenchyma	1.0% ($n=4$)
Total		100% ($n=405$)

CHA common hepatic artery, *LGA* left gastric artery, *SA* splenic artery

Table 3 Comparison of the incidence of LGV injury by the anatomic types

	Incidence of LGV injury (*n*/total)	*p* value
Type Ia	8.3% (1/12)	
Type Ip	14.4% (28/195)	
Type II	5.8% (7/121)	
Type IIIa	18.0% (9/50)	
Type IIIp	17.4% (4/23)	
Type IV	0% (0/4)	
Categorized by type I, II, and III		**0.025**
Type I (Ia + Ip)	14.0% (29/207)	
Type II	5.8% (7/121)	
Type III (IIIa + IIIp)	17.8% (13/73)	
Categorized by anterior group and posterior group		0.117
Anterior group (Ia + II + IIIa)	9.3% (17/183)	
Posterior group (Ip + IIIp)	14.7% (32/218)	

Significant values are indicated in bold

LGV left gastric vein

Table 4 Univariate and multivariate analysis of the risk factor for LGV injury

	Univariate		Multivariate	
	OR [95% CI]	*p* value	OR [95% CI]	*p* value
Age (years)		0.297		
< 60	1			
≥ 60	0.72 [0.4–1.32]			
BMI (kg/m^2)		0.629		
< 28	1			
≥ 28	1.22 [0.51–2.64]			
T stage		**0.0495**		0.599
pT1	1		1	
pT ≥ 2	1.83 [1.0–3.35]		1.25 [0.54–2.78]	
N stage		**0.024**		0.143
pN0	1		1	
pN ≥ 1	2.04 [1.09–3.76]		1.87 [0.81–4.38]	
LND ≥ D2		0.947		
D1+	1			
≥ D2	0.97 [0.47–2.23]			
Total retrieved LN		0.609		
< 40	1			
≥ 40	0.83 [0.39–1.64]			
LGV type				
Type II	1		1	
Type I	2.59 [1.16–6.62]	**0.029**	2.55 [1.13–6.53]	**0.034**
Type III	3.53 [1.37–9.83]	**0.011**	3.76 [1.45–10.59]	**0.008**

LGV left gastric vein, *BMI* body mass index, *LN* lymph node, *LND* lymph node dissection

Significant values are indicated in bold

to ligate during LG. In type II, the incidence of LGV injury was 5.8%, and this rate was significantly lower than that of type I or III. According to the risk factor analysis for LGV injury, type II LGV was identified as a negative risk factor in both univariate and multivariate analysis. The reason for this result might be that type II LGV could be easily detected at the anterior side of the CA without complete dissection of the lymph nodes around the CA. In addition, although the trend was not significant, the incidence of injury of anteriorly drained LGVs (type Ia, II and IIIa) was lower than that of posteriorly drained LGVs (type Ip and IIIp). Therefore, during LND in LG, considering that type Ip was the most common type, if the LGV does not appear on the anterior side of the CA, surgeons should take special care not to injure the hidden LGV among the lymph nodes of the CHA or SA.

Another major factor that may have affected the incidence of LGV injury was lymphatic metastasis, which was more extensive in the IG than that in the non-IG patients. D2 LND itself was not a risk factor for injury in the present study, but lymphatic invasion of the nodes around the CHA, LGA, and SA made LND more difficult, and this may result in injury of perigastric vessels, including the LGV. Furthermore, in reference to pathological stages, the prevalence of AGC was significantly higher in the IG than that in the non-IG patients; consequently, the proportion of patients who had lymphatic metastasis and the average number of metastasized lymph nodes were both higher in the IG than that in the non-IG patients. However, the influence of LGV injury on the outcome of the operation remains unclear. Although patients whose LGV was injured during LG required extended operation times and exhibited increased total intraoperative bleeding and because there are many factors that affect the surgical outcome other than the ligation of LGV and dissection of LND around this vessel, the actual clinical effectiveness of minimizing LGV injury needs to be confirmed by further studies.

Selective use of preoperative MDCT with 3D reconstruction to confirm the course of the LGV in those patients who have clinically advanced tumors or suspicious lymphatic metastasis can be a reasonable option. Such CT angiography was validated by previous studies identifying vascular anomalies in the preoperative period [9, 12, 19, 20]; however, this modality is expensive, and patients are exposed to substantial amounts of radiation and contrast medium. Miyamoto et al. [9] reported that preoperative 3D reconstruction of the perigastric vasculature was useful for reducing intraoperative blood loss in 84 patients undergoing radical gastrectomy, but more studies are needed to validate the efficacy of preoperative CT angiography to enhance the safety of LG, especially in clinically AGC patients.

The present study does have some limitations. First, no relationship could be demonstrated between LGV variations and accompanying arterial variations. Our classification is based on the anatomic relationship of the LGV to the arteries of the CA. Therefore, when arterial variations accompany LGV variations, the former may affect the classification of the latter. There was also a limitation on the ability to fully describe arterial variations from a review of intraoperative videos. More studies using CT angiograms or cadavers are needed to clarify the relationship between LGV variations and arterial variations. Recently, Wu et al. reported that LGV variation could be determined and classified by preoperative dynamic-enhanced MDCT [12]. Preoperative findings of arterial structures that are carefully evaluated by radiologists can be correlated with intraoperative LGV variants in future studies.

Second, the definite location where the LGV drained into the portal venous system could not be observed in most patients. The LGV typically drains into the PV or splenic vein, but in many cases, this drainage occurs by the deep dorsal side of the pancreas; therefore, the definite location is difficult to detect in the laparoscopic field during gastrectomy. The anatomic location where the LGV terminates can be identified during pancreatectomy [18]; therefore, the analysis of intraoperative findings from pancreatectomy may be helpful in identifying the anatomic relationship between the variation in the LGV and the site of its termination.

Conclusion

In most patients, the LGV drains posteriorly to the CHA or anteriorly to the LGA; therefore, gastric surgeons should take special care not to injure the LGV when approaching these areas, especially when it does not appear on the anterior side to the celiac axis.

Compliance with ethical standards

Disclosures Hayemin Lee and Junhyun Lee have no conflicts of interest or financial ties to disclose.

References

1. Douglass BE, Baggentoss AH, Hollinshead WH (1950) The anatomy of the portal vein and its tributaries. Surg Gynecol Obstet 91:562–576
2. Natsume T, Shuto K, Yanagawa N, Akai T, Kawahira H, Hayashi H, Matsubara H (2011) The classification of anatomic variations in the perigastric vessels by dual-phase CT to reduce intraoperative bleeding during laparoscopic gastrectomy. Surg Endosc 25:1420–1424
3. Yuasa Y, Okitsu H, Goto M, Kuramoto S, Tomibayashi A, Matsumoto D, Edagawa H, Mori O, Tani R, Akagawa T, Kinoshita M, Akagawa Y, Tani H, Ohnishi N, Shirono R (2016) Three-dimensional CT for preoperative detection of the left gastric artery and left gastric vein in laparoscopy-assisted distal gastrectomy. Asian J Endosc Surg 9:179–185
4. Kim HH, Hyung WJ, Cho GS, Kim MC, Han SU, Kim W, Ryu SW, Lee HJ, Song KY (2010) Morbidity and mortality of laparoscopic gastrectomy versus open gastrectomy for gastric cancer: an interim report—a phase III multicenter, prospective, randomized trial (KLASS trial). Ann Surg 251:417–420
5. Kim HH, Han SU, Kim MC, Hyung WJ, Kim W, Lee HJ, Ryu SW, Cho GS, Song KY, Ryu SY (2014) Long-term results of laparoscopic gastrectomy for gastric cancer: a large-scale case-control and case-matched korean multicenter study. J Clin Oncol 32:627–633
6. Kim YW, Baik YH, Yun YH, Nam BH, Kim DH, Choi IJ, Bae JM (2008) Improved quality of life outcomes after laparoscopy-assisted distal gastrectomy for early gastric cancer. Ann Surg 248:721–727
7. Wottawa CR, Cohen JR, Fan RE, Bisley JW, Culjat MO, Grundfest WS, Dutson EP (2013) The role of tactile feedback in grip force during laparoscopic training tasks. Surg Endosc 27:1111–1118
8. Sakaguchi T, Suzuki S, Morita Y, Oishi K, Suzuki A, Fukumoto K, Inaba K, Kamiya K, Ota M, Setoguchi T, Takehara Y, Nasu H, Nakamura S, Konno H (2010) Analysis of anatomic variants of mesenteric veins by 3-dimensional portography using multidetector-row computed tomography. Am J Surg 200:15–22
9. Miyamoto R, Inagawa S, Nagai K, Maeda M, Kemmochi A, Yamamoto M (2016) Three-dimensional reconstruction of vascular arrangement including the hepatic artery and left gastric vein during gastric surgery. Springerplus 835:1–6
10. Kawasaki K, Kanaji S, Kobayashi I, Fujita T, Kominami H, Ueno K, Tsutida S, Ohno M, Ohsawa M, Fujino Y, Tominaga M, Nakamura T (2010) Multidetector computed tomography for preoperative identification of left gastric vein location in patients with gastric cancer. Gastric Cancer 13:25–29
11. Li CY, Gao BL, Song B, Fan QY, Zhou LX, Feng PY, Zhang XJ, Zhu QF, Xiang C, Peng S, Huang YF, Yang HQ (2016) Evaluation of left gastric vein in Chinese healthy adults with multi-detector computed tomography. Postgrad Med 128:701–705
12. Wu Y, Chen G, Wu P, Zhu J, Peng W, Xing C (2017) CT imaging-based determination and classification of anatomic variations of left gastric vein. Surg Radiol Anat 39:249–255

13. Japanese Gastric Cancer Association (2011) Japanese gastric cancer treatment guidelines 2010 (ver. 3). Gastric Cancer 14:113–123
14. Osaki T, Saito H, Murakami Y, Miyatani K, Kuroda H, Matsunaga T, Fukumoto Y, Ikeguchi M (2015) Usefulness of preoperative assessment of perigastric vascular anatomy by dynamic computed tomography for laparoscopic gastrectomy. Yonago Acta Med 58:157–164
15. Hiwatashi A, Yoshimitsu K, Honda H, Kuroiwa T, Irie H, Tajima T, Jimi M, Chijiiwa K, Masuda K (1999) Pseudolesion in segment II of the liver observed on CT during arterial portography caused by the aberrant left gastric venous drainage. Abdom Imaging 24:357–359
16. Roi D (1993) Ultrasound anatomy of the left gastric vein. Clin Radiol 47:396–398
17. Huang CM, Wang JB, Wang Y, Zheng CH, Li P, Xie JW, Lin JX, Lu J (2014) Left gastric vein on the dorsal side of the splenic artery: a rare anatomic variant revealed during gastric surgery. Surg Radiol Anat 36:173–180
18. Rebibo L, Chivot C, Fuks D, Sabbagh C, Yzet T, Regimbeau JM (2012) Three-dimensional computed tomography analysis of the left gastric vein in a pancreatectomy. HPB 14:414–421
19. Iino I, Sakaguchi T, Kikuchi H, Miyazaki S, Fujita T, Hiramatsu Y, Ohta M, Kamiya K, Ushio T, Takehara Y, Konno H (2013) Usefulness of three-dimensional angiographic analysis of perigastric vessels before laparoscopic gastrectomy. Gastric Cancer 16:355–361
20. Miyaki A, Imamura K, Kobayashi R, Takami M, Matsumoto J, Takada Y (2012) Preoperative assessment of perigastric vascular anatomy by multidetector computed tomography angiogram for laparoscopy-assisted gastrectomy. Langenbeck's Arch Surg 397:945–950