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TECHNICAL NOTES

Topographic anatomy and laparoscopic technique for dissection of no. 6 infrapyloric lymph nodes in gastric cancer surgery

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Abstract We focused on the embryology and topographic anatomy of the infrapyloric lymph region, which is frequently involved in node metastases but technically complicated for dissection in gastric cancer surgery. Gastrointestinal organs possess their own mesenteries composed of double layers of peritoneum that enclose the intermediate adipose layer providing pathways for vessels, nerves, and lymphatic channels. The frontal layer of the mesoduodenum, in which no. 6 infrapyloric nodes lie, directly faces the pancreas and during gestation is overlain by the greater omentum and transverse mesocolon through the membranous connective tissue called the fusion fascia. Therefore, we performed no. 6 node dissection using the following process: (1) we traced out the mesoduodenum by detachment of the greater omentum and transverse mesocolon; (2) we transected the fusion fascia and (3) removed the adipose layer on the anterior face of the pancreas with its included lymph nodes together with the right gastroepiploic and infrapyloric vessels. The described technique is feasible and in keeping with the anatomical logic for oncologically reliable dissection of no. 6 infrapyloric nodes.

Keywords Infrapyloric lymph nodes · Mesoduodenum · Laparoscopic surgery · Regional anatomy · Gastric cancer

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Introduction

Radical surgery for gastric cancer comprises adequate resection of the stomach together with removal of lymph nodes connected with the stomach [1, 2]. Nodes should be removed as a series of the lymph channels included in the intermediate adipose layer of proper mesenteries [3, 4]. Metastases of the no. 6 infrapyloric nodes, which drain the lymphatic flow from the right gastroepiploic vessels [5], are very frequent if the cancer is localized in the lower and middle third of the stomach [2]. However, dissection of no. 6 nodes requires delicate manipulations since the frontal layer of the mesoduodenum in which they are included directly faces the pancreas and small vessels, whose injury results in annoying postoperative complications such as pancreatitis, peripancreatic abscess, and pancreatic fistula [6–8].

Recent advances in laparoscopic techniques have provided surgeons with magnified and highly defined operation images, which enable us to identify dissection layers of the mesenteries correctly to perform safe and oncologically reliable lymphadenectomy [9–12]. To use this advantage, knowledge of the anatomy based on embryology is indispensable. In this article, we have described an optimal laparoscopic technique in keeping with the anatomical logic for dissection of no. 6 infrapyloric lymph nodes in gastric cancer surgery.

Embryological background

At 5–6 weeks of gestation, the developing stomach and duodenum are suspended from the body wall by mesenteries composed of double layers of peritoneum that enclose the intermediate adipose layer providing pathways for vessels, nerves, and lymphatic channels [4] (Fig. 1). The pancreas grows into the mesoduodenum, and eventually its tail extends into the dorsal mesogastrium, anatomically known as the greater omentum [13] (Fig. 2a). Following 90° clockwise rotation of the stomach around its longitudinal axis, the no. 6 lymph nodes initially lying on the left side of the pancreas to drain lymphatic flow from the greater curvature of the stomach [5] move anteriorly (Fig. 2b). Until 12 weeks, the primary midgut loop rotates 270° counterclockwise around the superior mesenteric artery. The greater omentum expands and swells in the upper abdomen to develop the omental bursa. Until 20 weeks, the greater omentum and the transverse mesocolon overlay the frontal surface of the mesoduodenum [13] (Fig. 3). The peritonea at the attachment site are fused together and degenerate to form membranous connective tissue called the fusion fascia [14].

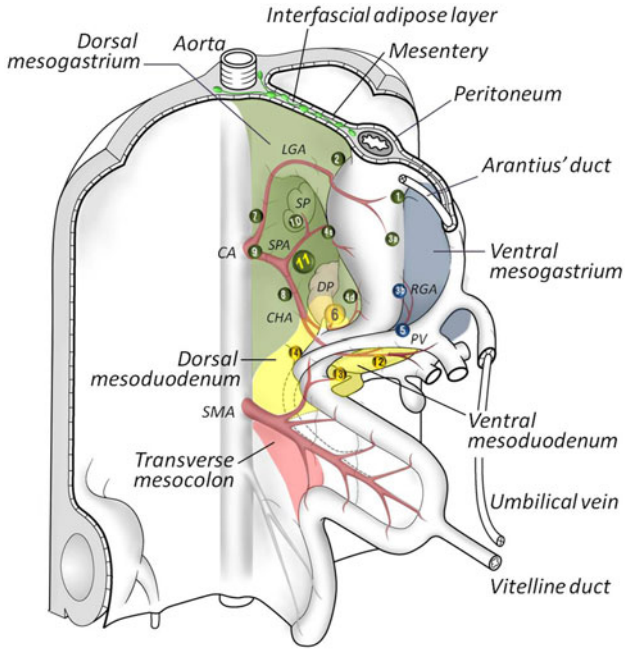

Fig. 1 Primitive dorsal and ventral mesenteries of the stomach and duodenum. The numbers in *circles* indicate regional lymph nodes of the stomach. *CA* celiac artery, *SMA* superior mesenteric artery, *LGA* left gastric artery, *RGA* right gastric artery, *CHA* common hepatic artery, *SPA* splenic artery, *PV* portal vein, *DP* dorsal pancreas, *VP* ventral pancreas, *SP* spleen

Topographic anatomy

Figure 4 shows a representative vascular anatomy of the mesoduodenum, which provides the border of the infrapyloric lymph region. Number 6 nodes lie along the proximal part of the right gastroepiploic vein (RGEV, named no. 6v), the right gastroepiploic artery (RGEA, no. 6a), and the infrapyloric vessels (no. 6i). The lower border of no. 6v should be the confluence of the anterior superior pancreatoduodenal vein (ASPDV), which is usually folded with an attachment of the transverse mesocolon (Fig. 2). The omental bursa and the highest branch of the ASPDV are assumed to be the medial and lateral borders, respectively. Number 6a is separated from no. 6i by the infrapyloric artery (IPA) and from no. 4d by the first branch of the RGEA feeding the greater gastric curvature.

Figure 5 shows, by means of a transverse section, the depth and surrounding membranous structures of the infrapyloric lymph region. Number 6 nodes are included in the frontal layer of the mesoduodenum. RGEA, RGEV, and infrapyloric vessels creep along the face of the pancreas, whereas the anterior superior pancreatoduodenal artery (ASPDA) and ASPDV gradually submerge into its parenchyma (shown in Fig. 3). Therefore, after removal of no. 6 nodes, the pancreatic parenchyma, preserved ASPDA and ASPDV should be exposed.

Surgical technique

The setting of our laparoscopic gastrectomy has been described previously [10, 11, 15]. The greater omentum is divided to open the omental bursa using ultrasonically activated coagulating shears about 3 cm apart from the gastroepiploic vessels to harvest no. 4 nodes with the specimen. The division continues rightward beyond the right border of the omental bursa until the descending part of the duodenum. The divided omentum is then detached from the fusion fascia to trace out the frontal surface of the mesoduodenum (Fig. 6a). The transverse mesocolon is also taken down to identify the RGEV and the confluence of the ASPDV (Fig. 6b). This is the "first viewpoint" to determine the lower border of the no. 6v. Subsequently, the fusion fascia is transected, and adipose tissue surrounding the confluence is dissected to bare the RGEV (Fig. 6c). This is the "second viewpoint" to determine the depth of no. 6v. After dividing the RGEV with clips above the confluence, the adipose tissue with its included lymph nodes is carefully dissected from the anterior face of the head of the pancreas (Fig. 6d). An appropriate layer to avoid parenchymal injury is the outermost layer of nerves that twine around the surface of the pancreas, ASPDA and ASPDV [16]. The infrapyloric vein and the perivascular

nerves surrounding the root of the RGEA are dissected to bare the artery (Fig. 6e). The RGEA is then divided with double clips at its root, and no. 6a is dissected. Finally, the IPA is divided, and the inferior wall of the duodenal bulbous is skeletonized. The infrapyloric lymph area including the no. 6 nodes is removed en bloc with the gastric specimen (Fig. 6f).

Results

Between January 2009 and March 2012, 105 patients with preoperatively diagnosed T1 (mucosa/submucosa) or T2 (muscle propria) gastric adenocarcinoma were treated by laparoscopic surgery at Hyogo Prefectural Amagasaki Hospital and Toranomon Hospital. The type of lymph

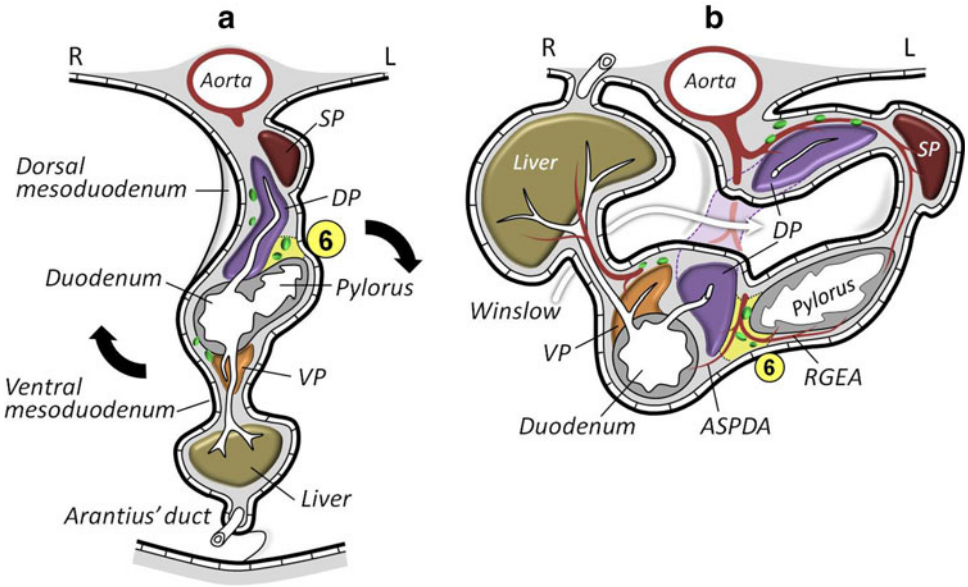

Fig. 2 Transverse sections of the mesoduodenum and the growing pancreas before (**a**) and after clockwise rotation of the stomach (**b**). Number 6 lymph nodes initially lying on the *left side* of the pancreas move anteriorly after 90° clockwise rotation of the stomach. *DP* dorsal pancreas, *VP* ventral pancreas, *SP* spleen, *RGEA* right gastroepiploic artery, *ASPDA* anterior superior pancreatoduodenal artery

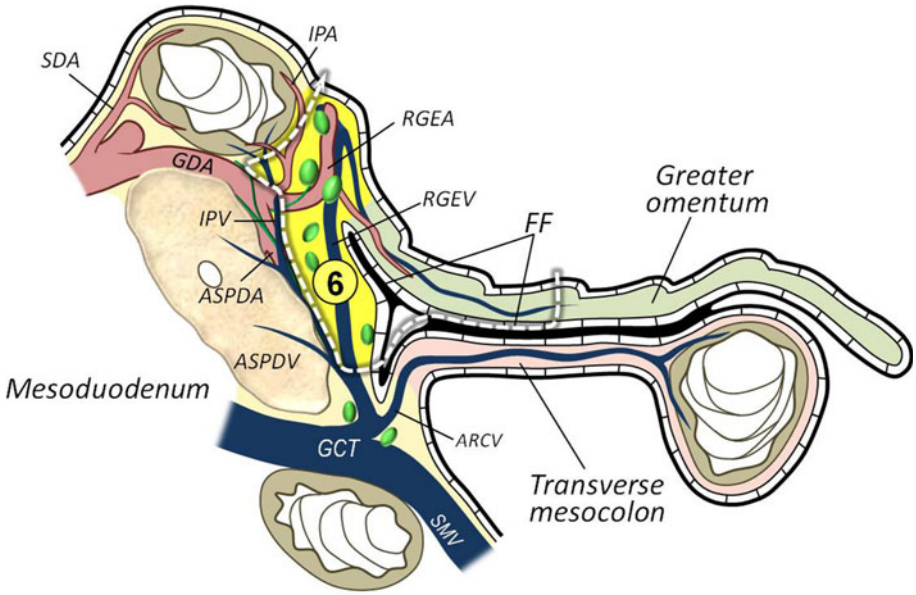

Fig. 3 A sagittal section of the mesoduodenum after embryological development. The greater omentum and the transverse mesocolon overlay the anterior surface of the mesoduodenum. The peritonea at the attachment site are fused together to form the fusion fascia (FF). *Dotted line* indicates the optimal route for dissection of the no. 6 lymph region. *RGEA* right gastroepiploic artery, *RGEV* right gastroepiploic vein, *GDA* gastroduodnal artery, *SDA* superior duodenal artery, *ASPDA* anterior superior pancreatoduodenal artery, *ASPDV* anterior superior pancreatoduodenal vein, *IPA* infrapyloric artery, *IPV* infrapyloric vein, *SMV* superior mesenteric vein, *ARCV* accessory right colic vein, *GCT* gastrocolic trunk

dissection was determined according to the Japanese Gastric Cancer Treatment Guidelines [17]. The median follow-up period of these patients was 27 months (range 7–45 months). The mean time required to complete infrapyloric lymphadenectomy was 46 ± 8 min. The mean number of retrieved lymph nodes was 5.8 ± 3.6, which did not differsignificantly from that of 5.4 ± 4.7 in our 87 conventional surgeries performed on patients with T1/T2 gastric cancer during the same period. Metastasis to at least one lymph node was found in 14 (13.3 %) patients (N1, $n = 9$; N2, $n = 5$) and to the no. 6 node was found in 6 (5.7 %) patients (N1, $n = 3$; N2, $n = 3$). Grade A and B postoperative pancreatic fistulae, according to the International Study Group on Pancreatic Fistula definition [18], were observed in 18 patients (17.1 %) and 3 patients (2.9 %), respectively. One patient categorized as grade B required readmission because of no. 6 dissection-related abscess formation. However, two other grade B cases were considered to be caused by dissection of lymph nodes along the splenic artery. Although one patient had liver metastases 10 months after surgery, no local or regional lymph node recurrences have been observed to date.

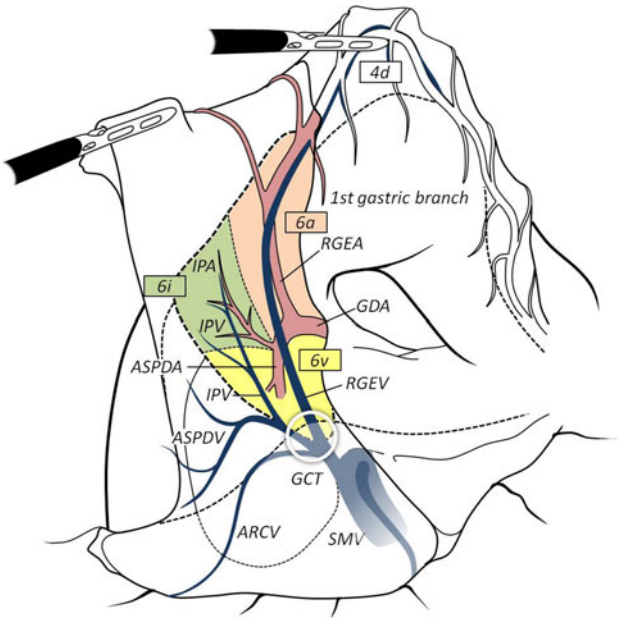

Fig. 4 Representative vascular anatomy and the border of the infrapyloric lymph region. Number 6 nodes lie along the proximal part of the right gastroepiploic vein (RGEV, no. 6v), the right gastroepiploic artery (RGEA, no. 6a), and the infrapyloric vessels (no. 6i). The lower border of no. 6v should be the confluence of the anterior superior pancreatoduodenal vein (ASPDV), which is usually folded with the attachment of transverse mesocolon (*circle*). *GDA* gastroduodnal artery, *ASPDA* anterior superior pancreatoduodenal artery, *IPA* infrapyloric artery, *IPV* infrapyloric vein, *SMV* superior mesenteric vein, *ARCV* accessory right colic vein, *GCT* gastrocolic trunk

Discussion

The significance of lymphadenectomy lies in the resection of regional nodes as a series of lymphatic channels, but not in just picking out certain nodes. Theoretically, interception of lymphatic drainage could be ensured by en bloc resection of the proper mesenteries. In radical colectomy, systematic excision of the mesocolon is routinely performed because the structure remains well preserved. The prognosis after resection of rectal cancer has been improved by "total mesorectal excision" as proposed by Heald et al. [19]. In contrast, in radical gastrectomy, the proper mesenteries (greater omentum and mesoduodenum)

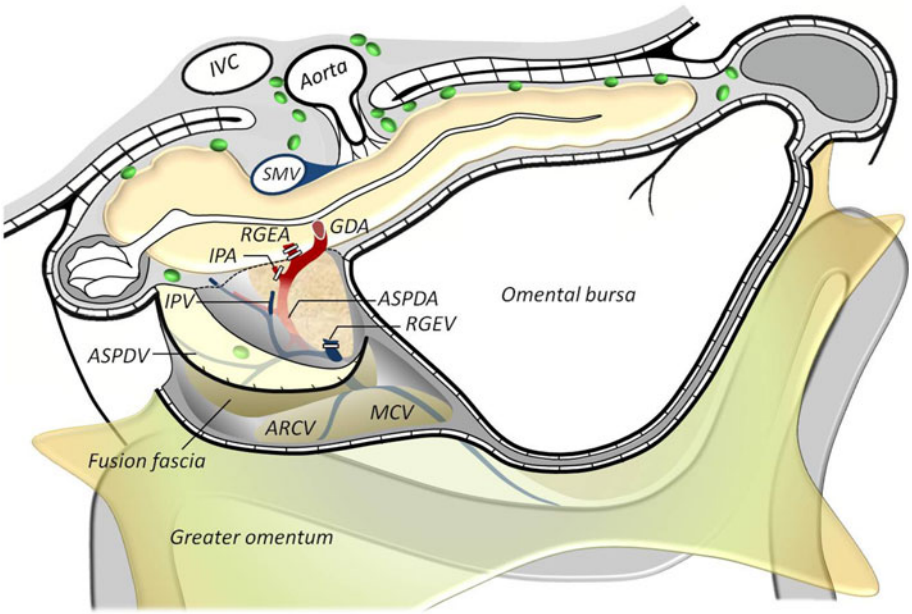

Fig. 5 Transverse sections demonstrating the depth and surrounding membranous structures of the infrapyloric lymph region. After removal of no. 6 nodes, the pancreatic parenchyma, the preserved anterior superior pancreatoduodenal artery (ASPDA) and vein (ASPDV) should be exposed. *RGEA* right gastroepiploic artery, *RGEV* right gastroepiploic vein, *GDA* gastroduodnal artery, *ASPDA* anterior superior pancreatoduodenal artery, *IPA* infrapyloric artery, *IPV* infrapyloric vein, *SMV* superior mesenteric vein, *ARCV* accessory right colic vein, *MCV* middle colic vein, *IVC* inferior vena cava

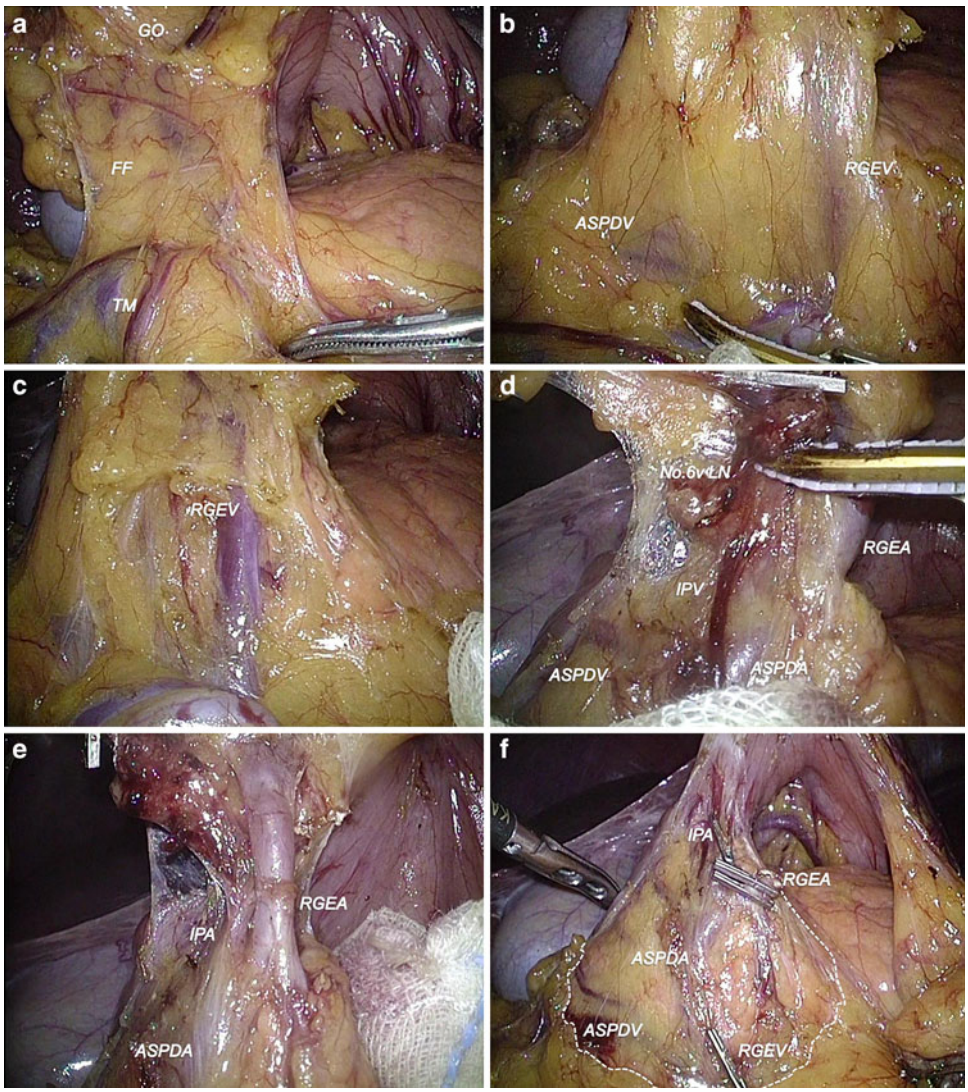

Fig. 6 Operative procedure of no. 6 node dissection. **a** Exposure of the fusion fascia (FF) on the frontal surface of the mesoduodenum by detachment of the greater omentum (GO) and the transverse mesocolon (TM). **b** The "first viewpoint" to identify the right gastroepiploic vein (RGEV) and the confluence of the anterior superior pancreatoduodenal vein (ASPDV). **c** The "second viewpoint" to determine the depth of no. 6v. **d** Dissection of the adipose tissue with its included no. 6v nodes from the anterior face of the head of the pancreas. *IPV* infrapyloric vein. **e** Isolation of the right gastroepiploic artery (RGEA) and the infrapyloric artery (IPA). **f** After removal of the no. 6 lymph region. A *broken line* indicates the dissection margin

have lost primitive structures during gestation, i.e., they are spiralized, fixed, fused with adjacent mesenteries, and included by the pancreas, required to be preserved. Therefore, we focused on the embryological background and topographic anatomy of the mesoduodenum for optimal no. 6 lymph dissection. In our series of patients, the mean number of retrieved no. 6 lymph nodes did not differ from that in our conventional surgeries and is almost equivalent to that of six in open gastrectomy according to expert Japanese surgeons [20]. However, we would like to emphasize that our concept of aiming at en bloc excision of the adipose layer of the proper mesenteries with its included lymphatic channels should be considered.

Since the lymphatic drainage system provides a predominant pathway for the systematic dissemination of gastric cancer cells [3, 21], it is probable that free cancer cells are introduced into the peritoneal cavity when the surgeon opens the lymphovascular vessels during lymphadenectomy. Indeed, peritoneal recurrence has been reported even in T1N0 early gastric cancer cases [22, 23]. Yang et al. demonstrated in an ex vivo simulation model that the released gastric cancer cells and the carcinoembryonic antigen-mRNA levels are significantly increased by inadequate closure of lymphovascular vessels [24]. To achieve oncologically reliable lymphadenectomy, we aim to minimize the spillage of cancer cells from lymphovascular pedicles by carrying out correct dissection of the mesenteric layers as described here.

The infrapyloric region can be regarded as one of the most technically complicated stations for dissection, because it directly faces the pancreas so that careless manipulations will result in postoperative complications such as pancreatic fistula and abscess [6–8]. Recently, laparoscopic techniques have gained wide clinical acceptance in gastric cancer surgery. The endoscopic view enables us to identify small vessels, nerves, and fascial laminations that are invisible to the naked eye in conventional surgery. We and others have reported the safety of

laparoscopic lymph node dissection in the suprapancreatic (along the common hepatic and splenic arteries) regions [10–12, 16]. In the present study including 105 patients, we performed dissection of no. 6 nodes with little intraoperative blood loss and a low incidence or severity of postoperative pancreatic fistulas, suggesting that our technique is feasible and safe.

In conclusion, we have described an optimal laparoscopic technique in keeping with the anatomical logic for dissection of no. 6 infrapyloric lymph nodes. We believe our concept for radical lymphadenectomy based on embryology and the regional anatomy of the mesenteries is applicable to the other lymph stations during gastric cancer surgery.

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