Anatomical variation of arterial supply to the rabbit stomach

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ABSTRACT. Gastric stasis is common in rabbits, and gastrotomy may be performed to cure this pathological condition. Detailed descriptions of the arterial supply to the stomach are essential for this surgical operation, but published descriptions are limited. Here, we investigated anatomical variations of the arterial supply to the stomach in 43 New Zealand White rabbits by injecting colored latex into arteries. We observed that the left gastric artery that arose as the second branch from the celiac artery provided 1–3 parietal and 1–3 visceral branches to the stomach, with various branching patterns depending on the case. In 34 of 43 cases, the left gastric artery ended upon entering the gastric wall at the lesser curvature, whereas in the remaining cases, the artery continued as the hepatic artery without entering the gastric wall. The right gastric artery that branched off from the gastroduodenal artery also supplied the lesser curvature sinistrally but did not anastomose with the left gastric artery. In 40 cases, the hepatic artery provided 1–4 pyloric branches. In the fundic region, the short gastric arteries arose from the splenic artery and varied in number from 2 to 6. The right and left gastroepiploic arteries anastomosed to give 2–7 branches to the greater curvature. The results showed that many variations occurred in the arteries supplying the rabbit stomach, suggesting that such variations should be considered when performing veterinary surgical treatments in rabbits.

KEY WORDS: angiology, artery, macroscopic anatomy, rabbit, stomach

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The rabbit has the largest stomach relative to body size among monogastric animals [15] and may be affected by gastric stasis, which is a common pathologic condition in this species [10, 16, 20]. Although gastric obstruction can be caused by the simple intake of groomed hair [10], recent studies have revealed that ingested hair moves along with food out of the stomach under normal gastric conditions [10, 11, 16]. However, when gastric motility is reduced, food impaction in the stomach may occur [10, 11, 16]. Gastric motility is under the considerable influence not only of the autonomic nervous system but also of hormones and nutritional contents [9, 11]; the arterial supply to the stomach is important, because hormones and some nutrients are delivered through the bloodstream. Furthermore, knowledge of the arterial distribution to the stomach is necessary during gastrotomy for treatment of serious cases of gastric stasis.

Several anatomical textbooks and atlases show that the rabbit stomach receives its arterial supply from the left and right gastric arteries, the short gastric arteries, and the left and right gastroepiploic arteries [3, 18, 21]. However, macroscopic descriptions of the arterial pattern often differ and are incomplete in textbooks and atlases as well as in research articles. For example, the left gastric artery reportedly arises as one of the trifurcated branches of the celiac artery [21] or as the second branch of the celiac artery in the rabbit [1, 3]. Other studies have shown that the left gastric artery originates from a trunk in common with either the splenic [18] or hepatic artery [4, 18]. Furthermore, one study has demonstrated that the left gastric artery varies in number from 1 to 3 [4], while other studies have reported no more than 1 left gastric artery in the rabbit [1, 3, 18, 21].

Descriptions of the right gastric artery in the literature are also inconsistent. The right gastric artery has been reported to originate from the gastroduodenal artery [21] or the left gastric artery [3]. Other researchers have shown that the right gastric artery arises from the hepatic artery or may be absent [4]. Some studies describe further branching of the arteries supplying the stomach in the rabbit. For example, Barone et al. [3] demonstrated that the left gastric artery provides 2 groups of branches; those supplying the parietal gastric wall and those supplying the visceral wall. Two later studies described individual variations of the branches of the left gastric artery [1, 4]. However, their descriptions are not conclusive, because neither of these research groups determined whether the branches terminated in the parietal or in the visceral gastric wall.

In the present study, we characterized in more detail the variations of the number and patterns of arteries supplying the rabbit stomach macroscopically by injecting colored latex into these arteries.

MATERIALS AND METHODS

We used 36 male and 7 female New Zealand White rabbits (weight, 2.5–3.0 kg; ages, 11–13 weeks old) purchased from Tokyo Laboratory Animal Science Co. (Tokyo, Japan). This
study was approved by the Research Ethical Committee for Animal Experimentation of the Tokyo University of Agriculture and Technology.

The experimental protocols were similar to those in our previous study [13]. Briefly, the rabbits were sacrificed with intraperitoneal injections of sodium pentobarbital (60 mg/kg) and then perfused through the heart with fixative containing either 4% paraformaldehyde and 0.05% glutaraldehyde or 10% formalin. A cannula was subsequently inserted caudally into the thoracic aorta for the injection of 3 to 8 ml of colored latex (Neoprene latex 601A or 842A, Showa Denko, Kawasaki, Japan) for visualization of the arteries supplying the stomach. After further fixation for more than 7 days in 10% formalin, we observed the macroscopic arterial distribution to the stomach.

RESULTS

We observed that the rabbit stomach was supplied by the left and right gastric arteries and the pyloric branch of the hepatic artery along the lesser curvature and by the short gastric arteries and left and right gastroepiploic arteries along the greater curvature (Figs. 1 and 2). In all of the rabbits examined, the left gastric artery, which was the most predominant of the arteries supplying the stomach, arose from the celiac artery after the splenic artery branched off (Figs. 1, 2A and 2B). The left gastric artery then proceeded toward the lesser curvature of the stomach (Figs. 1, 2A and 2B) and gave off the parietal and visceral branches (Fig. 2A and Table 1). Whereas the visceral branches were distributed over the viscer al surface of the gastric corpus (Fig. 2A), the parietal branches were distributed over the parietal surface of the corpus and fundus (Fig. 2A). After giving off these branches, the left gastric artery entered the stomach wall at the lesser curvature between the parietal and visceral surfaces in 34 rabbits (79%), which were 1 case in each of Types A1, B1, B4, B6-8, C1-5, C7, C10 and D4; 2 cases in each of Types A3, A5, A6, B2 and C6; 3 cases in Type A4; and 7 cases in Type A2 (Figs. 1 and 2A, and Table 1). On the other hand, the left gastric artery continued as the hepatic artery without entering the stomach wall in 9 rabbits (21%), which were 1 case in each of Types B5, C8 and D1-3; and 2 cases in each of Types B3 and C9 (Fig. 2B and Table 1).

We found remarkable individual differences in the number and ramification patterns of the parietal and visceral branches of the left gastric artery (Table 1). The pattern was classified into 28 types based on the total number of branches, the number of parietal and visceral branches, the branching point, the existence or nonexistence of a common trunk with the parietal and visceral branches, and the branching pattern or point of the hepatic artery (Table 1).

The number of parietal and visceral branches was 2 in 17 of 43 cases (40%), 4 in 10 cases (23%), 5 in 12 cases (28%) and 6 in 4 cases (9%). The combinations of the numbers of parietal and visceral branches in each case are shown in Fig. 3, indicating that the number of parietal branches has a significant positive correlation with the number of visceral branches ($R=0.731, P<0.01$).

The most frequent branching pattern of the left gastric artery was observed in 7 cases (16.3%) with 2 branches (Type A2 in Table 1), where the first branch was the parietal and the second branch was the visceral. In this pattern, the parietal branch originated from the left gastric artery at the same level as the branching point of the hepatic artery, and the left gastric artery ultimately terminated at the gastric wall (Table 1).

In 19 cases, the parietal and visceral branches originated from 1 (17 cases=1 case in each of Types B1, B6, B7, C3-5, C7, C8, D1, D2 and D4; and 2 cases in each of Types A6, C6, and C9) or 2 (2 cases=1 case in each of Types B8 and D3) common trunk(s) that arose from the left gastric artery (Table 1). As the total number of branches increased, the number of common trunk(s) tended to increase. In particular, in all 4 cases having a total of 6 parietal and visceral branches (Table 1), there was at least 1 common trunk that issued 1 parietal and 1 visceral branch. Thus, 5 was the maximum number of direct branches from the left gastric artery (Table 1).

In 42 rabbits (98%), the first branch of the left gastric artery, regardless of whether it was parietal or the common trunk, also gave off a branch to the esophagus. In 1 rabbit (2%), on the other hand, the esophageal branch arose directly from the left gastric artery.

The gastroduodenal artery arose from the hepatic artery (Figs. 1A and 2A) when the hepatic artery was a branch from the left gastric artery. In contrast, the gastroduodenal artery arose directly from the left gastric artery (Fig. 2B) when the hepatic artery was the direct continuation of the left gastric artery (Fig. 2B and Table 1). The gastroduodenal artery proceeded to the right (Figs. 1A and 2A) and gave off the right gastric artery and the right gastroepiploic artery near the pylorus (Figs. 1, 2A and 2B). The right gastric artery was distributed to the pylorus with no anastomosis with the left gastric artery (Figs. 1, 2A and 2B). The right gastroepiploic artery proceeded to the left in the greater omentum to give some small branches to the greater curvature (see below) (Figs. 1, 2A and 2B).

Furthermore, we found that branches that arose from the hepatic artery supplied the pyloric region (Figs. 1 and 2C) in 40 of 43 rabbits (93%). The number of these branches from the hepatic artery varied from 1 to 4, with 1 branch being the most frequent (56%) (Figs. 1, 2C and 4A).

The rabbit stomach was also supplied by short gastric arteries that arose from the splenic artery and were distributed over the greater curvature on the parietal surface of the stomach (Figs. 1, 2A and 2B). The number of short gastric arteries varied from 2 to 6, with 4 being the most frequent (37%) (Fig. 4B).

After giving off the short gastric arteries, the splenic artery entered the greater omentum from the gastroplenic ligament and continued as the left gastroepiploic artery (Figs. 1 and 2A). The left gastroepiploic artery proceeded to the right in the greater omentum and anastomosed with the right gastroepiploic artery (Fig. 1). The right and left gastroepiploic arteries gave small branches to the greater curvature. We could successfully count the number of these branches in only 12 of 43 rabbits; these branches were difficult to fill with
latex because of their positioning, which was most distal to the latex injection site at the thoracic aorta. The number of branches varied from 2 to 7: 2 branches in 2 rabbits (17%), 3 in 3 rabbits (25%), 4 in 3 rabbits (25%), 5 in 2 rabbits (17%) and 7 in 2 rabbits (17%). These branches were mostly distributed to the right side of the greater curvature (Fig. 1). The left side of the greater curvature was mainly supplied by the short gastric arteries, as described above (Fig. 1).

There were no sex differences in the number and patterns of arterial distributions to the stomach.

DISCUSSION

We characterized the details of individual anatomical variations of the arterial supply to the stomach in New Zealand White rabbits. In all rabbits examined, the left gastric artery arose from the celiac artery distal to the origin of the splenic artery. This is consistent with previous reports in the rabbit [1, 3]. Although the origin of the left gastric artery has been reported to differ in individual rabbits [4] and in rodent species that are phylogenetically close to lagomorphs, such as guinea pigs [4, 19], North American beavers [6], muskrats [7], hamsters [8], rats [12], wood mice [14], degus [23] and Mediterranean pine voles [24], no such individual variation was seen in the present study. The difference between the previous rabbit study [4] and the present one may be due to the difference in rabbit breeds and/or ages, although the breed and age were not specified in the previous study [4].

Whereas the left gastric artery finally entered the stomach wall at the lesser curvature in 79% of the rabbits, this artery...
continued as the hepatic artery without entering the stomach wall in 21% of the rabbits in the present study. The latter pattern has previously been seen in 6.7% of New Zealand rabbits [1], but not in other studies of rabbits [3, 4, 18, 21] and rodents [2, 4, 6–8, 12, 14, 17, 19, 22–24]. Thus, we think that this direct continuation of the left gastric artery to the hepatic artery may occur more frequently in the New Zealand White rabbit than in other breeds and/or in rabbits with different ages, and in rodent species studied previously.

We found remarkable individual differences in the ramification pattern of parietal and visceral branches of the left gastric artery. Although the existence of such visceral and parietal branches has been reported in the rabbit [3, 5], porcupine [2], North American beaver [6], muskrat [7], rat [12], chinchilla [17], guinea pig [19] and Mediterranean pine vole [24], the details of the number of the branches and ramification patterns have not been described in these studies. The number of the parietal and visceral branches varied from 2 to 6, with 2 branches (Type A) being the most frequent (40%; Table 1). In a previous study in the rabbit [1], the number of these branches was 2 to 5. This finding is similar to that of our study, wherein 95% of the rabbits have 2 to 5 branches.

The right gastric artery arose from the gastroduodenal artery to supply the pylorus in all rabbits examined. This finding is consistent with previous reports in the rabbit [21], North American beaver [6] and rat [12]. Although the right gastric artery is reportedly sometimes absent in the rabbit [4] and guinea pig [5], this was not the case in the rabbits examined in the present study. Furthermore, we found that the right gastric artery never anastomosed with the left gastric artery, in agreement with studies in the rabbit [3, 4], rat [12] and chinchilla [17]. However, such anastomosis is described in a previous rabbit report by Tsuzaki [21]. Although Tsuzaki [21] did not specify the rabbit breed and age, this difference could be attributed to either a difference in breed/age or to incidental observation of a very rare case.

Our results showed that the short gastric arteries supplied the gastric fundus on the parietal surface of the stomach and the greater curvature. These arteries varied in number from 2 to 6, with 4 arteries (37%) being the most frequent. In contrast, Abidu-Figueiredo et al. [1] reported that the number of short gastric arteries varied from 0 to 5, with 0 (33.4%) being the most frequent and that these arteries, when present, were distributed only to the greater curvature [1]. These differences may be due to the possibility that Abidu-Figueiredo et al. [1] used another breed of New Zealand rabbit, such as New Zealand Red [15], and/or were not able to visualize arteries distributed to the parietal surface of the stomach. In the study by Bednárová and Malinovský [4], the ramus gastricus lienalis, which arose from the splenic artery, seemed to correspond to the short gastric arteries. Bednárová and Malinovský [4] reported that these rami were distributed to the fundus and the transition to the corpus and that they numbered from 1 to 3, with 2 rami (60%) being the most frequent. Bednárová and Malinovský [4] also reported that
these rami were distributed to the greater curvature and were 0 to 3 in number, with 2 arteries (60%) being the most frequent. The differences between their findings and ours may again be due to the breed and/or age difference.

We found pyloric branches of the hepatic artery in 93% of the rabbits examined. In the study by Bednářová and Malinovský [4], these branches occurred only in 13.3% of rabbits; in those rabbits, the right gastric artery was always absent. However, the right gastric artery was present in all of the rabbits in our study. We found that this artery was distributed to the aboral region of the pylorus, whereas the pyloric branches of the hepatic artery were distributed to the more oral region of the pylorus.

Bednářová and Malinovský [4] described the arterial supply to the greater curvature from the branches of the right and left gastroepiploic arteries, but their description was vague and incomplete. Our data show that the left and right gastroepiploic arteries anastomose to give branches mainly to the right part of the greater curvature. The number of branches varies from 2 to 7, with 3 and 4 (25% each) being the most frequent.

In this report, we provide for the first time complete macroscopic descriptions of the arterial supply to the rabbit stomach and details of individual variations. Such findings should always be taken into account when performing experimental or therapeutic surgical operations of the rabbit stomach.

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