

Variations in the Configuration of the Celiac Trunk Among South Africans: Clinical Relevance

Variaciones en la Configuración del Tronco Celíaco en Sudafricanos: Relevancia Clínica

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SUMMARY: The celiac trunk is the first major unpaired branch of the abdominal aorta found at the twelfth vertebral level (T12). It gives off branches supplying the spleen, liver and the stomach. However, the branching patterns of the celiac trunk tend to vary by population throughout the world. We sought to investigate the branching patterns of the celiac trunk in a South African Caucasian sample. The celiac trunk was assessed by visual observation in 66 dissected bodies comprised of both males (n= 30) and females (n=36). These samples were obtained at the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg. The celiac trunk arose directly from the abdominal aorta in all cases, with none connected to the superior mesenteric artery. We observed celiac trunk trifurcation in 84.84 % of the sample, although a celiac trunk with four branches was observed in 10.61 %. Bifurcation into the common hepatic and splenic arteries forming a hepatosplenic trunk (2 females) or into the left gastric artery and splenic artery forming a splenogastric trunk (1 male) was also observed. The results are largely comparable with other studies in Caucasians, showing a high rate of celiac trunk trifurcation (above 75 %). Our sample exhibited fewer variations than reported in previous studies worldwide. Therefore, a larger study with more samples may be required in the future to ascertain all the existing celiac trunk branching patterns in the South African Caucasian population.

KEY WORDS: Celiac trunk; Splenogastric; Hepatosplenic; Abdominal aorta; Superior mesenteric.

INTRODUCTION

The celiac trunk is found on the ventral aspect of the aorta, below the diaphragmatic aortic hiatus. It is the first major visceral artery to branch from the abdominal aorta. This short blood vessel originates at the level between the twelfth thoracic (T12) and first lumbar vertebra (L1). It gives off branches that supply the liver, gallbladder, stomach, pancreas and spleen (Moore *et al.*, 2014). The branches are the common hepatic artery (CHA), left gastric artery (LGA) and splenic artery (SA). However, variations in the configuration, length and diameter of the celiac trunk and its main branches often occur. The latest description of celiac trunk branching patterns was by Panagouli *et al.* (2013), and more recently, by Pinal-Garcia *et al.* (2018) (Table I).

The nomenclature of the variations depends on the configuration of the branches to the liver, gallbladder, stomach, pancreas and spleen. The configuration is a tripod if the left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA) arise directly from the celiac trunk (CT). This is further divided into a true or false tripod

depending on the position of the branches relative to the trunk. A true tripod is considered when all these three branches arise at the terminal aspect of the trunk whereas it is a false tripod if there is a branch arising on the stem of the trunk before its terminal portion (Fig. 1a & b). Other variations in configuration include a splenogastric trunk in which the common hepatic artery arises from the abdominal aorta (Fig. 1c). In some cases, it is the left gastric artery arising directly from the aorta (Fig. 1d). Several classifications of the celiac trunk branching patterns have been reviewed by Panagouli *et al.*, who also suggested a more comprehensive categorisation (Table I) that was recently adopted by Pinal-Garcia *et al.*

Cases exhibiting hexafurcation and heptafurcation have also been described in other studies (Pinal-Garcia *et al.*) whereas some have reported a missing celiac trunk (Fahmy & Sadek, 2015). In the latter, the left gastric, hepatic and splenic arteries each have a separate origin directly from the aorta. The knowledge, recognition and awareness of

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Table I. A summary of the celiac trunk branching patterns. CT, Celiac trunk; CHA, common hepatic artery; LGA, Left gastric artery; SA, Splenic artery; SMA, superior mesenteric artery; AA, abdominal aorta. Adopted from (Panagouli *et al.*; Pinal-Garcia *et al.*).

Type	Subtype	Description
I		Trifurcation of the CT into LGA, CHA and SA
	1	True tripod - LGA, CHA and SA share a common
	2	False tripod - division into two branches
	2a	The LGA is the first branch
	2b	The CHA is the first branch
II	2c	The SA is the first branch
		Bifurcation of the CT
	1	Hepatosplenic trunk, LGA arising from the AA
	2	Hepatosplenic trunk, no normal LGA
	3	Hepatosplenic trunk, and gastrosplenic trunk
	4	Splenohepatic trunk, CHA arising from the AA
	5	Splenohepatic trunk, CHA arising from the SMA
	6	Splenohepatic trunk and gastrosplenic trunk
	7	Hepatohepatic trunk, SA arising from the AA
8	Hepatohepatic trunk, SA arising from the SMA	
9	Hepatohepatic trunk and gastrosplenic trunk	
III		Additional branches
IV		Celiac-mesenteric trunk (CT and SMA)
V		Variations in the origin of the CHA
VI		Hepatosplenohepatic trunk, LGA arising independently or as a branch
VII		Absence of the CT (LGA, CHA and SA arising independently)
VIII		Splenohepatohepatic trunk, CHA arising independently or as a branch
IX		Splenohepatic trunk giving rise to a common inferior phrenic trunk
X		Celiac-biomesenteric trunk (CT, SMA and IMA)

celiac trunk configuration and branching pattern variations plays an important role in preoperative planning and in minimising postoperative complications (Koops *et al.*, 2004).

Celiac trunk variations have been studied and reported in American (Lipshutz, 1917), Japanese (Chen *et al.*, 2009), Korean (Song *et al.*, 2010), Indian (Prakash *et al.*, 2012), and Greek (Venieratos *et al.*, 2013) cadaveric samples, however, no such reports exist for a sample of South African cadaveric specimens. Therefore, the primary aim of this study was to document and report on the number and frequency of celiac trunk variations seen in a South African cadaveric sample. The clinical relevance of these variations is also put into perspective.

MATERIAL AND METHOD

Study design. Ethics for the study falls under the ethics waiver (W-CJ-140604-1) granted by the University of the Witwatersrand Human Research Ethics Committee in respect of the Human Tissue Act No. 65 of 1983 and the National Health Act No. 61 of 2003 (of South Africa) that make provision for use of cadaveric material for research purposes. The celiac trunk was assessed by visual observation in 66 Caucasian dissected bodies comprised of both males (n = 30) and females (n = 36). These samples were obtained at the School of Anatomical Sciences, University of the Witwatersrand, Johannesburg. We adapted our findings to the most recent classification system for all variations seen in the configuration of the celiac trunk as in a recent report by Pinal-Garcia *et al.*

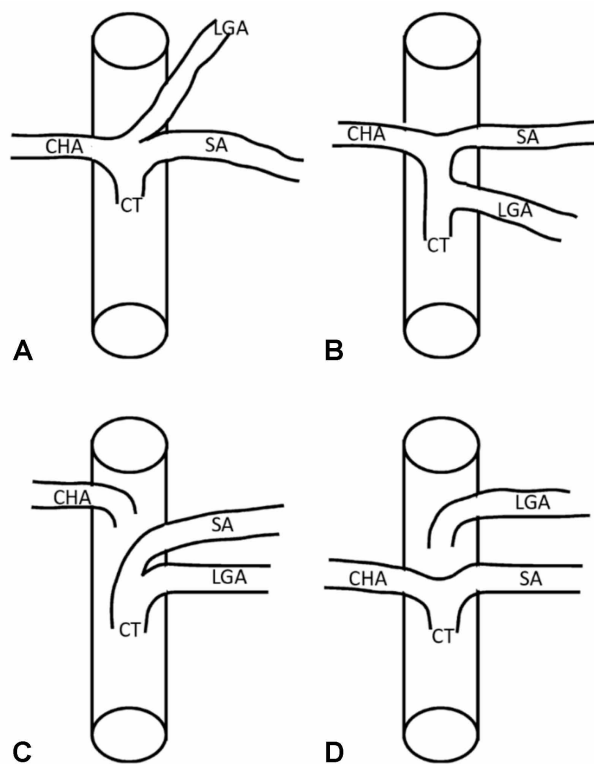


Fig. 1. A schematic diagram representing the 4 major and most common variations of the celiac trunk branching patterns. (A) True tripod, all 3 branches arise at the terminal aspect of the trunk; (B) false tripod there is a branch arising on the stem of the trunk (LGA) before its terminal portion; (C) splenohepatic trunk, the common hepatic artery arising from the abdominal aorta; (D) hepatosplenic trunk, the left gastric artery arising directly from the aorta. CT, celiac trunk; CHA, common hepatic artery; SA, splenic artery; LGA, left gastric artery (Illustration by R Ndou).

Dissection. A midline incision was made from the xiphoid process of the sternum to the level of the anterior superior iliac spine. Two lateral incisions were then made, one superiorly along the subcostal plane and one more inferiorly, at the level of the anterior superior iliac spine with both lateral incisions ending at the mid-axillary line. These dissections revealed the abdominal cavity and visceral organs of the abdomen. The pancreas and stomach were then dissected and mobilised to view the celiac trunk and its main branches as well as the superior mesenteric artery. The stomach was dissected at the gastroduodenal junction and reflected superiorly, while the pancreas was carefully dissected at the head and reflected laterally and to the left taking special care to preserve the arteries in the immediate vicinity. The branches of the celiac trunk were then traced from their source to termination at their respective visceral organs and the normal pattern and variations of the celiac trunk were photographed and recorded for further analysis.

RESULTS

Trifurcated celiac trunk. The majority of individuals (84.84 %) exhibited a normal celiac trunk configuration (Type I), and occurred in equal proportions in both males and females (42.52 % Table I). The true tripod or Type I was observed in 46.96 % of the sample, with a lower prevalence in males 21.21 % than females 25.75 % (Table II, Fig. 2a). In contrast, the false tripod or Type II was observed in 37.88 % of the sample, with a higher prevalence in males (21.21 %) than females 16.67 % (Table II, Fig. 2b).

Hepatosplenic and splenogastric trunk. In 2 females, the celiac trunk bifurcated into the common hepatic and splenic arteries forming a hepatosplenic trunk, with the left gastric artery arising from the abdominal aorta (Table

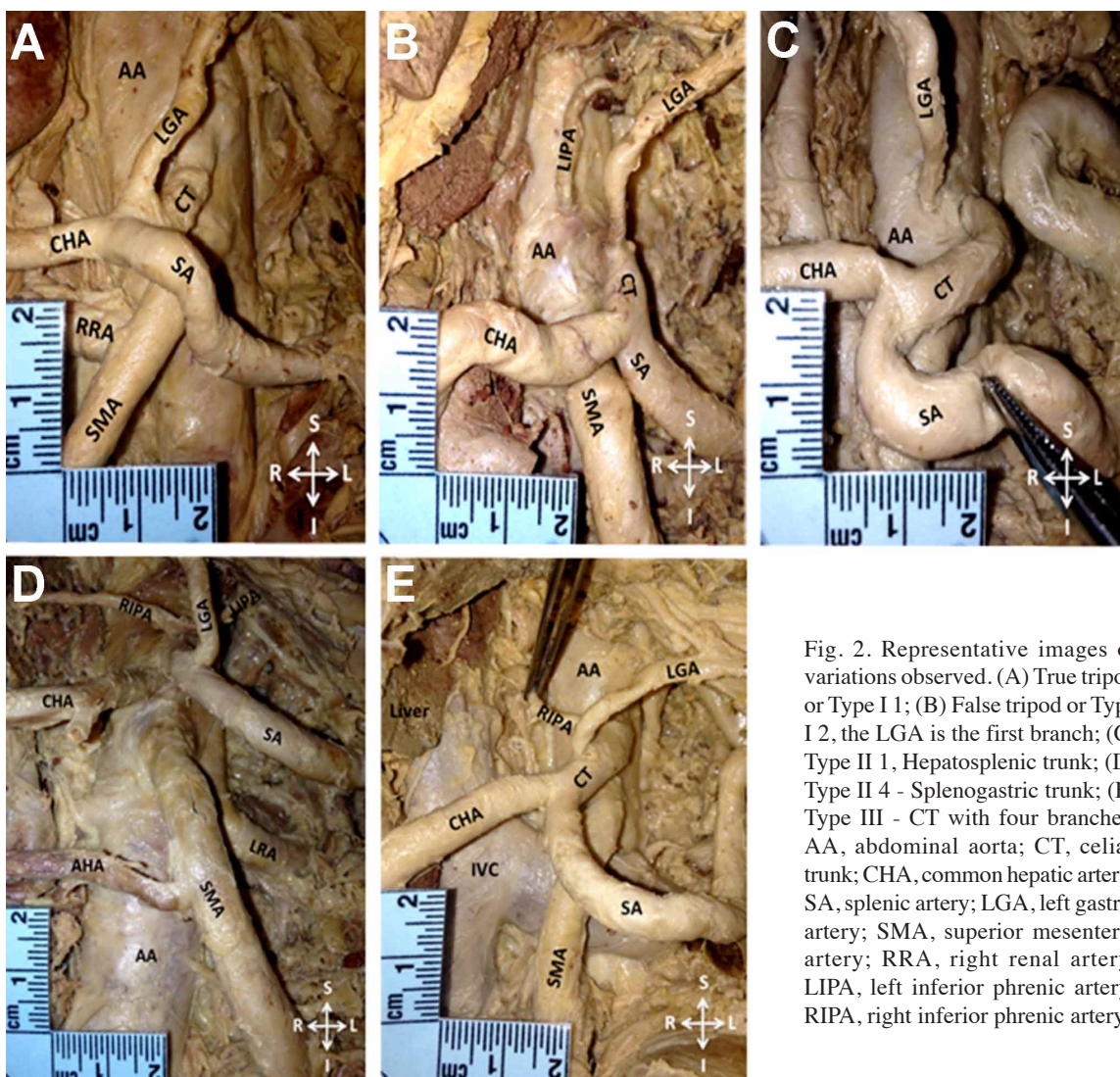


Fig. 2. Representative images of variations observed. (A) True tripod or Type I 1; (B) False tripod or Type I 2, the LGA is the first branch; (C) Type II 1, Hepatosplenic trunk; (D) Type II 4 - Splenogastric trunk; (E) Type III - CT with four branches. AA, abdominal aorta; CT, celiac trunk; CHA, common hepatic artery; SA, splenic artery; LGA, left gastric artery; SMA, superior mesenteric artery; RRA, right renal artery; LIPA, left inferior phrenic artery; RIPA, right inferior phrenic artery.

II; Fig. 2c). No males exhibited this pattern. In one male, the celiac trunk bifurcated into the left gastric artery and splenic artery forming a splenogastric trunk or Type II 4, with the common hepatic artery arising independently from the abdominal aorta (Table II; Fig. 2d). No female showed this pattern.

Celiac trunk with four branches. The celiac trunk gave off four branches (Type III) in 10.61 % of the specimens. This consisted of 1 male and 6 (9.1 %) females (Table II, Fig. 2e). This configuration consisted of a final bifurcation into the common hepatic and splenic arteries, with the third

branch always being the left gastric artery and the fourth branch being either the right or left inferior phrenic artery.

Relationship of the celiac trunk and superior mesenteric artery. All specimens in the study exhibited a celiac trunk arising directly from the abdominal aorta. The common hepatic artery, splenic artery and left gastric artery either arose from the celiac trunk or directly from the abdominal aorta. There were no cases of any of these vessels arising from the superior mesenteric artery. In all specimens, the superior mesenteric artery arose independently from the abdominal aorta.

Table II. Frequency of celiac trunk variations observed. Note that the prevalence of Type I is the sum of Type I 1 Type I 2. CT, Celiac trunk; CHA, common hepatic artery; LGA, Left gastric artery; SA, Splenic artery

Variation Type	Male n = 30	Female n = 36	Total n = 66
Type I - Trifurcation of the CT into LGA, CHA and SA	28 (42.52 %)	28 (42.42 %)	56 (84.84 %)
Type I 1 - true tripod, common origin of LGA, CHA and SA	14 (21.21 %)	17 (25.75 %)	31 (46.96 %)
Type I 2 - false tripod, the LGA, CHA or SA is the first branch	14 (21.21 %)	11 (16.67 %)	25 (37.88 %)
Type II 1 - Hepatosplenic trunk - LGA from AA	0 (0.00 %)	2 (3.03 %)	2 (3.03 %)
Type II 4 - Splenogastric trunk; CHA arising from AA	1 (1.52 %)	0 (0.00 %)	1 (1.52 %)
Type III - CT with four branches	1 (1.52 %)	6 (9.1 %)	7 (10.61 %)

DISCUSSION

Due to the clinical significance of the celiac trunk and its main branches, knowledge and correct identification of variations in its configuration is a prerequisite for successful abdominal surgery (Wang *et al.*, 2014). The prevalence and types of variation in celiac trunk branches may vary by population. Panagouli *et al.*, summarised the prevalence of celiac trunk variations in different populations worldwide. However, the variations for the South African population was missing in their review as no published data was available at the time. Therefore, we describe the variations of the celiac trunk among South Africans using a cadaveric sample. Since various descriptions exist, and to minimise the possibility of misunderstandings, the latest classification by Panagouli *et al.* which was recently adopted by Pinal-Garcia *et al.*, was used in the present study.

The incidence of a normal celiac trunk configuration, namely a trifurcation into the common hepatic, splenic and left gastric arteries, is reported to range from 54 % to 95.9 % in previous studies (Koops *et al.*; Chitra, 2010). In the current study, the normal branching pattern of the celiac trunk occurred in 84.84 % of the sample. This is higher than the 75 % reported by, Lipshutz in a predominantly Caucasian cadaveric study done in the United States of America. Greeks are reported to have 90.9 % celiac trunk trifurcation

(Venieratos *et al.*). Our findings are relatively more similar to the studies that used Caucasians, in contrast to Pinal-Garcia *et al.*, found a much lower prevalence of 43 %, in Maxicans. This indicates that the celiac trunk configuration may be a partly genetically determined trait.

In the current study, celiac trunk trifurcation (Type I) was further subdivided into either a true tripod (Type I 1) or false tripod (Type I 2) as previously explained (Panagouli *et al.*). Some studies document variations in the celiac trunk configuration but do not classify them separately as either a true tripod or false tripod (Iezzi *et al.*, 2008; Mburu *et al.*, 2010). In the current study the true tripod was found in 46.96 % of the sample, with the false tripod presenting 37.88 % of the specimens. This finding is aligned with the findings in Greeks with a predominance of the true tripod over the false tripod (74.0 % vs. 16.9 %) (Venieratos *et al.*). However, contrasting findings were made in other studies that report a predominance of the false tripod over the true tripod configuration (Petrella *et al.*, 2007; Higashi *et al.*, 2009).

In the present study, the presence of a fourth branch (10.6 %) was the second most common variation after the false tripod. The additional fourth branch always presenting as the right or left inferior phrenic artery. This is similar to

previous reports that found the celiac trunk to give off additional branches (Nayak *et al.*, 2008; Mburu *et al.*) and in some cases the inferior phrenic arteries being the additional branch in 8 to 10 % of the samples (Petrella *et al.*).

In 2 (3 %) specimens the celiac trunk bifurcated into the common hepatic and splenic arteries, with the left gastric artery arising independently from the abdominal aorta. Previous studies (Chen *et al.*; Song *et al.*) report the frequency of a hepatosplenic trunk in 4.3 % and 4.4 % respectively. However, Venieratos *et al.*, did not find this pattern in a Greek sample. The rarest variation of the celiac trunk documented in the current study was that of the celiac trunk bifurcating into the splenic artery and left gastric artery to form a splenogastric trunk. Previous studies have reported bifurcation of the celiac trunk into a splenogastric trunk in 1.2 %, 1 % and 1.3 % of their studies respectively (Petrella *et al.*; Chen *et al.*; Venieratos *et al.*).

Clinical interest in the origin of celiac trunk and superior mesenteric arteries is well documented (Winston *et al.*, 2007; Song *et al.*; Wang *et al.*). The celiac trunk and superior mesenteric artery are the two of the largest arteries to arise from the abdominal aorta and many variations in their origin at the abdominal aorta have been reported (Winston *et al.*; Song *et al.*; Wang *et al.*). In the current study all the celiac trunks and superior mesenteric arteries that were assessed arose independently from the abdominal aorta. This finding is aligned with previous studies that found all celiac trunks and superior mesenteric arteries in their studies to arise independently from the abdominal aorta (Iezzi *et al.*; Ugurel *et al.*, 2010; Prakash *et al.*).

Clinical relevance of the celiac trunk and its branches.

In liver transplantation cases where the recipient hepatic artery cannot always be used, other celiac trunk branches may be used to provide conduits for liver irrigation. The flow of the recipient hepatic artery needs to be adequate for this vessel to be used. If inadequate flow exists, dissection of the recipient celiac trunk is performed at a distance from the pancreases. Conduits that take a long and often winding pathway, especially passing on the anterior aspect of the pancreases increase the risk of thrombosis. Aorto hepatic conduits are possible but are mostly used in emergency cases to maintain blood supply as they have a higher risk of long term post-surgical thrombosis (Stange *et al.*, 2003).

Pancreaticoduodenectomy is indicated for cholangiocarcinoma and ampullary tumors (Feng *et al.*, 2014). This becomes complicated when there are variations in the hepato-biliary vasculature which usually originates from the celiac trunk. Ye *et al.* (2017) recently reported a case in which they successfully performed

pancreaticoduodenectomy in a cholangiocarcinoma patient without a classic celiac trunk. In this patient, the LGA and SA arose from the abdominal aorta and an accessory LHA arising from the LGA. The CHA arose from the SMA and the common origin was termed the “hepatomaesenteric trunk” (HMT). In this case the preoperative identification of the unusual arterial configuration and its relationship with the tumor was crucial in preventing intraoperative vascular injury and post-surgical complications.

Celiac trunk stenosis is reported in approximately one out of ten patients undergoing pancreaticoduodenectomy (Thompson *et al.*, 1981). The existence of an extensive anastomotic network between the celiac and superior mesenteric arteries renders celiac trunk stenosis asymptomatic in most cases. This anastomosis may occur through branches of the superior and inferior pancreaticoduodenal arteries in the head of the pancreas, or branches of the dorsal pancreatic artery in the body of the pancreas. In rare circumstances, an artery of Buhler linking the two trunks may exist (Rong & Sindelar, 1987). Liver irrigation through the gastroduodenal artery in celiac trunk stenosis has been reported despite the celiac trunk branches appearing to be normal (Soonawalla *et al.*, 2007).

CONCLUSIONS

In the majority of South Africans, the celiac trunk exhibits trifurcation and the branches are exhibited in a true tripod configuration. Having found fewer variations than reported in other populations suggests that a future study with a larger sample may yield more conclusive results. Also, observing that no branches supplying the liver, spleen and stomach arose from the superior mesenteric artery may need a larger sample to be able to infer the finding to the general South African population.

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RESUMEN: El tronco celíaco es la primera rama principal de la parte abdominal de la aorta en el nivel de la duodécima vértebra torácica (T12), con ramas que irrigan el bazo, el hígado y el estómago. Sin embargo a nivel mundial, las ramificaciones del tronco celíaco tienden a variar según la población. En este estudio se investigaron los patrones de ramificación del tronco celíaco en una muestra caucásica sudafricana. El tronco celíaco se analizó mediante observación visual en 66 cuerpos disecados compuestos por hombres (n = 30) y mujeres (n = 36). Estas muestras se obtuvieron en la Facultad de Ciencias Anatómicas de la Universidad

de Witwatersrand, Johannesburgo. El tronco celíaco surgió directamente de la parte abdominal de la aorta en todos los casos, sin que ninguno estuviera unido a la arteria mesentérica superior. Se observó trifurcación del tronco celíaco en el 84,84 % de la muestra, aunque en el 10,61 % se observó un tronco celíaco con cuatro ramas. También se observó bifurcación en las arterias hepática y esplénica común formando un tronco hepatoesplénico (2 mujeres) o en la arteria gástrica izquierda y la arteria esplénica formando un tronco esplenogástrico (1 hombre). Los resultados son comparables con otros estudios en caucásicos que muestran una alta tasa de trifurcación del tronco celíaco (mayor al 75 %). Nuestra muestra presentó menos variaciones que las reportadas en estudios previos. Por lo tanto, es posible que se requieran estudios más amplios con más muestras en el futuro, para determinar todos los patrones de ramificación del tronco celíaco en la población caucásica sudafricana.

PALABRAS CLAVE: Tronco celíaco; Esplenogástrico; Hepatoesplénico; Parte abdominal de la aorta; Mesentérico superior.

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