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Macroscopic, mesoscopic and microscopic morphology of the gastric plexus – ontogeny of the celiac ganglion

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Abstract

The vagus trunks, anterior and posterior, and their respective branches control the parasympathetic innervation of the stomach. After giving off a few thin branches, at the lower part of the esophagus and the cardiac region of the stomach, the anterior vagal trunk divides into its main branches: four or five consecutive direct branches which supply the upper part of the lesser curvature; these nerves do not form plexuses and thus, they may be individually dissected. One of the branches is stronger than the others and is called the principal anterior nerve of the lesser curvature (anterior nerve of Latarjet). The present study was conducted on eight fetuses of different gestational age (resulting from spontaneous abortions, without malformations), observing the Romanian laws of professional ethics, and 15 adult cadavers (male and female) whose celiac region was dissected macro- and mesoscopically to reveal both the celiac ganglia and their afferent and efferent vessels. For the microscopic study, we used the Bielschowsky silver staining method. The meso- and macroscopic dissections revealed the anterior and posterior vagal trunks in all the specimens (100%), as well as a rich gastric periarterial plexus. The microscopic samples focused on the ontogeny of the celiac ganglion in various gestational stages.

***Keywords*:** anterior vagal trunk, cardiac region of the stomach, pylorus, neurons.

Introduction

The celiac plexus is divided into three major components, which are extremely important in medical practice: the gastric plexus, the hepatic plexus and the splenic plexus.

The gastric plexus is an unpaired structure consisting of the following components:

▪ The superior gastric plexus – accompanies the left gastric artery and divides at the level of its branches; it consists in a neural network that accompanies the left gastric artery in the area of the lesser curvature of the stomach, forming an actual neural sheath lying in direct relation to the left gastric vein and its affluents. Proximally, the gastric/coronary plexus lies in an intermediary position between the plane (plexus) of the anterior vagal trunk (anterior) and the plane (plexus) of the posterior vagal trunk. It anastomoses with the vagal trunk.

▪ The inferior gastric plexus – unpaired structure, is supplied *via* the periarterial plexus of the right gastro-epiploic artery (from the plexus of the hepatic and gastro-duodenal arteries) and *via* the periarterial plexus of the left gastroepiploic artery (from the plexus of the splenic artery).

The terminal regions of the gastric plexus give off parasympathetic fibers originating in the ganglia of the celiac plexus, vagal parasympathetic fibers and sensory fibers (the splanchnic nerves, the right phrenic nerve).

The pylorus has a particular innervation. Latarjet A (1921), McCrea ED (1924), Mitchell GAG (1940), Jackson RG (1948), Skandalakis LJ *et al.* (1986) [1–8] show that the main, and in several cases the only, nervous supply of the anterior vagal trunk at the level of the pylorus is the hepatic branch/branches. The region thus innervated outsizes the stomach by a few centimeters, including the pylorus and the first part of the duodenum.

In most cases, the principal anterior nerve of the lesser curvature (anterior nerve of Latarjet) does not innervate the pyloric sphincter; therefore, it is obvious that the pyloric sphincter is region that is not innervated by the posterior vagal trunk. Skandalakis LJ *et al.* (1986) list a few exceptions that contain nervous fibers of the posterior gastric branches that reach the pylorus [8]. The plexus of the left gastric artery is supplied by the celiac plexus when the latter winds around the celiac trifurcation (tripod).

The sympathetic innervation of the stomach is almost entirely supplied by the celiac plexus. The gastric branches of the celiac plexus accompany the stomach vessels and their density is highest at the level of the left gastric artery, the hepatic and diaphragmatic arteries, while other sympathetic fibers follow the splenic plexus, the right gastric plexus and the gastro-epiploic plexuses.

Materials and Methods

The present study was conducted, observing the

Romanian laws of professional ethics, on eight fetuses of different gestational age (resulting from spontaneous abortions, without malformations) and 15 adult cadavers (male and female) whose celiac region was dissected macro- and mesoscopically.

To approach the dissection of the celiac plexus we used the following technique: we opened the abdominal cavity through a transverse incision at the anterior extremity of the seventh ribs, practicing also the resection of the lower ribs.

The supra-umbilical abdominal wall was reflected antero-inferiorly, highlighting and then cutting liver round ligament to the umbilical opening.

It was pointed the inferior border of the liver and the anterior surface of the stomach, followed by a superiorly removal of the liver and highlighting the lesser omentum.

It was approached the celiac tripode, following its branches.

On the anterior border of the abdominal esophagus, distally to the esophageal hiatus of the diaphragm, was recognized the anterior vagal trunk, followed along to the lesser curvature of the stomach; also, it was recognized the lesser curvature principal anterior nerve of Latarjet; from the anterior vagal trunk was recognized and dissected the gastrohepatic nerve.

Reflection to the left of the abdominal esophagus and the lesser curvature of the stomach showed the posterior vagal trunk; its dissection highlighted the gastric branches and then the celiac branches.

Dissection of the celiac region on the superior border of the pyloric part of the stomach revealed the pancreas, the common hepatic and splenic arteries.

The microscopic study showed the neuronal structures using the Bielschowsky silver staining method; intracellular, extensions neurofibrils being colored in black, and connective tissue in yellow-grey.

Results

The dissection of the celiac plexus in adults revealed the anterior vagal trunk. It runs on the anterior face of the esophagus and, after giving off short nervous fibers to the cardia, both to the left and to the right, it gives off two long branches: the principal anterior nerve of the lesser curvature of the stomach (anterior nerve of Latarjet) and the gastrohepatic nerve (Figure 1). The authors also identified the posterior vagal trunk and its accessory nerve fibers, the left gastric plexus, and a juxtaceliac ganglion.

The principal anterior nerve of the lesser curvature descends between the sheets of the lesser omentum, joining the anterior branch of the left gastric artery (coronary artery of the stomach). The trunk of this nerve gives off short gastric collateral fibers to the adjacent segments of the gastric wall (Figure 2). The gastro-hepatic nerve enters the Arantius venous ligament canal and continues to the hepatic hilum where it starts descending to anastomose in the anterior hepatic plexus (the periarterial plexus).

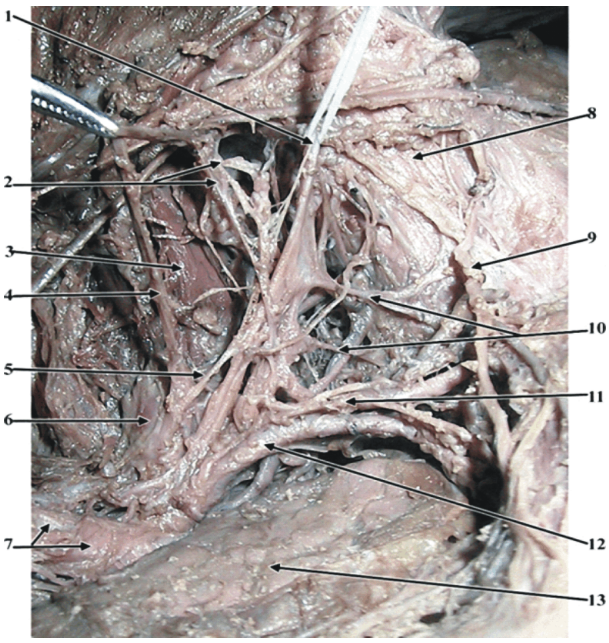

Figure 1 – ***Macroscopically dissection of the abdominal region, formalized adult human body. 1. Posterior vagal trunk; 2. Accessories posterior vagal branches; 3. Right pillar of the diaphragm; 4. Esophageal artery; 5. Celiac branch; 6. Juxtaceliac ganglion; 7. Common hepatic artery, periarterial hepatic plexus; 8. Cardia; 9. Main anterior nerve of the lesser curvature of the stomach (Latarjet); 10. Gastric branches; 11. Left gastric plexus; 12. Left gastric artery; 13. Pancreas.***

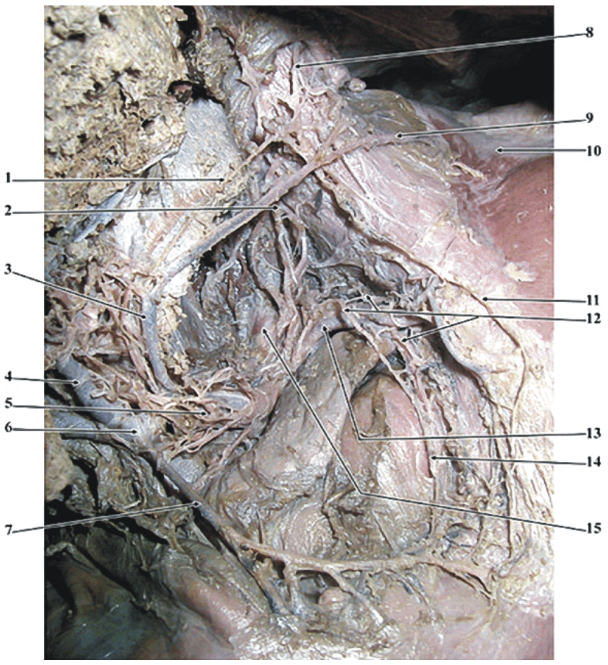

Figure 2 – ***Celiac region dissection, formalized adult human body. 1. Gastrohepatic nerve; 2. Branches of the posterior vagal trunk; 3. Left accessory hepatic artery; 4. Left hepatic artery; 5. Hepatic periarterial plexus; 6. Proper hepatic artery; 7. Right gastric artery; 8. Anterior vagal trunk; 9. Tuberosity branch from accessory hepatic artery; 10. Stomach fundus; 11. Main anterior nerve of the lesser curvature; 12. Left gastric plexus; 13. Left gastric artery; 14. Main posterior nerve of the lesser curvature; 15. Juxtaceliac ganglion.***

In conjunction with McCrea ED (1924), Mitchell GAG (1940), Jackson RG (1948) [5–7], our dissections showed the following results:

- The anterior vagal trunk divides into 3–6 main branches; to the left, it gives off a group of gastric branches that supply the anterior face of the cardia, the fornix and the proximal part of the body of the stomach; these may or may not form the anterior gastric plexus.
- It continues along the lesser curvature and gives off 4–6 posterior gastric branches – the largest being the principal nerve of the lesser curvature of the stomach (anterior nerve of Latarjet).
- Together with the other posterior branches, it innervates the posterior wall of the stomach, with the exception of the pylorus and the immediate pre-pyloric segment.
- It anastomoses with sympathetic nerve fibers from the celiac plexus, as well as with the principal anterior nerve of the lesser curvature.

Microscopy shows that as far as the anatomic development of the celiac ganglion is concerned, at either four months (gestational period) the celiac ganglion is not yet configured macroscopically or microscopically. Locally, we found elements of nerve cells with neuroblastic characteristics following two tendencies: (a) to group; (b) to disperse and migrate. The grouping-tendency neuroblasts are small, round cells, generally lacking cellular prolongations, and forming relatively small groups intermingled with dispersed neuroblasts similar in size.

In the celiac region, at a gestational stage of four months, nerve bundles alternate with neuroblast bands with a relatively high cellular density. The disorganized neuroblast bands and the nerve bundles intermingle with parallel vascular elements containing red blood cells in the lumen or with vessels, that lie perpendicular on the nerve bundles (Figures 3 and 4). Migratory neuroblastic cells may sometimes contain neuron-looking cells that are atypical/abnormal for this stage of development.

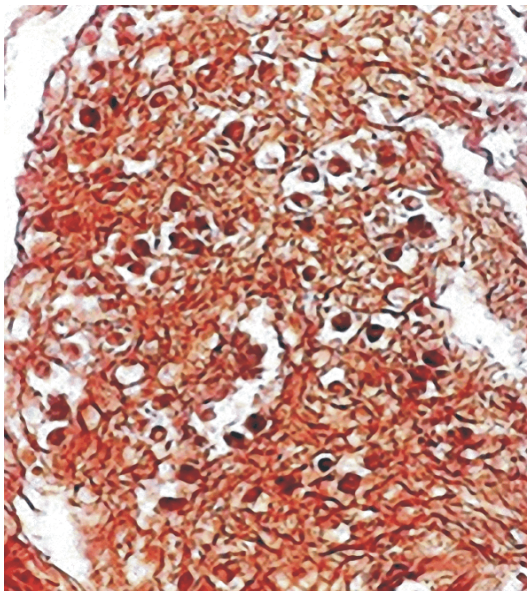

Figure 3 – ***Celiac ganglion structure; 28 cm human fetus. Primitive sympathetic neurons; tendency of disposal in neuronal small groups. Bielschowsky on block silver staining, ×400.***

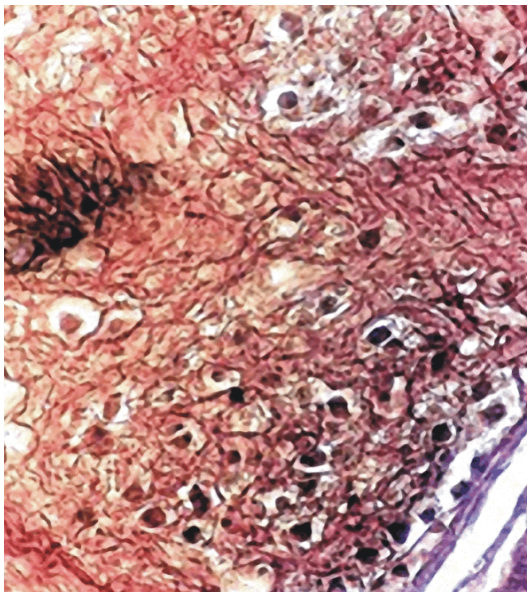

Figure 4 – ***Celiac ganglion structure; 28 cm human fetus. Groups of neurons and intra-ganglion efferent bundles. Bielschowsky on block silver staining, ×400.***

At a gestational stage of five months, the celiac ganglion is cytologic polymorphic and homogeneous. The subpopulations that are clearly delimited in an adult are still undefined and the morphological characteristics of the nerve cells have changed from neuroblasts to primitive nerves (with reduced cytoplasm) and young nerves (little cytoplasm). Cell prolongations are difficult to detect in primitive neuronal bundles – one might say that at this age the celiac ganglion is a neuronal ganglion, while at the age of four months it was a dispersed, migratory and neuroblastic ganglion (Figures 5–8). The vagal fiber bundles circumvent the ganglion population and the fibers morphologically interact with the peripheral ganglion cell.

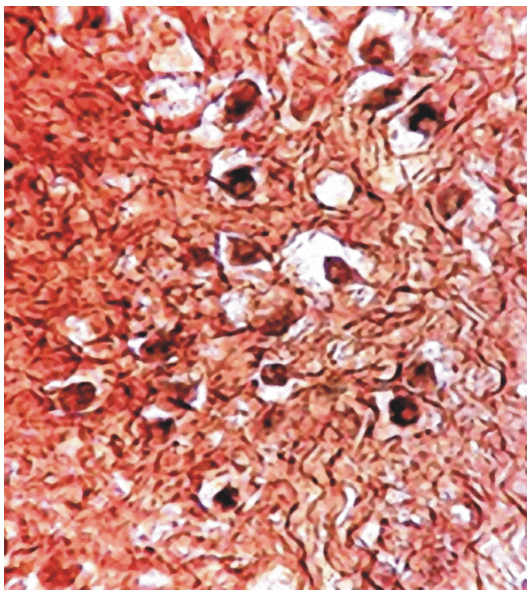

Figure 5 – ***Celiac ganglion; 28 cm human fetus. Cellular populations mainly composed of primitive neurons, intermingled with rare multipolar, neuroblastic cells. Primitive neurons with dendritic prolongations. Bielschowsky on block silver staining, ×630.***

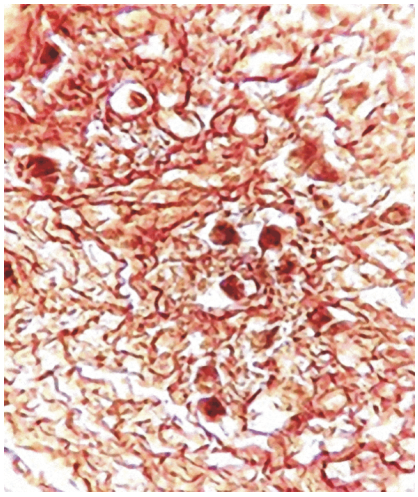

Figure 6 – ***Celiac ganglion; 28 cm human fetus. Primitive neuronal populations, intermingled with pre-ganglionic bundles; rudimentary dendritic branching. Bielschowsky on block silver staining, ×630.***

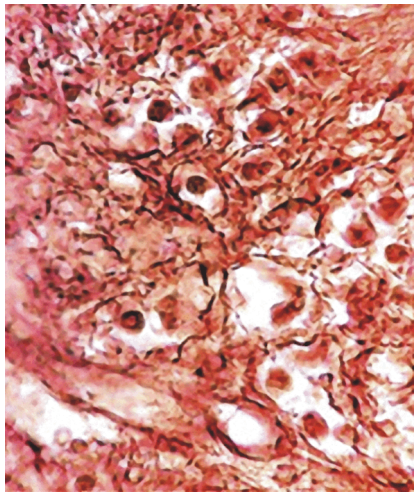

Figure 7 – ***Celiac ganglion; 28 cm human fetus. Primitive neurons in a network of an intra-ganglionic plexus intermingled with sympathetic preganglion fibers. Bielschowsky on block silver staining, ×630.***

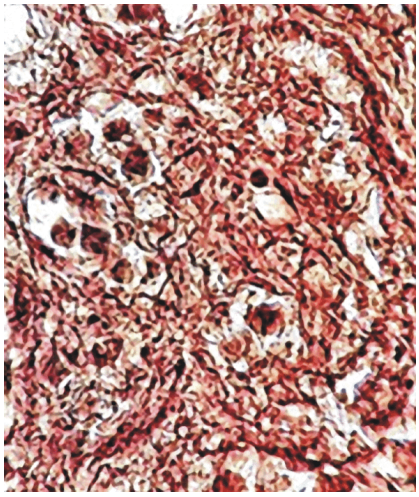

Figure 8 – ***Celiac ganglion; 28 cm human fetus. Neuronal grouping specialization. Bielschowsky on block silver staining, ×630.***

Discussion

Based on our dissection study, we consider that the anterior vagal trunk may be divided into two functionally distinct components:

▪ Direct branches that supply the body and fundus of the stomach (*pars digestoria*);

▪ *Via* the hepatic branches, which supply the pylorus and the first part of the duodenum (the sphincteric part of the stomach).

The principal anterior nerve of the lesser curvature does not supply the pylorus; the superior and inferior pyloric nerves innervate the latter and the first part of the duodenum. In 50 dissections of the posterior vagal trunk, Jackson RG (1984) draws a chart of the gastric branches and establishes the point of origin of the celiac branch [7]. The principal posterior nerve of the lesser curvature (Latarjet's nerve) was identified in 19 cases as it passes along the lesser curvature to the pylorus, but before reaching the pylorus, it changes direction along the posterior face of the stomach and continues towards the larger curvature. Jackson RG concludes that the hepatic branches of the anterior vagus ensure the vagal supply of the pylorus [7].

Conform Skandalakis LJ *et al.* (1986), the posterior gastric division form a Latarjet's posterior nerve; this division usually ends somewhat higher, in the area of the lesser curvature, than the anterior gastric division and seldom reaches the pylorus [8].

We may conclude that the vagal supply of the pyloric sphincter and the first part of the duodenum is mainly ensured by the hepatic branch of the anterior vagal trunk, which gives off the pyloric nerves. Cunningham DJ (1906) [9] also points out that the innervation of the pylorus is a distinctive one and has special characteristics.

In conjunction with McCrea ED (1924) [5], based on our dissections, we consider that the sympathetic gastric nerves may be grouped as follows:

▪ Fibers from the celiac plexus follow the left inferior diaphragmatic artery, pass the anterior face of the esophagus, anastomose with the branches of the anterior vagal trunk and are distributed to the cardia and gastric fornix;

▪ Fibers from the celiac plexus pass to the left gastric artery and are, in turn, divided into three groups:

(a) Fibers that go to the esophagus along the superior branches of this artery and go out to the cardia and the proximal part of the body of the stomach; these fibers anastomose with the branches of the anterior vagal trunk and those of the posterior vagal trunk;

(b) Fibers that join the main trunk of the left gastric artery along the lesser curvature and supply the anterior and posterior faces of the body of the stomach and the pyloric antrum;

(c) Fibers that pass through the folds of the lesser omentum to the portal vein and anastomose with the anterior vagal trunk.

▪ Fibers from the celiac plexus run at the same level with the plexus of the hepatic artery and are distributed together with the branches of the latter; they reach the pyloric region of the stomach via the right gastric artery and the right gastroepiploic artery.

The dissections carried out by us show that the gastroduodenal trunk gives off superior pyloric nerve fibers, which supply the pylorus, going down and lateral to the right gastric artery. Another group of superior pyloric nerve fibers and duodenal nerve fibers descend from the plexus of the hepatic artery, running along the right-posterior flank of the right gastric artery; the superior pyloric nerve fibers run adjacent to the artery while the duodenal fibers are situated at some distance.

It is common knowledge that the vagal nerves are tightly related to the food-control mechanisms, the latter being plurifactorial and complex. The vagal nerves play an important role in the interactions of the central and peripheral mechanisms, representing the afferent pathway of the cerebro-intestinal axis. Peripheral signals

are connected to sensory information, circulatory factory, metabolic signals and nutritional deposits [10]. The stomach and small bowel are short-term nutritional deposits, which initiate peripheral satiety, important in intermeal digestive activity. The food quantity in the upper gastrointestinal tract and its chemical contents trigger a negative feedback loop in the vagal nerves [11–13]. Food induces an afferent vagal discharge and a release of gastrointestinal hormones, determining metabolic alterations.

The vagal nerves are surgically relatively accessible hence the possibility to influence vagal transmission temporarily using local vagal pacemakers, following certain parameters that could create physiological models of vagal discharge. The variability of vagal trunks still poses a problem in medical practice, their accurate knowledge representing a serious problem [14] in cases such as pyloric spasm and gastric hypomotility.

Due to great number of nervous fibers, the celiac plexus plays an important role in both curative and palliative surgical practice. Neural invasion represents an important prognostic factor in pancreato-biliary tumors [15]. The use of MRI to determine the exact location of the celiac ganglion is useful the therapeutic neurolysis of the celiac plexus [16].

The vagal nerves play a major role in the communication between the central nervous system (CNS) and enteric nervous system (ENS) [17]. Although, they contain both sensory and motor fibers, they also have most of the afferent axons [18]. Very little is known about the mechanisms that permit descending vagal fibers to "travel" through several fetal regions to reach the intestine [19].

The celiac plexus is known to give off efferent nerves to the abdominal organs, which it supplies: the stomach, liver, gall bladder, kidney, suprarenal gland [20]. Some authors also measured the diameter of both celiac ganglia to find any significant differences in the practice of achieving a celiac plexus block, performing the so-called "plexus anesthesia", necessary in the inoperable unbearable intra-abdominal pain and in various pancreatites [16, 21]. Fukuda T *et al.* (1988) used a CT scan for the study of neural invasion in a case of choledochal carcinoma, hepatoduodenal ligament and other malignant pathologies [22]. They found that the size and morphology of the celiac ganglia are different in cadavers from those of living human beings.

Migratory neuroblast populations consist of neuroblasts (dendritic or polar) whose cytoplasm is quasi-absent and whose nuclei are characterized by a perinuclear chromatin border. Their dendrites are well represented, thick, with many collateral branches/spines, perpendicular on the trajectory. Cellular aspects also suggest an ongoing phase of neuronal differentiation in the neuroblasts, determined most likely by the vicinity induction exercised by the adjacent nerve bundles.

In a 5-gestational-month-old fetus (20 cm vertex–coccyx) the celiac population is morphologically established, but not macro- or mesoscopically but microscopically; the pathognomonic location on the side of the origin of the celiac tripode, at the level of the bifurcation of the posterior vagal trunk, confirming the histological diagnosis.

The celiac ganglion in an 8-month-old fetus shows a predominant (but not complete) neuronal population; the neurons have different shapes: oval, fusiform, mitral, piriform. Compared to younger fetal ages, the intra-ganglionic cellular density is clearly diminished and integrative dendritic structures mainly represented by dendritic plexuses develop both in the ganglion, as a whole, and in the ganglionic subunits.

In the prenatal stage, the celiac ganglion is not a distinct morphological unit but, on the contrary, its neuronal elements although morphologically similar correspond to different individual cellular ages; the individual cytoplasm quantity varies and neuroblastic aspects may sometimes occur. The individual dendritic filaments are still numerically reduced and short; during their short course, they form local inter-neuronal networks, which receive nerve fibers from adjacent bundles.

The intra-ganglionic nerve bundles have a more pregnant morphological development – primitive neurons with more developed filaments, which start forming integrative dendritic structures. The distribution of the fibers from the bundles to the ganglion cells takes place "in showers".

At this age, in the structure of the celiac ganglion it is difficult to discern glial elements, either Schwann cells or satellite cells. This aspect can be explained easily: the development of glial cells is subsequent to that of neurons. Several peri-bundle elements in this developmental stage are morphologically closer to adult sensory neurons; nerve cells have one or two filaments running along variable courses.

Conclusions

The differences in the vagal distribution of peri-celiac organs reflect the fact that the central nervous system exerts a direct, less modular, control over proximal segments (esophagus, the vertical part of the stomach) and an indirect control, via the celiac plexus, over the more distant structures (distal stomach, duodenum, biliary ducts). We consider that the location of the gastric plexuses is important for the presumptive diagnosis of gastric disorders (interpretation of pain and reflexes).

Due to its location, the celiac plexus and, implicitly, its nervous components are involved in various potential diseases at this level: perforated gastro-duodenal ulcer on the posterior face, pancreatic tumors, extensive lymphomas, vagal trunk damage, peritonitis or any acute/subacute surgical syndrome, and last but not least, malformations of the abdominal aorta which, although rare, may induce severe disorders.

The basic unit both in the CNS and in the ENS is the neuron. Nervous influx propagation is determined by a release of neurotransmitters. The neuronal system cannot function unless the connections necessary for the functioning of this network are set up. The nervous tissue also consists in a support tissue formed of glial cells and stroma. Our specimens showed a neurological

and stromal abundance of celiac ganglion elements, and element that supports the role of dissection and confirms the richness of the celiac plexus and the special role it plays in medical practice. All these findings plead for an accurate knowledge of the anatomical and morphological structures that make up the celiac plexus.

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