„CAROL DAVILA” UNIVERSITY OF MEDICINE AND PHARMACY, BUCHAREST, ROMANIA

DOCTORAL SCHOOL

MEDICINE

ANATOMIC STUDY OF THE ABDOMINO-PELVIC SYMPATHETIC CHAIN

ABSTRACT OF THE PHD THESIS

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The fundamental issue: hypothesis, objectives, research methodology

Hypothesis

The sympathetic chains are integrating structures extending from the cranium to the coccyx. The cranial sympathetic generally has a periarterial distribution. The cervical one is organized in three ganglia united by latero-cervical interganglionic fibres, and the thoracic one forms paravertebral ganglion chains. In the abdomen, the sympathetic also includes the preaortic plexus and prevertebral ganglia, which is dominated by the celiac, mesenteric and renal ganglia. The most important celiac ganglia are connected to the thoracic splanchnic nerves and send periarterial efferents to the organs of the upper abdomen, with an essential right-left interganglionic connection. In the pelvis, the sympathetic system is distributed along two pathways: the superior hypogastric plexus with the hypogastric nerves and the inferior hypogastric plexus, respectively, the sacral ganglion chains parallel to the anterior sacral foramina. The sympathetic branches are difficult to identify anatomically and surgically along the route.

Objective

We aim to emphasize all abdominal, pelvic and pelvi-abdominal border sympathetic structures.

The celiac ganglia are found in a deep retroperitoneal and retrovisceral region, in a connective-adipatous mass that protects them but limits surgical access.

In this paper, I aim to highlight in detail the position of the relations and configuration of the celiac ganglia and their connections with the coordinated organs and the sympathetic structures on the opposite side. This approach alone would have been sufficient for an independent study. However, my research is part of a departmental research option whereby the collective aims to dissect the entire cranio-caudal sympathetic territory.

I also aim to elucidate confusions related to the notion of mesopancreas. To this end, I propose to define the embryologic, anatomic, functional, and surgical definition of the mesopancreas. I believe that meticulous dissection, as the main research tool, will allow me to fulfill this goal.

I aim to identify the paravertebral sympathetic paravertebral sympathetic chains, the abdominal splanchnic nerves and the prevertebral (preaortic) sympathetic plexus, and their interconnections.

Finally, I will try to characterize the sympathetic structures located at the abdomino-pelvic border, the hypogastric plexuses and the presacral sympathetic chains and their connections.

Materials and methods

My study is a descriptive one and starts from an extensive review of current data on the anatomy of the sympathetic nervous system. Thereby, I identified a significant deficit of detailed anatomical information.

We performed dissections on eight adult formalinized cadavers (60-80 years of age) and four infants (two 3-month-old and two 4-month-old). The dissections were performed according to the law no. 104/2003. Formolization was performed by arterial injection and immersion in 9% formalin solution for 60 days, followed by grooming.

Dissections followed standard surgical techniques such as the paraduodenal Kocher incision for retroperitoneal access. We used complex surgical kits and dissecting loupes, approaching the retroperitoneal sympathetic structures anteriorly and posteriorly, including sagittal and transverse sections of the pelvis.

The detailed photographs were taken with a Nikon D7500 camera under special lighting conditions and minimally processed in Adobe Lightroom and Photoshop, without scientific modifications. Each selected image comes from a series of at least twenty frames, labeled in Adobe Illustrator.

In addition, we performed a histologic evaluation (HE staining and Masson trichrome staining) of the upper mesenteric lymph nodes and mesopancreatic structures. For didactic clarity we made personal summary illustrations in Adobe Illustrator.

Study I: Demonstration by dissection of the formation of the prevertebral aortic sympathetic plexus and its relationships

1. Introduction

The abdomino-pelvic sympathetic chain is a major component of the autonomic nervous system, which is essentially involved in regulating the activity of the abdominal and pelvic viscera (stomach, intestine, kidneys, gonads). Its structure and connections with organs determine the sympathetic control of visceral functions. The abdomino-pelvic chain continues superiorly with the thoracic chain, together forming an extensive nerve network, integrated from the base of the skull to the pelvis(1). The aortic prevertebral plexus is part of the abdominal sympathetic system (2). It is represented by a variable nerve network anterior to the abdominal aorta (3).

The prevertebral aortic plexus consists of the efferents of the celiac ganglia, aortic-renal ganglia and the three lumbar splanchnic nerves. The lumbar splanchnic nerves originate in the paravertebral sympathetic chains (1). We have outlined all these sympathetic structures and described how the plexus is formed and its relationships. Nerve fibers of different origins form a network arranged longitudinally, anterolateral to the abdominal aortic artery(4). The lower part of this network continues with the superior hypogastric plexus (5). The superior mesenteric, renal, gonadal and inferior mesenteric plexuses branch from the aortic prevertebral plexus.

This study analyzed the detailed structure of the prevertebral aortic plexus, its anatomical relationships and connections with the viscera. Through dissections, we documented the plexus and integrated it in the context of the sympathetic nervous system, clarifying its role in regulating visceral functions.

2. Materials and methods

This is a descriptive study, performed on eight human cadavers (five males and three females, 60-80 years old), preserved in 9% formaldehyde solution, with no history of surgery or abdominal pathology altering the anatomy. Dissections followed standardized protocols for complete exposure of the abdomino-pelvic sympathetic chain and identification of connections with visceral structures. The study took place in the laboratory of the Department of Morphology of the University of Medicine and Pharmacy "Carol Davila", Bucharest, in compliance with the law no. 104/2003 on the use of cadavers for teaching and research purposes.

3. Results

Dissection was performed systematically in anatomic planes to expose the abdomino-pelvic sympathetic chain. After making a median incision from the xiphoid appendix to the pubic symphysis and opening the abdominal cavity, intraperitoneal viscera were removed for retroperitoneal access. Subsequently, the parietal peritoneum was incised and laterally retracted, thus exposing the aorta and inferior vena cava, landmarks for identifying the sympathetic chain.

The abdomino-pelvic sympathetic chain was carefully dissected along the lateral margins of the lumbar spine, identifying the lumbar and sacral ganglia and their connections to the mesenteric and hypogastric plexuses. The sympathetic branches were traced to the visceral plexuses (celiac, superior and inferior mesenteric, superior hypogastric).

In Figure 1, a posterior approach to the celiac region shows the posterior aspect of the aorta and, to the right, the inferior vena cava. The right celiac ganglion, situated posterior to the vena cava, between the aorta and the right adrenal gland, shows radially oriented efferences ('solar plexus') to the adrenal gland, aorta, renal arteries and inferiorly to the prevertebral aortic plexus.

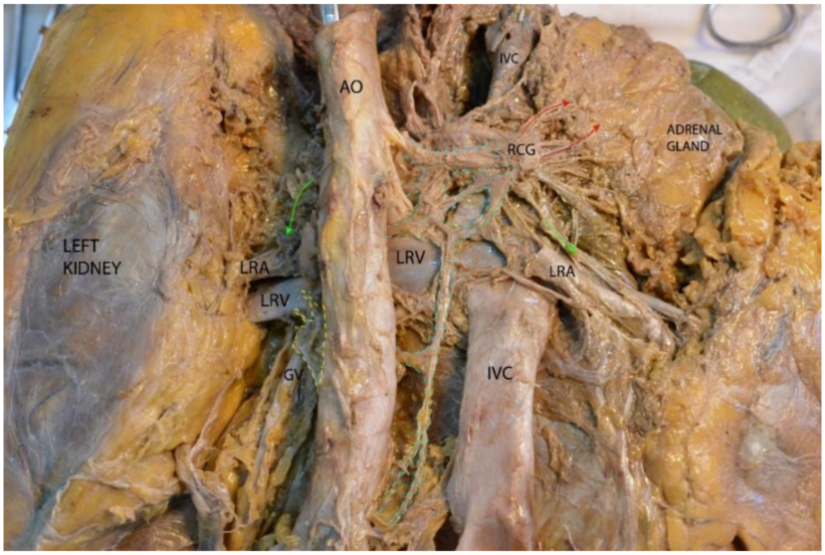

Figure 1 - Posterior view of celiac ganglia, aorta, and inferior vena cava. AO - aorta; IVC - inferior vena cava; RCG - right celiac ganglion; LRV - left renal vein; LRA - left renal artery; GV - left gonadal vein; Red arrows - efferent fibers from the celiac ganglion to the adrenal nerve plexus; Green arrows - ganglion efferents to right and left kidneys; Blue dotted line - efferent fibers from celiac ganglion to prevertebral aortic plexus; Yellow dotted lines - left aortic-renal ganglion.

Figure 2 shows the prevertebral aortic sympathetic plexus descending anteriorly from the abdominal aorta, which in this case is convex to the left (aortic kinking). From the pre-aortic nerve network, fine branches branch off to form a perivascular plexus around the gonadal artery.

Figure 3, after removal of the inferior vena cava, exposes the lumbar vertebrae and the origins of the psoas maximus muscle. The proper paravertebral sympathetic chain descends anteriorly from the psoas muscle, emitting three lumbar splanchnic nerves that converge on the lumbar aortic plexus. The contribution of the right celiac ganglion to the aortic plexus is marked (dotted lines), emphasizing the close relationship with the interaorticcaval lymph nodes.

In Figure 4, the psoas major muscle on the left side has been removed, thus revealing the paravertebral sympathetic chain and the origin of the left lumbar splanchnic nerves at this level. The three lumbar splanchnic nerves converge to the left group of aortic plexus nerve fibers. From the level of the paravertebral sympathetic chain, its connection with the lumbar (somatic) plexus structures via the white and gray communicating branches was revealed.

Figure 2 - Highlighting the origin of the sympathetic nerve plexus around the right gonadal artery. AO - abdominal aorta with kinking; RCIA - right common iliac artery; LCIA - left common iliac artery; RGV - right gonadal vein; RGA - right gonadal artery; IVC - inferior vena cava; RRV - right renal vein; LRV - left renal vein; DD - descending duodenum (retracted); HP - head of pancreas (retracted); RK - right kidney; With dotted line - prevertebral plexus from which branches branch off along the right gonadal artery

Figure 3 - Dissection highlighting of right lumbar splanchnic splanchnic and right paravertebral paravertebral sympathetic chain. IVC - inferior vena cava (trailed at both ends); LRV - left renal vein; RK - right kidney; PM - psoas maximus muscle; RU - right ureter; GFN - genitofemoral nerve; LN - pre-aortic lymph nodes; RCIA - right common iliac artery; 1 - superior lumbar splanchnic nerve; 2 - middle lumbar splanchnic nerve; 3 - lower lumbar splanchnic nerve; With black dotted line - group of fibers on the right side of aortic plexus; With blue dotted line - paravertebral sympathetic chain; Red arrow - efferents to the upper hypogastric plexus

Figure 4 - Dissection highlighting of the left lumbar splanchnic splanchnic nerves, paravertebral sympathetic chain and communicating branches in the chain. AO - aorta (dissected); asterisk (*) - efferent fibers from the left celiac ganglion; L1 - L1 vertebral body; L2 - L2 vertebral body; L3 - L3 vertebral body; SMA - origin of the superior mesenteric artery; LRA - origin of the left renal artery; PSC - paravertebral sympathetic chain; IHN - iliohypogastric nerve; IIN - ilioinguinal nerve; 1 - upper lumbar splanchnic nerve; 2 - middle lumbar splanchnic nerve; 3 - lower lumbar splanchnic nerve; White arrow - white communicating branch; Black arrow - gray communicating branch

4. Discussion

Abdominal sympathetic structures are located deep retroperitoneally, surgical access is difficult because of their close relationship with the great vessels, and there is a risk of major bleeding in case of injury.

The main contribution of fibers to the prevertebral aortic plexus comes from the celiac ganglia, where neuron II of the sympathetic pathway is located. Neuron I is located in the lateral horn of the thoracic medulla (6) between T9-T10 for the small splanchnic nerve (ending in the aortic-renal and superior mesenteric ganglia), and at T12 for the inferior splanchnic nerve (ending in the renal plexus)(7). So, the sympathetic pathway for most abdominal organs has neurons arranged in one thoracic and one abdominal. There are three main groups of prevertebral ganglia: celiac, superior mesenteric, and inferior mesenteric ganglia(8). The celiac nodes receive afferents from the large thoracic splanchnic nerve, the superior mesenteric nodes from the small splanchnic nerve, and the inferior mesenteric nodes from the first two lumbar splanchnic nerves(9,10). The lumbar splanchnic nerves, usually three in number, arise from the paravertebral sympathetic chain. The upper lumbar splanchnic nerve originates from L1, the middle from L2, and the lower from L3(11). The paravertebral ganglion contains neuron II of the sympathetic pathway, and neuron I is located in the lateral medullary horn at L1-L2. The lumbar splanchnic nerves contribute to the formation of the prevertebral aortic plexus, generating two groups of preaortic fibers, right and left, which join at the bifurcation of the aorta, forming the superior hypogastric plexus.

5. Conclusions

This study contributes significantly to understanding the structure and visceral connections of the abdomino-pelvic sympathetic chain. The dissections confirmed a well-organized architecture of it and the prevertebral aortic plexus, revealing constant anatomical relationships with the major retroperitoneal structures (abdominal aorta, inferior vena cava) and clear connections with the visceral plexuses. At the same time, we emphasize the need for more precise anatomic descriptions of the sympathetic system in the literature, reflecting the complexity observed in our study. The dissection results provide an essential basis for future research and clinical applications, particularly in surgeries involving the risk of injury to sympathetic structures and associated visceral dysfunction.

Study II: Contributions to the study of the concept of mesopancreas

1. Introduction

The term 'mesopancreas' is used in the surgical literature to describe the nerve pathway of metastasis in pancreatic head cancer. Introduced in 2007 by Gockel and coworkers, this term defines a conjunctival-neurovascular lamina located retroportally, posterior to the pancreatic head, extending to the superior mesenteric artery. Resection of this structure may reduce regional metastasis. Gockel's initial study also emphasizes the role of mesopancreatic lymphatic structures in metastatic spread(12). Perineural tumor metastasis was identified in up to 77% of resection specimens analyzed from patients with carcinoma of the pancreatic head(13,14).

Some studies have questioned the existence of the mesopancreas as a distinct anatomical entity (15).

The existence of conflicting opinions emphasizes the need for a clear definition and further development of the anatomy of the mesopancreas in pancreatic surgery. Further research is essential to standardize the delineations of this structure and to develop effective surgical techniques to improve patient prognosis(16). The hypothesis of my study is that a clear and detailed understanding of the mesopancreas, similar to the mesorectal approach in colorectal surgery, may reduce local recurrence and postoperative complications. We considered the mesopancreas as a well-defined anatomic structure important in tumor dissemination and surgical planning. Thus, we anticipated that precise surgical dissection may improve oncologic outcomes in pancreatic cancer by analyzing the relationships of the mesopancreas with the abdominal nerve plexuses and major blood vessels.

The main objective was to clarify the anatomical structure and boundaries of the mesopancreas through detailed cadaveric dissections and exploration of its nerve and vascular connections. This provided surgeons with precise data for the development of standardized and efficient operative techniques.

2. Materials and methods

This is a descriptive anatomical study performed on human cadavers with the aim of clarifying the structures and connections of the mesopancreas with the nerve plexuses and major blood vessels. The dissection study was performed on eight cadavers, aged between 60 and 80 years (five males and three females). For this study, cadavers without a history of major abdominal surgery were selected to minimize variations that could have altered the retroperitoneal structures and mesopancreas. The use of cadavers was performed in accordance with the law no. 104/27.03.2003 (cadaver handling law), which regulates in Romania the use of cadavers in anatomy laboratories.

3. Results

For the dissection, some of the intraperitoneal abdominal organs, such as the small intestine and colon, were removed in order to have visibility of the retroperitoneal space. Initially, the duodenum and the head of the pancreas were identified and mobilized by the Kocher maneuver, allowing exposure of the right portion of the retroperitoneum. In the dissection, this step involved identification of the lateral edge of the duodenum (along the second portion of the duodenum, which is fixed retroperitoneally). To gain access to the left side, the splenorenal ligament was transected, allowing mobilization of the spleen and tail of the pancreas. After transection of the splenorenal ligament, the spleen was mobilized and structures such as the left adrenal gland, left renal vein and left kidney were exposed. It was also possible to reveal the left celiac ganglion and the formation of the celiac plexus.

After revealing the pancreas, a gentle traction on the inferior margin allows retro-pancreatic revealing of the portal vein formation (Figure 1).

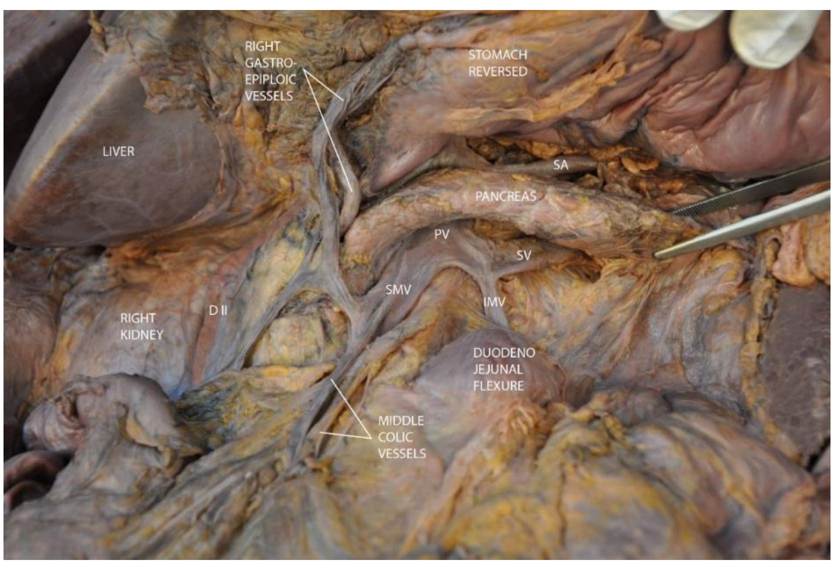

Figure 1 - View from the lower edge of the pancreas. DII - duodenal segment II; SMV - superior mesenteric vein; PV - portal vein; SA - splenic artery; SV - splenic vein; IMV - inferior mesenteric vein.

In Figure 2, we cross-section the pancreas, separating the head from the body. The image plane shows the classic portal vein formation.

Figure 2 - Sectioning of the pancreatic isthmus. Highlighting the portal vein. HP - pancreatic head (traced); BP - pancreatic body (traced); SMV - superior mesenteric vein; SMT - splenomenteric trunk; IMV - inferior mesenteric vein; SPV - splenic vein; PV - portal vein.

In the following figures (Figure 3 and Figure 4), after sectioning the portal vein at the level of the splenomesenteric trunk and folding the sectioned structures to the right and left, we have highlighted the mesopancreatic (retroportal) lamina and a group of small retroportal ganglia, located predominantly posterior to the lamina.

Figure 3 - Section of the splenomesenteric trunk from the left side of the portal to show the mesopancreatic blade. HP - pancreatic head (traced); BP - pancreatic body (traced); SMV - superior mesenteric vein; SMT - splenomeenteric trunk; IMV - inferior mesenteric vein; SPV - splenic vein; PV - portal vein; CT - celiac trunk; *(asterisk) – mesopancreas

Figure 4 - Highlighting the retroportal lymph nodes. HP - head of pancreas (traced); BP - body of pancreas (traced); SMV - superior mesenteric vein; SMT - spleno-meenteric trunk; IMV - inferior mesenteric vein; SPV - splenic vein; PV - portal vein; *(asterisk) - mesopancreas

In Figure 5, the retroportal mesopancreatic lamina was gently tractioned to reveal the superior mesenteric artery.

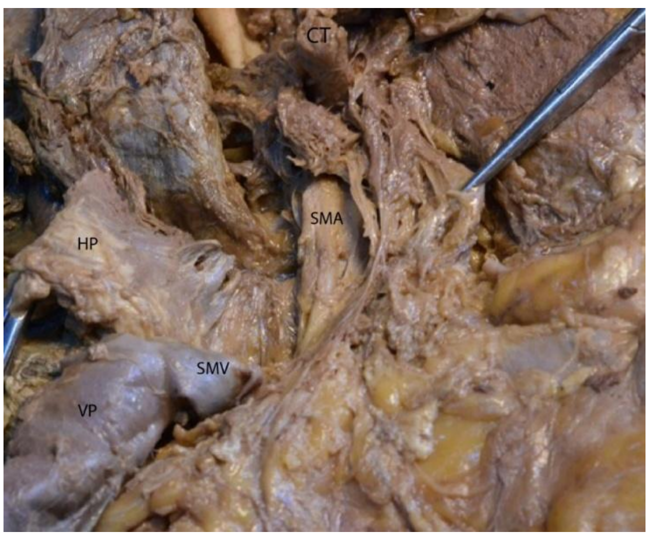

Figure 5 - Reflected retroportal aspect. SMV - superior mesenteric vein; VP - portal vein; HP - pancreatic head (right traced); CT - celiac trunk; SMA - superior mesenteric artery. In the clamp - retroportal lamina slightly tractioned to the left.

In Figure 6, the retroportal mesopancreatic lamina is loaded on the clamp for good demonstration. In Figure 7, after sectioning the pancreas and portal vein, the mesopancreatic lamina and a retropancreatic lymph node are clearly visible. After the portal vein and the sectioned pancreatic segments are lowered, the retropancreatic lamina is clearly visible, anterior and to the right of the superior mesenteric artery. Note the presence of the inferior pancreatico-duodenal and dorsal pancreatic arteries.

Figure 6 - Retroportal lamina highlighting - mesopancreas. HP - head of pancreas (retracted); BP - body of pancreas (retracted); PV - portal vein; dotted line - mesopancreas.

Figure 7 - Mesopancreatic lamina and a retropancreatic lymph node, located anterior and to the right of the superior mesenteric artery. HP - pancreatic head (traced); PHA - hepatic proper artery; RGA - right gastric artery; CHA - common hepatic artery; LGA - left gastric artery; SA - splenic artery; LGV - left gastric vein; SV - splenic vein; PV - portal vein; SMV - superior mesenteric vein; SMA - superior mesenteric artery; MP - mesopancreas; D III - segment III of the duodenum; IPDA - inferior pancreatico-duodenal artery; DAP - dorsal pancreatic artery; *(asterisk) - prelaminar ganglion

Figure 8 clearly illustrates the nervous component of the mesopancreas and the origin of the nerve fibers. The right celiac ganglion in relation to the right renal ganglion is shown in green. From the celiac ganglion there are both efferences to the mesopancreatic lamina and transverse fibers to the left celiac ganglion. For orientation, the branches of the celiac trunk are marked and, at the top, the connections of the celiac ganglion with the phrenic nerve, the sympathetic chain and the posterior vagal trunk.

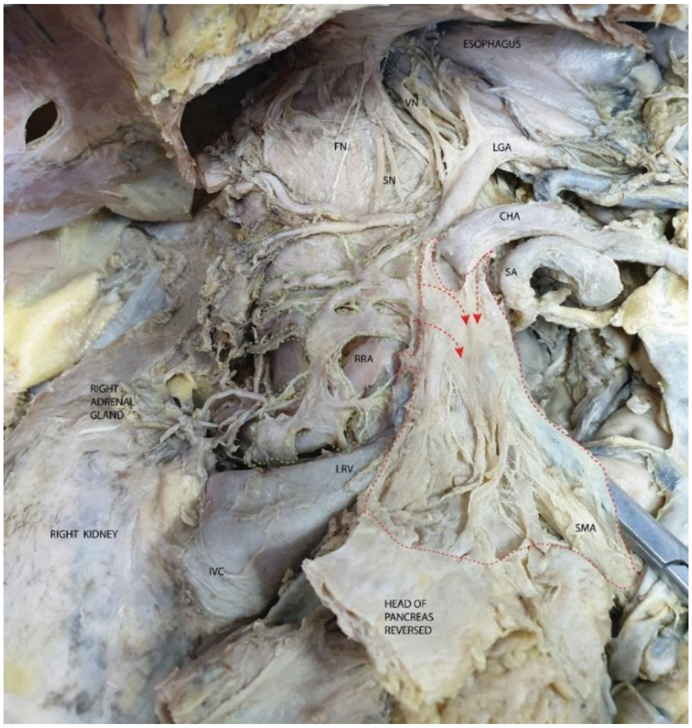

Figure 8 - Right celiac ganglion and its nerve connections with the right renal ganglion, sympathetic chain and posterior vagal trunk. FN - phrenic nerve; SN - sympathetic nerves; VN - vagus nerve; LGA - left gastric artery; CHA - common hepatic artery; RRA - right renal artery; IVC - inferior vena cava; LRV - left renal vein; SMA - superior mesenteric artery; red arrows - afferent fibers from the celiac ganglia to the mesopancreas

In Figure 9, the mesopancreas was loaded on 2 surgical forceps inserted between the mesopancreatic lamina and the superior mesenteric artery.

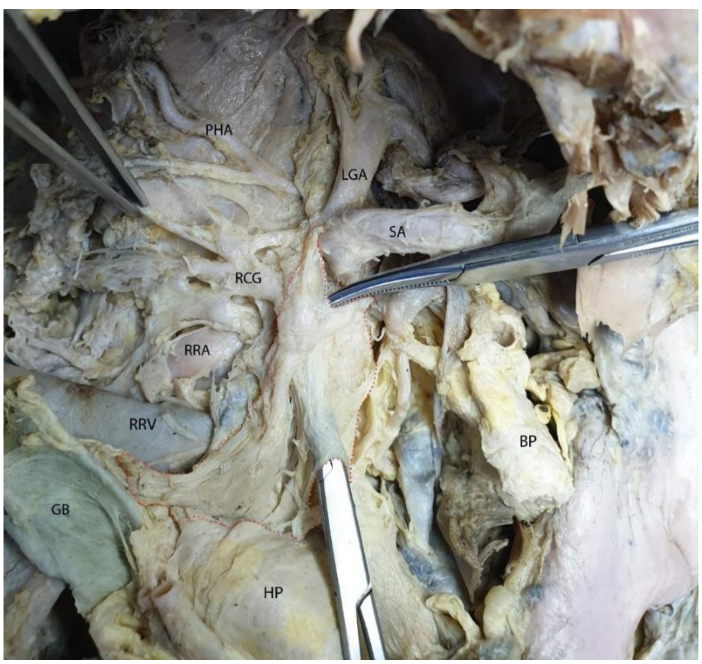

Figure 9 - Mesopancreas loaded on two clamps. RRV - right renal vein; RRA - right renal artery; GB - gallbladder; RCG - right celiac ganglion; PHA - right phrenic artery; SA - splenic artery; LGA - left gastric artery; BP - pancreas body; HP - pancreas head; The structure surrounded by the red dotted line is the mesopancreas.

Nerve fibers arise from both celiac ganglia and form the superior mesenteric nerve plexus around the superior mesenteric artery. This carries sympathetic innervation to all abdominal organs served by the superior mesenteric artery. In the following figure, the origin of the superior mesenteric artery is seen from the left side to highlight the perimesenteric efferents of the left celiac ganglion (Figure 10).

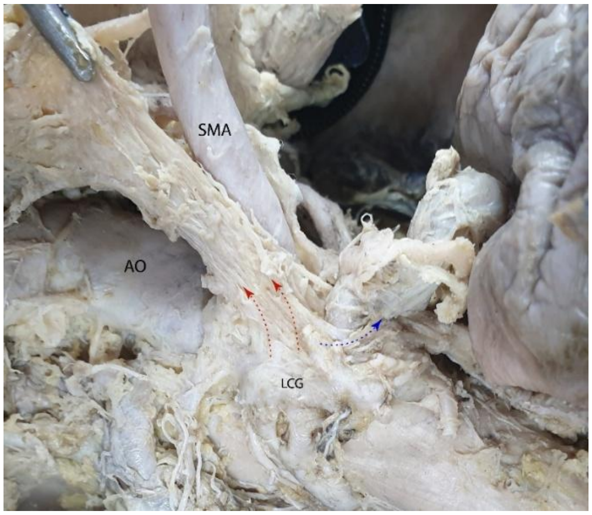

Figure 10 - Superior mesenteric plexus contained in the periarterial tissue surrounding the superior mesenteric artery. AO - abdominal aorta; LCG - right celiac ganglion; SMA - superior mesenteric artery; red arrows - efferent fibers from the left celiac ganglion to the superior mesenteric plexus; blue arrow - connections between the right celiac ganglion and the left celiac ganglion.

Figure 11 is a detail image of the periarterial connective tissue around the superior mesenteric artery, which is accompanied by nerve efferents from the celiac ganglion that will form the superior mesenteric plexus around the artery.

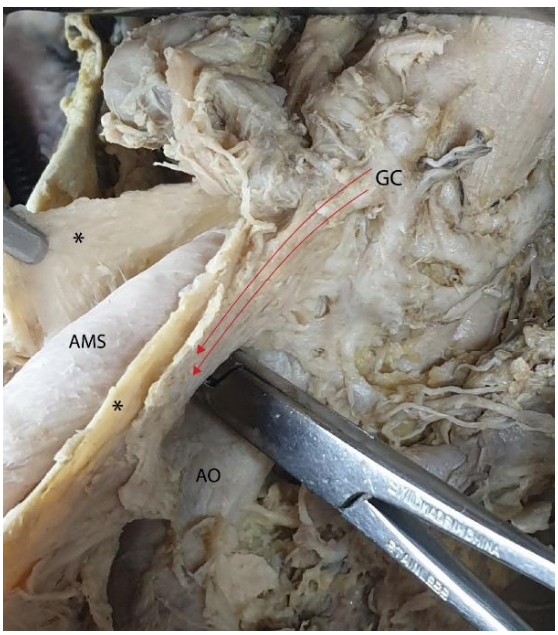

Figure 11 - Periarterial connective tissue and superior mesenteric plexus (detail). AMS - superior mesenteric artery; AO - abdominal aorta; LC - left celiac ganglion; the two asterisks (*) - periarterial connective tissue; the red arrows - efferent fibers from the left celiac ganglion, which will contribute to the formation of the superior mesenteric plexus

Microscopic images demonstrate the presence of nerve fibers and neurons in the dissected mesopancreatic structures as well as abundant blood and lymphatic vascularization. These represent the substrate of possible metastatic migration from the pancreas to the celiac lymph nodes.

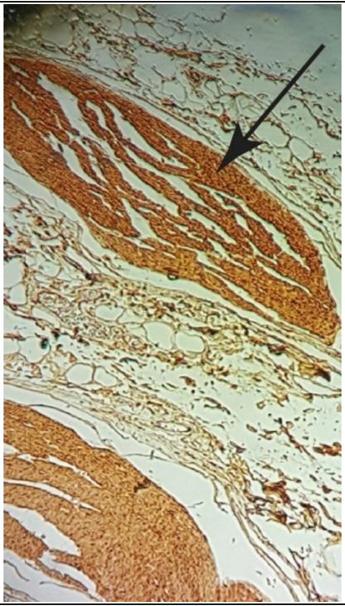

Figure 12: Masson trichrome staining - nerve fibers in the mesopancreatic lamina (arrow)

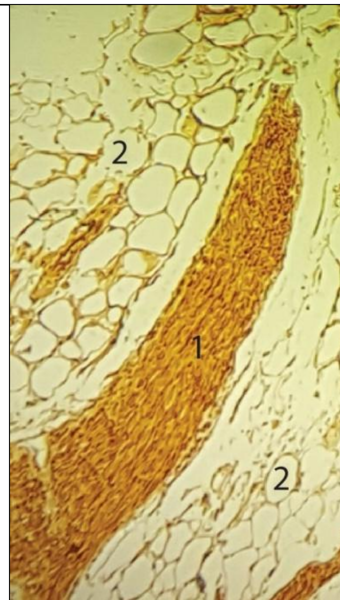

Figure 13: Masson trichrome staining - nerve fibers (1) and adipose tissue (2) in the mesopancreatic tissue

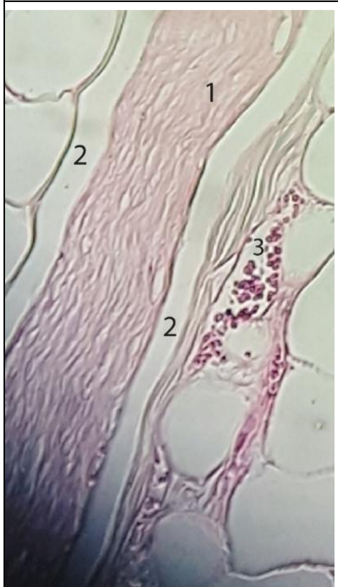

Figure 14: Hematoxylin - eosin staining - Nerve fiber (1) accompanied by blood capillaries (3) and lymphatic vessels (2) in the mesopancreas

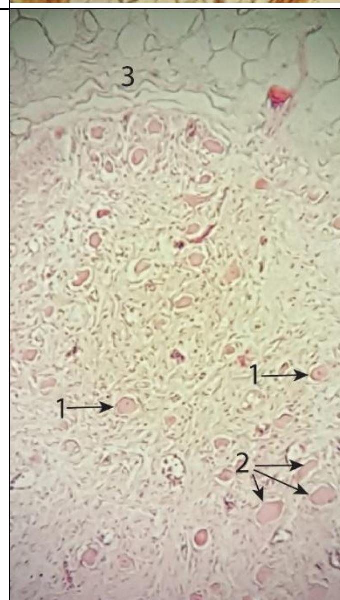

Figure 15: Hematoxylin - eosin staining - Celiac ganglion, contains spherical (1) and multipolar (2) neurons, among which numerous satellite cells are observed. Externally, a capsule with connective structures (3)

4. Discussion

From a semantic point of view, the prefix “mezo” in the term “mesopancreas” may mislead us about the definition of the structure. We might assume that it refers to the mesosoma of the pancreas. However, we know for certain that the pancreas is a secondary retroperitoneal organ without a mesosa. The main component of the mesopancreatic lamina is the afferents and efferents of the two celiac ganglia. As we have shown, both the left and right celiac ganglia contribute to the formation of the mesopancreatic lamina and the superior mesenteric plexus. The relationship of the mesopancreatic lamina to the superior mesenteric artery is defining.

We note the presence of lymph nodes both superficial and deep to the mesopancreatic blade. The celiac ganglia are deep nervous structures, which belong to the group of prevertebral sympathetic ganglia and are involved in the control of sympathetic activity of numerous abdominal viscera. Damage to the interganglionic connections may alter sympathetic control of these organs. Injury to the superior mesenteric plexus basically involves sympathetic denervation of the intestinal loops and right colon. The deep location of the mesopancreatic lamina and its relationship to numerous vascular structures make the surgical approach difficult and risky.

5. Conclusions

Following our study, we can propose a plausible definition of the term ‘mesopancreas’. It is represented by the structures that were part of the contents of the primordial meso after the primordial meso disappeared by coalescence, generating the Treitz fascia. In short, the mesopancreas is the content of a former meso. These contents are functional and consist largely of nerve fibers that connect the celiac ganglia and the superior mesenteric plexus to the head and body of the pancreas. The mesopancreas also includes blood vascular and lymphatic structures, as well as connective-adipose tissue. All these may be involved in regional metastasis of pancreatic head cancer.

Resection of the mesopancreas seems justified to prevent this metastasis. However, the mesopancreas is a complex, deep structure in relation to important vascular structures, which makes surgical access very difficult and risky. This should be taken into account when determining the surgical strategy.

Study III: The study of the sympathetic chain at the border between the abdomen and the pelvis

1. Introduction

At the level of the recto-sigmoid junction, the digestive tract becomes totally intraperitoneal or partly intraperitoneal. Posterior to the rectum, between the rectum and the sacrum, the retrorectal space is delimited, which will contain the presacral fascia, the anterior sacral foramina through which the sacral spinal nerves and their branches exit, and the sacral sympathetic chains, which join inferiorly at the level of a coccygeal ganglion.

This space also contains the presacral artery, presacral lymph nodes, and a mass of lax connective tissue called angel's hairs(17), which occurs as a result of rectal coalescence and the disappearance of the primitive meso(18). Around the rectum, there is a differentiation of the proper fascia of the rectum (rectal sheath according to Thoma Ionescu (19)). Between the fascia and the rectum is the mesorectal space or mesorectum (20). It contains the upper rectal vessels, upper rectal lymph nodes, and connective adipose tissue. Block resection of the rectum (21) and the mesorectum (22,23) is today a gold standard in modern rectal oncologic surgery (24,25).

To this standard, the concept of nerve sparing surgery is added (26,27), which involves protection of the nerve structures described above, as well as protection of the superior hypogastric plexus and the two hypogastric nerves, which follow a latero-rectal, subperitoneal route to the pelvis-subperitoneal space(28), where they form the inferior hypogastric plexus(29). Of utmost importance is also the protection of the pelvic splanchnic (erector) nerves to maintain sexual function (30,31).

2. Materials and methods

We performed dissections on eight cadavers, aged between 65 and 74 years with no history of previous surgery. The cadavers were preserved with a 9% formalin solution in the dissection room of the Anatomy Discipline of the Carol Davila University of Medicine and Pharmacy, Bucharest, Romania.

3. Results

After removal of the posterior parietal peritoneum, we revealed the bifurcation of the aorta and the common iliac arteries, as shown in Figure 1. From the prevertebral plexus descend two groups of nerve fibers that join below the bifurcation, forming the superior hypogastric plexus, a rectangular nerve lamina approximately 4-5 cm long and 2 cm wide. There are fine branches to the periarterial plexuses around the common iliac and the two hypogastric nerves that branch inferiorly. From the right hypogastric nerve a ureteral branch is noted. The dissection also identified the presacral vessels, presacral fascia, and the retrorectal conjunctival-adipal lamina located between the two hypogastric nerves. Figure 2 shows a deviation of the lumbar aorta, which is convex to the left. This alteration partially alters the relations of the superior hypogastric plexus, but the plexus formation still occurs anterior to the lumbar aorta, slightly above the aortic bifurcation.

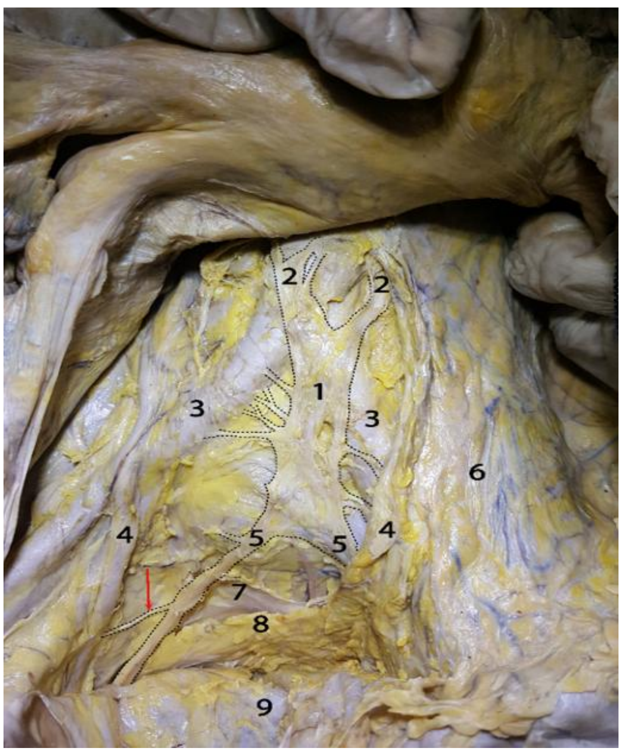

Figure 1: Detailed dissection showing the formation of the superior hypogastric plexus and hypogastric nerves. 1 - superior hypogastric plexus; 2 - fascicles of origin of the hypogastric plexus; 3 - right and left common iliac artery; 4 - right and left ureter; 5 - right and left hypogastric nerves; 6 - posterior parietal peritoneum; 7 - presacral fascia; 8 - conjunctival adipose nervous lamina/ neuroconjunctival lamina between the hypogastric nerves; 9 - rectum reflected anteriorly; Red arrow - nervous branch for the ureter

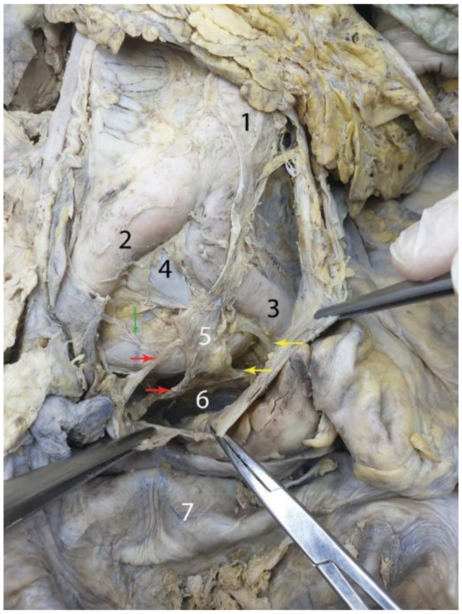

Figure 2 - Relationships of the superior hypogastric plexus after posterior parietal peritoneal detachment. 1 - Aorta; 2 - Right common iliac artery; 3 - Left common iliac artery; 4 - Left common iliac vein; 5 - Inferior part of the superior hypogastric plexus; 6 - Interhypogastric lamina; 7 - Rectum retracted anteriorly; Red arrows - Right hypogastric nerve origins; Yellow arrows - Left hypogastric nerve origins; Green arrow - Arterial branches to common iliac artery; Between the tweezers - Posterior parietal peritoneum

In the presacral space and on the lateral wall of the pelvis, we performed a detailed dissection of the main structures found in the pelvis-subperitoneal space.

Figure 3 - Highlighting the erector nerves; Yellow arrows - sacral nerves S2, S3, S4; Green arrows show the pelvic splanchnic nerves; Red stars - piriformis muscle; 1 - iliopsoas muscle; 2 - external iliac artery; 3 - Internal iliac artery; 4 - Inferior hypogastric plexus; 5 - Sacro-ischial ligament; 6 - Branches of the pudendal nerve seen after removal of the levator ani muscle; 7 - Internal obturator muscle; 8 - Rectum

Posterior to the rectum, between the rectum and the S3, S4 vertebrae, is a mass of lax connective tissue known as ANGEL'S HAIRS. This connective tissue is found in the plane of dissection that separates the rectum from the sacrum. The left hypogastric nerve is held in tension and in this way suspends the laterorectal peritoneum under which it engages. In the pelvis-subperiotneal space, the outlines of the nerve fibers that make up the superior hypogastric plexus are distinguished. The dissection specimen has the merit of highlighting exactly the area at risk for severing the erectile nerves.

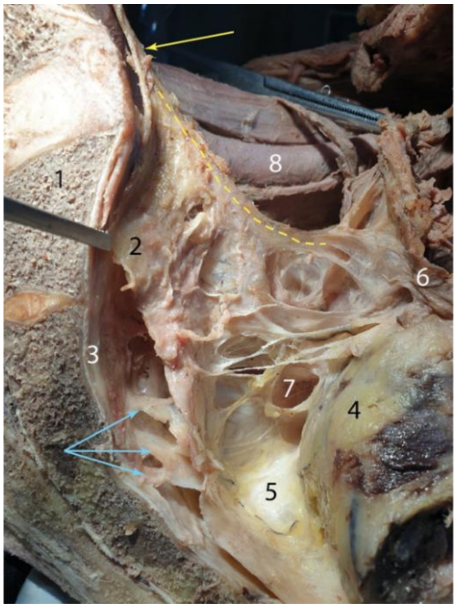

Figure 4 - sagittal section highlighting the appearance of the latero-rectal subperitoneal structures in situ (dissection in the left hemipelvis). 1 - Sacral bone - S1 vertebra sectioned; 2 - Interhypogastric conjunctival-nerve lamina; 3 - Presacral fascia; 4 - Rectum; 5 - Angel hair; 6 - Peritoneum of the left laterorectal sac fundus; 7 - Rectal branches of the inferior hypogastric plexus; 8 - Left external iliac artery; yellow arrow - Left hypogastric nerve; blue arrows - Erector nerves; dotted yellow line shows the direction of the left hypogastric nerve in close contact with the latero-rectal peritoneum

In Figure 5, we have highlighted by dissection the nerve structures that carry sympathetic impulses from the sacral sympathetic chain to the inferior hypogastric plexus. These nerve impulses originate in the L1-L2 lateral horns of the L1-L2 spinal cord, take the pathway of the sacral sympathetic chain, and via the sacral splanchnic nerves enter the inferior hypogastric plexus. Thus, the sacral splanchnic nerves represent anatomoses between the sacral sympathetic chain and the inferior hypogastric plexus.

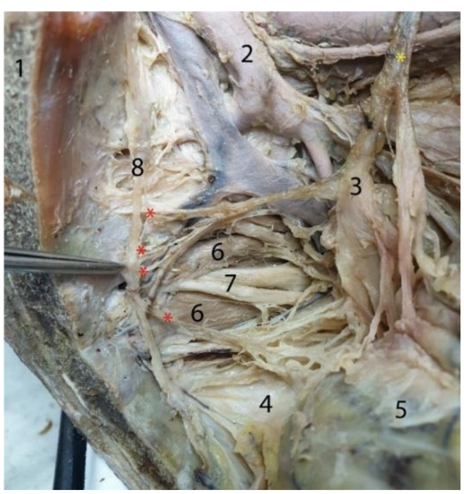

Figure 5 - Evidence of the sacral splanchnic nerves (sympathetic nerves) by dissection in the left hemibazin in the laterosacral region. 1 - The sacral bone; 2 - Left external iliac artery; 3 - Left inferior hypogastric plexus; 4 - Angel's hairs; 5 - Rectum; 6 - Piriformis muscle; 7 - Branches of the sacral plexus; 8 - Sacral sympathetic chain; red stars - Sacral splanchnic nerves; yellow star - Left hypogastric nerve

4. Discussion

As we suggested, modern surgery aims in addition to resection of the rectum and mesorectum to achieve oncologic safety and to preserve the patient's comfort of life, performing so-called nerve sparring surgery(32). This surgery concerns the preservation of the nervous structures that we have highlighted by dissection. We have highlighted important anatomic landmarks that allow these structures to be identified and protected during surgical dissection. Thus, the superior hypogastric plexus is retroperitoneal and in direct relation to the bifurcation of the aorta(33). Sometimes, the superior hypogastric plexus inferiorly shows a continuation with the appearance of a ganglionic lamina of different sizes and shapes (Figure 2). The right and left hypogastric nerves emerge from the inferior part of the superior hypogastric plexus. They run inferiorly and laterally in direct relation to the peritoneum of the pararectal recesses. This relationship is essential for nerve protection in rectal resections.

The inferior hypogastric plexus arises from the abundant branching of the hypogastric nerve into the pararectal pelvis-subperitoneal space (34,35). This plexus originates mainly from the lumbar sympathetic and provides sympathetic innervation to the pelvic organs. It also contains fibers from the sacral sympathetic and the sacral parasympathetic(5).

The pelvic splanchnic nerves (erector or erector spinae) are anastomoses between the somatic spinal nerves of the sacral plexus S2-S3-S4 and the inferior hypogastric plexus (36,37). These nerves carry the parasympathetic component to the pelvic organs and erect genital structures (37). The sacral splanchnic nerves are anastomoses between the sacral sympathetic chain and the inferior hypogastric plexus. They carry sympathetic nerve impulses originating in L1-L2 to the pelvic organs. They are delicate, thin nerve structures that are difficult to visualize in direct relation to the pelvic wall. They are therefore even more difficult to damage than the erector nerves.

5. Conclusion

Once again, detailed anatomic dissection studies provide support for the establishment of modern surgical strategies in a large-scale intervention such as rectal resection. Through this study, we have reviewed the totality of the nervous structures that need to be protected in rectal surgery, establishing useful relationships and the optimal theoretical support for the surgical procedure.

Personal conclusions and contributions

For study number 1, "Evidence by dissection of the prevertebral aortic sympathetic plexus formation and its relationships":

The conclusions are:

- The formation and distribution of the prevertebral aortic plexus exhibits significant morphofunctional complexity, revealed by detailed dissection.

- The prevertebral aortic plexus is a well-organized nerve network extending longitud longitudinally along the abdominal aorta, almost to the aortic bifurcation.

- The main sources of the plexus are the efferents of the celiac, superior and inferior mesenteric ganglia, aortic-renal ganglia and paravertebral sympathetic chain.

- The celiac ganglia play an essential role in the formation of the plexus, receiving afferents from the thoracic splanchnic nerves and distributing sympathetic fibers to the preaortic plexus.

- The superior hypogastric plexus, as an inferior extension of the preaortic plexus, marks the transition between the abdominal and pelvic sympathetics.

- The literature requires more detailed descriptions of the prevertebral aortic plexus and its connections to support the development of more precise and safer surgical techniques.

- The results of this study may help optimize minimally invasive interventions and improve the management of pathologies involving the abdominal and pelvic sympathetic innervation.

Personal contribution:

Given the significant anatomic variability of the sympathetic structures, I consider each dissection successful. The integration of the dissections in the context of surgical anatomical landmarks constitutes the most important achievement of my thesis, given the almost complete lack of such detailed descriptions in the literature. The didactic manner of data presentation lends uniqueness to each study. In this context, the main personal contributions obtained through dissection are:

- Complete outlining of the course of the prevertebral aortic plexus and its connections with the celiac, mesenteric and superior hypogastric ganglia.
- Dissection of the three lumbar splanchnic nerves (superior, middle and inferior) from the paravertebral sympathetic chain to the prevertebral aortic plexus, clarifying the mechanisms of transmission of sympathetic impulses to the pelvic organs.

- Description of the connections between the prevertebral aortic plexus and the renal and gonadal plexuses.
- Highlighting the preaortic and interaorticcaval lymph nodes in relation to the preaortic plexus, suggesting a possible interaction between lymphatic and nervous pathways in metastasizing.
- Demonstration of direct connections between the celiac ganglia and the superior mesenteric plexus, with distribution of efferences to the digestive organs through the periarterial mesenteric plexus.
- Highlighting the superior hypogastric plexus as a bridge between abdominal and pelvic sympathetic innervation.
- Identification of anatomical landmarks useful for the localization of the prevertebral aortic plexus in the surgical context.

For study number 2, "Contributions to the study of the mesopancreas":

Considering that the notion of mesopancreas is inadequately explained in the literature, my conclusions are:

- The mesopancreas is a distinct anatomical structure, located retroportally, composed of connective-neurovascular elements.
- By dissection, we have demonstrated that the mesopancreas derives from the fusion of the primordial mesos during embryonic development, generating the Treitz fascia.
- Dissections confirmed that the mesopancreas consists predominantly of nerve fibers connecting the celiac ganglia with the superior mesenteric plexus.
- In addition to nerve structures, the mesopancreas contains blood vessels, lymphatic vessels and connective adipose tissue.
- We have emphasized the relationships of the mesopancreas to major retroperitoneal structures, in particular the superior mesenteric artery, abdominal aorta and inferior vena cava.
- My study confirms the role of the mesopancreas as a pathway for metastasis of pancreatic head cancer to the celiac lymph node.

Personal contribution:

- Clear highlighting of the entire course of nerve connections in the mesopancreas, demonstrating its direct relationship to the celiac ganglia and superior mesenteric plexus.

- Providing a detailed dissection of the retroportal lamina and its connections with the major lymphatic and neurovascular structures, providing essential anatomical support for the standardization of oncologic surgical techniques.

- Demonstration, by dissection, of the direct relationship between the mesopancreas and the superior mesenteric artery, highlighting the surgical implications in oncologic resection of the pancreatic head.

- Highlighting the retroportal lymph nodes and their distribution in relation to the mesopancreas, providing a sound anatomic basis for understanding the metastatic spread of pancreatic head cancer.

For study number 3, "Contributions to the study of the behavior of sympathetic chains at the border between abdomen and pelvis":

Conclusions:

- The most important achievement was the clear definition and differentiation between the sacral splanchnic nerves (sympathetic) and the pelvic splanchnic nerves (parasympathetic).
- The study highlighted the complexity of the sympathetic nervous system at the abdomen-pelvis border, demonstrating the relationships between the superior and inferior hypogastric plexuses.
- The superior hypogastric plexus was shown to be a retroperitoneal, lamellar nerve formation located just below the bifurcation of the aorta, essential in the transmission of sympathetic impulses to the pelvic organs.
- The hypogastric nerves are the continuation of the superior hypogastric plexus, with a subperitoneal course and close relations with the pararectal recesses; their protection in nerve-sparing rectal surgery is crucial for the maintenance of sexual function.
- The inferior hypogastric plexus consists of a mixed nerve network arising from lumbar sympathetic, sacral sympathetic, and pelvic parasympathetic fibers.
- The pelvic splanchnic nerves have been identified as key elements of the pelvic parasympathetic innervation, anastomosing with the inferior hypogastric plexus.

- The study emphasizes the importance of protecting erector nerve fibers for preservation of sexual and urinary functions in pelvic surgery. The dissections confirmed the mixed sympathetic and parasympathetic content of the inferior hypogastric plexus, explaining its control of rectal, urinary and genital functions.
- The relationships of the hypogastric plexuses to the common iliac arteries were clearly documented, providing useful surgical landmarks.
- Although individual variability was observed, the organization of the upper hypogastric plexus and hypogastric nerves was relatively constant, facilitating their intraoperative identification. The results contribute significantly to the understanding of abdomino-pelvic sympathetic anatomy and support the development of modern nerve-sparing surgical techniques.

Personal contribution:

- We performed a detailed dissection of the superior and inferior hypogastric plexus, establishing their relationships with the important structures at the abdomino-pelvic border and outlined the origin and course of the right and left hypogastric nerves, demonstrating the importance of their protection in rectal and pelvic surgery.
- We demonstrated by dissection the organization of the inferior hypogastric plexus and identified its connections with the sacral plexus.
- The study revealed the complex anastomoses between the pelvic splanchnic nerves and the inferior hypogastric plexus, demonstrating their importance in the vegetative innervation of the pelvic organs. The sacral splanchnic, the most difficult to emphasize, played a special role in my study, where I demonstrated the anastomosis between the sacral sympathetic chain and the inferior hypogastric plexus. They carry sympathetic nerve impulses originating in L1-L2 to the pelvic organs. They are delicate, thin nerve structures that are difficult to visualize in direct relation to the pelvic wall. As a result, they are even easier to damage than the erector nerves.

References

1. Gandhi KR, Verma VK, Chavan SK, Joshi SD, Joshi SS. The morphology of lumbar sympathetic trunk in humans: a cadaveric study. Folia Morphol (Warsz). 2013 Sep 5;72(3):217–22.
2. Beveridge TS, Johnson M, Power A, Power NE, Allman BL. Anatomy of the nerves and ganglia of the aortic plexus in males. J Anat. 2015 Jan 1;226(1):93–103.
3. Tubbs RS, Shoja MM, Loukas M. Abdominal Pre- and Para-aortic and Inferior Hypogastric Plexuses. In: Nerves and Nerve Injuries. Elsevier; 2015. p. 647–58.
4. Rodgers SD, Engler JA, Perin NL. A novel approach to the lumbar sympathetic chain: lateral access. Neurosurg Focus. 2013 Jul;35(v2supplement):Video12.
5. Hypogastric Plexus - an overview | ScienceDirect Topics [Internet]. [cited 2024 May 28]. Available from: https://www.sciencedirect.com/topics/medicine-and-dentistry/hypogastric-plexus
6. Peetermans M, Vanlommel J, Van Look L, Uyttebroek L, Van Schil P, van Nassauw L. The anatomical variations of the additional communicating rami in the proximal sympathetic trunk: A human cadaveric study. Translational Research in Anatomy. 2023 Mar;30:100240.
7. Ehrhardt JD, Weber C, Carey FJ, Lopez-Ojeda W. Anatomy, Thorax, Greater Splanchnic Nerves. StatPearls [Internet]. 2024 Jan 31 [cited 2025 Jan 24]; Available from: https://www.ncbi.nlm.nih.gov/books/NBK500026/
8. Murata Y, Takahashi K, Yamagata M, Takahashi Y, Shimada Y, Moriya H. Variations in the number and position of human lumbar sympathetic ganglia and rami communicantes. Clinical Anatomy. 2003 Mar 14;16(2):108–13.
9. Gest TR, Hildebrandt S. The pattern of the thoracic splanchnic nerves as they pass through the diaphragm. Clin Anat [Internet]. 2010 Sep [cited 2025 Jan 24];23(6):732. Available from: https://pubmed.ncbi.nlm.nih.gov/20669271/
10. Yang HJ, Gil YC, Lee WJ, Kim TJ, Lee HY. Anatomy of thoracic splanchnic nerves for surgical resection. Clin Anat [Internet]. 2008 [cited 2025 Jan 24];21(2):171–7. Available from: https://pubmed.ncbi.nlm.nih.gov/18288763/
11. Beveridge TS, Fournier DE, Groh AMR, Johnson M, Power NE, Allman BL. The anatomy of the infrarenal lumbar splanchnic nerves in human cadavers: implications for retroperitoneal nerve-sparing surgery. J Anat. 2018 Jan 1;232(1):124–33.
12. Gockel I, Domeyer M, Wolloscheck T, Konerding MA, Junginger T. Resection of the mesopancreas (RMP): A new surgical classification of a known anatomical space. World J Surg Oncol [Internet]. 2007 Apr 25 [cited 2024 Nov 22];5(1):1–8. Available from: https://wjso.biomedcentral.com/articles/10.1186/1477-7819-5-44

13. Neoptolemos JP, Stocken DD, Dunn JA, Almond J, Beger HG, Pederzoli P, et al. Influence of resection margins on survival for patients with pancreatic cancer treated by adjuvant chemoradiation and/or chemotherapy in the ESPAC-1 randomized controlled trial. Ann Surg [Internet]. 2001 [cited 2025 Jan 8];234(6):758–68. Available from: https://pubmed.ncbi.nlm.nih.gov/11729382/

14. Lüttges J, Vogel I, Menke M, Henne-Bruns D, Kremer B, Klöppel G. The retroperitoneal resection margin and vessel involvement are important factors determining survival after pancreaticoduodenectomy for ductal adenocarcinoma of the head of the pancreas. Virchows Arch [Internet]. 1998 [cited 2025 Jan 8];433(3):237–42. Available from: https://pubmed.ncbi.nlm.nih.gov/9769127/

15. Olakowski M. Mesopancreas—new unknown land or a mirage? Vol. 406, Langenbeck's Archives of Surgery. Springer Science and Business Media Deutschland GmbH; 2021. p. 2899–901.

16. Sharma D, Isaji S. Mesopancreas is a misnomer: time to correct the nomenclature. J Hepatobiliary Pancreat Sci. 2016 Dec 1;23(12):745–9.

17. Bunni J. The primacy of embryological, ontogenetic and specimen orientated (mesenteric) surgery as the most important tool in treating visceral (colorectal) cancer. Mesentery and Peritoneum. 2017;1:3–3.

18. Crolla RMPH, Coffey JC, Consten EJC. The Mesentery in Robot-Assisted Total Mesorectal Excision. Clin Colon Rectal Surg. 2022 Jul 10;35(04):298–305.

19. Popa F, Buda O, Purcarea VL, St ". Professor Thoma Ionescu (1860-1926) founder of the Modern Romanian School of surgery. J Med Life. 3(1):1–2.

20. Phang PT. Total mesorectal excision: technical aspects. Can J Surg. 2004 Apr;47(2):130–7.

21. Sijmons JML, Willem J, Dekker T, Jurriaan ·, Tuynman B, Mohan HM, et al. Evolution of surgical approach to rectal cancer resection: A multinational registry assessment. Int J Colorectal Dis [Internet]. 123AD [cited 2024 Jun 13];39:15. Available from: https://doi.org/10.1007/s00384-023-04578-4

22. MacFarlane JK, Ryall RDH, Heald RJ. Mesorectal excision for rectal cancer. The Lancet [Internet]. 1993 Feb 20 [cited 2024 Jun 13];341(8843):457–60. Available from: http://www.thelancet.com/article/014067369390207W/fulltext

23. Tulin A, Nitipir C, Slavu I, Braga V, Mihaila D, Alecu L. Watch and wait strategy for rectal cancer: 15 years after the first published study. Are we any closer to the non-operative management of rectal cancer? Vol. 114, Chirurgia (Romania). Editura Celsius; 2019. p. 174–8.

24. Faucheron JL. Pelvic Anatomy for Colorectal Surgeons. Acta Chir Belg. 2005 Jan 11;105(5):471–4.

25. Kim NK, Kim YW, Cho MS. Total mesorectal excision for rectal cancer with emphasis on pelvic autonomic nerve preservation: Expert technical tips for robotic surgery. Surg Oncol. 2015 Sep 1;24(3):172–80.

26. Balaya V, Guimiot F, Uhl JF, Ngo C, Delomenie M, Bonsang-Kitzis H, et al. Three-Dimensional Modelization of the Female Human Inferior Hypogastric Plexus: Implications for Nerve-Sparing Radical Hysterectomy. Gynecol Obstet Invest. 2019;84(2):196–203.

27. Li H, Jia J, Xiao Y, Kang L, Cui H. Anatomical basis of female pelvic cavity for nerve sparing radical hysterectomy. Surg Radiol Anat. 2015 Dec 24;37(6):657–65.

28. Church JM, Raudkivi PJ, Hill GL. The surgical anatomy of the rectum — a review with particular relevance to the hazards of rectal mobilisation. Int J Colorectal Dis. 1987 Sep;2(3):158–66.

29. Mauroy B, Demondion X, Bizet B, Claret A, Mestdagh P, Hurt C. The female inferior hypogastric (= pelvic) plexus: anatomical and radiological description of the plexus and its afferences–applications to pelvic surgery. Surg Radiol Anat. 2007 Feb;29(1):55–66.

30. Gutierrez S, Tubbs RS. The Pelvic Splanchnic Nerves. Surgical Anatomy of the Sacral Plexus and its Branches. 2020 Jan 1;87–98.

31. Pocard M, Zinzindohoue F, Haab F, Caplin S, Parc R, Tiret E. A prospective study of sexual and urinary function before and after total mesorectal excision with autonomic nerve preservation for rectal cancer. Surgery. 2002 Apr;131(4):368–72.

32. Kim NK, Kim YW, Cho MS. Total mesorectal excision for rectal cancer with emphasis on pelvic autonomic nerve preservation: Expert technical tips for robotic surgery. Surg Oncol. 2015 Sep 1;24(3):172–80.

33. Kim H, Nam YS, Lee UY, Kim IB, Kim YS. Anatomy of the superior hypogastric plexus and its application in nerve-sparing paraaortic lymphadenectomy. Folia Morphol (Warsz). 2021;80(1):70–5.

34. Spackman R, Wrigley B, Roberts A, Quinn M. The inferior hypogastric plexus: A different view. J Obstet Gynaecol (Lahore). 2007 Jan 2;27(2):130–3.

35. Waldman SD. Hypogastric Plexus Block. Atlas of Interventional Pain Management. 2015;617–22.

36. Haroun HS. Clinical anatomy of the splanchnic nerves. MOJ Anat Physiol. 2018;5(2).

37. Alkatout I, Wedel T, Pape J, Possover M, Dhanawat J. Review: Pelvic nerves – from anatomy and physiology to clinical applications. Transl Neurosci [Internet]. 2021 Jan 1 [cited 2024 Jun 13];12(1):362. Available from: /pmc/articles/PMC8500855/

List of published scientific papers

1. Mihaly Enyedi, **Georgian-Theodor Badea**, Radu-Tudor Ion, Daniela Elena Gheoca Mutu, Stefan Oprea, Zoran Florin Filipoiu. The dissection-based identification of the preaortic sympathetic plexus formation, anatomical relations, and clinical applications. JOURNAL of MEDICINE and LIFE, 2025, 4(18); PubMed article, chapter I, pages 39-52
   Doi: 10.25122/jml-2025-0069
   Link: https://medandlife.org/wp-content/uploads/13-JML-2025-0069.pdf

2. Filipoiu, Florin-Mihail, **Georgian-Theodor Badea**, Mihaly Enyedi, Ștefan Oprea, Zoran-Florin Filipoiu, and Daniela-Elena Gheoca Mutu, "Mesopancreas—Anatomical Insights and Its Implications for Diagnosis and Clinical and Surgical Practice" Diagnostics, 2025, 15(7), indexed in Web of Science – impact factor 3.0, Q1, chapter II, pages 53-92
   Doi: https://doi.org/10.3390/diagnostics15070914
   Link https://www.mdpi.com/2075-4418/15/7/914

3. **Theodor Georgian Badea**, Dogaru IA, Filipoiu ZF, Gheoca Mutu DE, Filipoiu F. Dissection of the Sympathetic Nerves Around the Mesorectum at the Abdominopelvic Border, Cureus, 2024, 16(9), PubMed article, chapter III, pages 93-105
   Doi: 10.7759/cureus.69091
   Link: https://www.cureus.com/articles/276942-dissection-of-the-sympathetic-nerves-around-the-mesorectum-at-the-abdominopelvic-border#!/