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The anatomical study of the pelvic autonomic plexuses

REZUMATUL TEZEI DE DOCTORAT

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INTRODUCTION

The importance and motivation of the chosen subject

Autonomic innervation has always been the touchstone for anatomists. The development of the vegetative nervous system, the classification of vegetative nerve fibres, their pathway, distribution and function remain today extremely difficult topics to tackle. The pelvic viscera, by their very position and location, are difficult to approach anatomically and surgically, dissections are complicated, and often preserving nerve threads in modern nerve-sparing surgery [1] is a difficult challenge.

In pelvic pathology, there is an increasingly clear chapter dedicated to the approach, interpretation and treatment of pelvic pain. Such a complex approach cannot be achieved without the basis represented by the anatomical study of the innervation of the pelvic viscera. The vegetative nervous system has the two classical components, the sympathetic nervous system and the parasympathetic nervous system. In addition to the vegetative innervation, there are pelvic structures with somatic innervation (perineal muscles and their fasciae, as well as the periosteum).

The ability to discern between different types of pain, as well as the ability to understand the involvement of each type of nervous system in pelvic pathology, is based on knowledge, identification and assessment of each pelvic nerve structure belonging to the three systems [2].

The way the vegetative nerves approach the pelvis is complicated and specific to each individual nerve structure [3].

The somatic innervation belongs to the sacral and lumbar plexuses, and the fibers of origin branch from these plexuses and approach the muscle structures extraperitoneally. Some of the somatic fibres reach the inferior hypogastric plexuses.

Sympathetic innervation enters the pelvis via two pathways:

- On the one hand, via the pre-aortic nerve networks, represented by the prevertebral plexuses - inferior mesenteric plexus, superior hypogastric plexus, hypogastric nerve and inferior hypogastric plexus;
- On the other hand, the sacral sympathetic chains enter the pelvis medial to the anterior sacral foramen, meet at a median sacral ganglion and give collaterals, which either approach the viscera via a subperitoneal route or take the inferior hypogastric plexus nerve network pathway to reach the viscera.

Parasympathetic nerve fibres arise from the pelvic parasympathetic nucleus S2-S4. Through communicating branches, they reach the sacral (somatic) nerves and branch from them as pelvic splanchnic nerves. Part of their fibres take the path of the inferior hypogastric plexus [4].

From this review of the pelvic innervation, the difficulty of the subject from an anatomical and clinical point of view is already apparent. It is also clear how important it is for the clinician to clarify and systematise the anatomical substrate. Pelvic surgery with dissection into the subperitoneal space must protect or intercept the large inferior hypogastric plexuses, which occupy the pelvic floor on either side of the pelvic organs [5].

In such a complicated anatomical context, a young doctor may find it difficult to orient himself. This was the reason for my choice of doctoral research topic, given that I am a specialist in Obstetrics and Gynaecology.

Research hypothesis

I aimed to highlight by careful dissection all the nerve components entering the pelvis and to describe the route, relationships and topography of these structures. From a topographical point of view, I proposed to study the pelvic innervation in the perivascular areas, in the presacral area and at the level of the great and small ischial incisions. I consider the question of the relationship of the pelvic innervation to the perineal components to be one of the great challenges of my study. I know from surgical practice how difficult it is to protect the nerve structures represented by the hypogastric nerves, the inferior hypogastric plexuses, the pelvic splanchnic and sacral splanchnic nerves. I propose to highlight the course of all these structures in relation to constant anatomical landmarks: the ischial incisions, the ischial spine, the sacral holes, the anterior face of the sacrum, etc. In the same way, I propose to highlight the most important relationships in pelvic surgery, and here I refer to the relationships, distribution and course of the branches of the internal iliac artery and to highlight how the nerve elements are arranged in relation to them.

Of the pelvic pain syndromes, I propose to highlight the anatomical basis for piriformis muscle syndrome. This is a complex undertaking, involving perhaps the most complicated dissection, that corresponding to the region of the piriformis muscle. Highlighting the neurovascular components belonging to the supra- and infrapiriform spaces, as well as the origins and efferent fibres of the pudendal nerve is the highest level of performance of my study.

The complete highlighting of the internal pudendal nerve pathway, ratios and distribution is an extremely difficult achievement.

I propose to carry out a study on the topography of parasympathetic and sympathetic nerve structures in the fetal pelvis. The motivation for such a complicated study, however, is to understand how the appearance of pelvic nerve structures in the adult is arrived at through embryonic development.

Scientific objectives

I aim to perform dissections in successive planes so that, by photographing each plane of dissection, I obtain clear and detailed images that can be used as a guide for surgical manoeuvres.

For pelvic access, I propose to make transverse and, above all, sagittal and parasagittal sections through the pelvis, in order to obtain wide anatomical and surgical approaches which, although not usual in surgical practice, are nevertheless satisfactory for teaching and guidance. In practice, the bibliography studied suffers the disadvantage of not providing concrete anatomical details on the characteristics of the pelvic innervation.

The study on embryos is performed by microdissection with surgical loupes and brings an important benefit of the lack of adipose tissue in the dissection planes. This favours the identification of nerve structures and a didactically superior evaluation of them.

Method and methodology

My research is based on performing thorough dissections of the pelvic extraperitoneal space to identify the nerve structures that approach and serve the pelvic organs. To perform these dissections, I used formalinized cadavers found in the Anatomy Discipline's laboratory, as well as formalized embryos from the embryo collection of the Anatomy Discipline of the U.M.F. "Carol Davila" in Bucharest. Transverse and sagittal pelvic sections were previously performed for the dissections. Some of the dissections were performed on hemipelvises. For embryonic dissections we used surgical loupes. Dissection planes were photographed under special lighting conditions with circular lamps to avoid the formation of shadows. The images obtained were digitally processed, without interventions that could affect the scientific content. The data obtained were compared with data from the classical literature and translated into concise summary presentations for each image. The sequence of images obtained thus becomes very effective for understanding the distribution of ratios and topography of nerve structures.

The paper is comprised of a general part and a personal contributions part.

In the general part there are three chapters:

1. The development of the nervous system
2. The descriptive anatomy of the sympathetic nervous system
3. The descriptive anatomy of the pelvic parasympathetic nervous system.

These chapters present at length, after consulting a significant bibliography, the current level of knowledge on the structures of interest in doctoral study.

The personal contributions part is comprised of four studies:

– 1st study: Contributions to the topographical study of the parasympathetic and sympathetic nervous structures in the fetal pelvis;
– 2nd study: Contributions to the anatomical study of the superior hypogastric plexus;
– 3rd study: Contributions to the anatomical study of the inferior hypogastric plexus;
– 4th study: Contributions to the anatomo-imagistic bases of the piriformis syndrome.

Work hypothesis and general objectives

The vegetative innervation of the pelvic viscera is the substrate on which the nervous system performs complex control of pelvic organ function. This innervation is also the substrate on which information is transmitted from the pelvic viscera to the nervous system. Thirdly, the pelvic innervation is the afferent and efferent basis through which pelvic reflexes are carried out.

Accordingly, the description of the pelvic nerve structures, how they traverse the pelvis to the visceral target, and the relationships and topography of the pelvic nerves is the main premise of my study.

I propose to identify the main pelvic nerve structures along their entire route from the entrance to the pelvis to the target organs, describing the morphology of the nerve networks in relation to clear landmarks that can be used intraoperatively.

My research work comprises four studies:

– 1st study: Contributions to the topographical study of the parasympathetic and sympathetic nervous structures in the fetal pelvis;
– 2nd study: Contributions to the anatomical study of the superior hypogastric plexus;
– 3rd study: Contributions to the anatomical study of the inferior hypogastric plexus;
– 4th study: Contributions to the anatomo-imagistic bases of the piriformis syndrome.

The development of nerve structures in the foetus offers two great advantages. The first is the possibility to observe the whole, multi-regional, nerve structures corresponding to each system. The second arises from the fact that adipose tissue is not developed in the foetus, and therefore nerve structures can be clearly differentiated and perfectly separated from surrounding tissues.

The superior hypogastric plexus is the source of most of the pelvic sympathetic innervation. There are many situations in which the surgeon may intercept these nerve structures, so knowledge of their composition, topography and distribution can be of real benefit in abdominal-pelvic border surgery.

The inferior hypogastric plexus is a vast and dense nerve network located deep in the pelvisubperitoneal space. Although it has a well-structured individuality, it is in connection with the pelvic sympathetic and parasympathetic. Its distributions, particularly with regard to the fibres serving the cavernous structures, must be clearly known, because in modern surgery their protection is an important point [6, 7].

Compression of nervous structures related to the piriformis muscle results in one of the most complex pelvic pain syndromes. Identification of the critical point of compression necessarily requires knowledge of the distribution of the branches of the sacral plexus and detailed knowledge of the course and relationship of the internal pudendal nerve. I aim to explicitly identify the anatomical site of the piriformis muscle in relation to the adjacent nerve structures, as well as to identify the route of the most complicated pelvic nerve, namely the perineal and gluteal route of the pudendal nerve.

General research methodology

S My studies are mainly based on dissections, because I felt that, this way, I could carry out the most beneficial research, related to my specialty as a gynaecologist. The dissections were performed on formalinized cadavers in the Anatomy Discipline laboratory.

I have also performed fetal dissections on formalised cadavers of girls from the Anatomy Discipline collection.

Access to dissection plans was facilitated by making cross-sections, sagittal and parasagittal sections at pelvic level. In this way, dissection was made much easier, allowing the entire pathway of the pelvic nerve structures to be traced.

The dissection fields were prepared and digitally photographed in successive planes so that the information benefit to the surgeon was substantial.

The images obtained were edited, indicating each structure individually, so that we obtained highly suggestive plates for further analysis.

We also used MRI images obtained from the imaging clinic of the "Dr. Victor Babes" Medical Centre for Diagnosis and Treatment in Bucharest. These images were compared with the dissection plates, establishing radiologically observable anatomical criteria, useful in identifying and describing critical nerve relationships in the piriformis muscle region.

Please note that each study contains, in full, specific objectives and methodologies.

1st study: Contributions to the topographical study of the parasympathetic and sympathetic nervous structures in the fetal pelvis

Introduction

In the early fetal period (III-IV months), pelvic organs and somatic and vegetative nervous structures are already formed. The ratios are almost identical to those of the adult, but throughout the fetal period a growth process occurs which is different for different topographic regions. As a consequence of the pseudoascensus and pseudodescensus processes, ratios undergo a relative change during the fetal period until close to birth.

We believe that an embryo-fetal anatomical study aiming to highlight the vegetative nerve structures in the pelvis can provide valuable information on the evolution of the relationships of the nerve structures with the pelvic organs.

On the other hand, given the small size of fetuses, dissection can be performed in planes and incidences that are otherwise difficult to obtain in the adult pelvis.

Results – I am presenting the most significant pictures from this study.

Fig. 0.1.: Frontal view of the disposition of the pelvic vegetative nerve structures below the bifurcation of the iliac vessels.

1. abdominal aorta, 2. inferior vena cava, 3. common iliac artery, 4. internal iliac artery, 5. external iliac artery, 6. right obturator nerve, 7. psoas muscle, 8. ascending kidney, 9. sacral sympathetic chain with sympathetic ganglion S_2, 10. superior hypogastric plexus, 11. hypogastric nerves, 12 anterior aspect of the sacrum.

In this picture we have identified the pelvic parietal lymph nodes and their relationship to the vascular structures, but especially to the hypogastric and sacral sympathetic nerves.

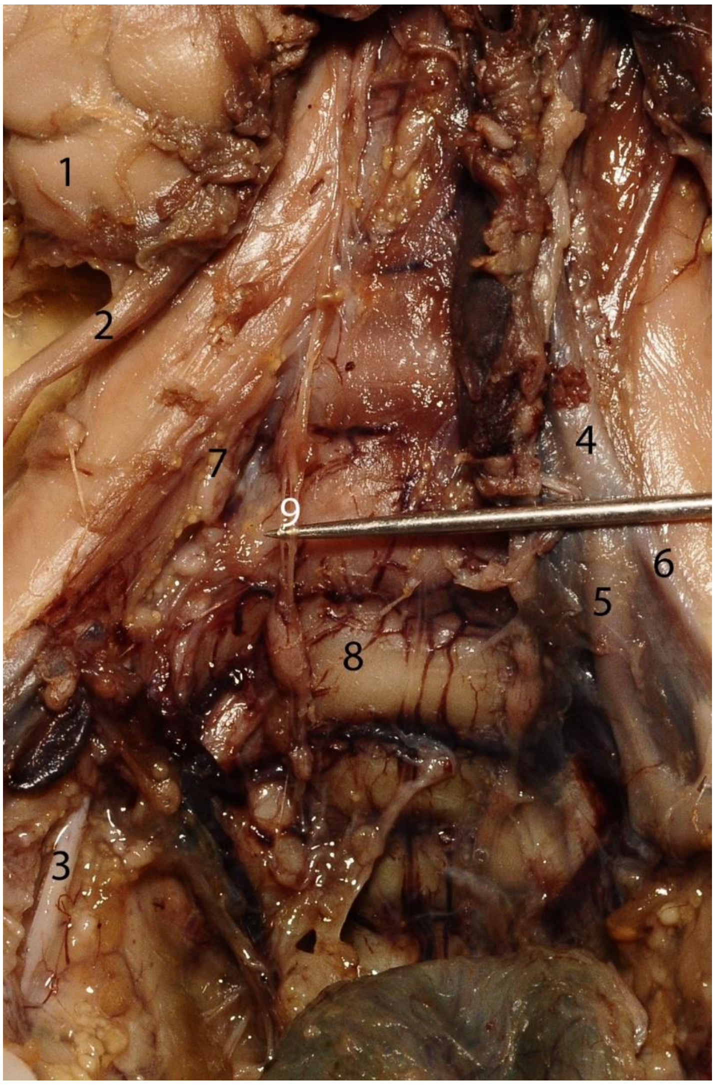

Fig. 0.2.: Identification of the presacral sympathetic chain.

1. kidney, 2. ureter, 3. obturator nerve, 4. left common iliac artery, 5. left internal iliac artery, 6. left external iliac artery, 7. right retroiliac lymph nodes, 8. sacrum with arterial network, 9. sacral sympathetic chain and sacral sympathetic nodes.

Conclusions and personal contributions for this study

– There are some major differences between the anatomical situations in the fetus and the adult:
  - The main difference is that the subperitoneal adipose tissue is not yet formed or is just beginning to form.
  - The upper hypogastric plexus initially appears as a dense cord of nerve fibres, more extensive than in the adult. Thus, the plexus starts preaortic and ends at the S3 level, compared to the situation in the adult, where it ends at the S1-S2 level. Consequently, the origins of the hypogastric nerves are lower in the fetus than in the adult.

    - The foetus lacks the connective-adipose lamina that connects the two hypogastric nerves. In this way, the nerves can be easily identified and their pathway is easier to quantify.
    - The critical surgical point for hypogastric nerve relationships is their relationship to the peritoneum. In the fetus it is more obvious that the hypogastric nerves descend into the pelvis tangent to the rectum and mesorectum and are immediately covered by the peritoneum. In the adult, identification of the laterorectal hypogastric nerves is much more difficult because they travel through a conjunctivoadipal atmosphere.
    - Emergent branches of the inferior hypogastric plexus can be obtained in the fetus by dissection in a single plane. This is extremely difficult to obtain in the adult. Topographically, fetal dissection demonstrates that the main network of the inferior hypogastric plexus is located pararectally, and the plexus emergences are grouped into an anterior, middle and posterior bundle. The anterior fascicle distributes to the bladder and genitals, the middle fascicle - to the rectum, and the posterior fascicle is represented by parasympathetic afferents from the pelvic splanchnic nerves.
    - The vascular structures on the anterior aspect of the sacrum are not the definitive adult ones. In the fetus there is a complex anastomosis between the anterior sacral arteries, with significant right-left anastomoses, from which the middle sacral artery is formed.
- From the point of view of lymphatic structures, we were able, through our dissection, to highlight the parietal pelvic lymph nodes. We have shown that they cluster around the main neurovascular formations, as follows: there are common iliac lymph nodes located superior and inferior to the trunk of the common iliac artery, but there are also retroiliac lymph nodes. We note that there are no mentions of the existence of these nodes in the studied literature.
- We have highlighted lymph nodes on either side of the internal and external iliac arteries. We have identified two ganglion groups accompanying the external iliac artery posterior to its entrance into the vascular gap. We found no citations in the literature about the existence of these ganglia.
- We identified lymph nodes distributed along the superior hypogastric plexus. In the literature, these midline presacral lymph nodes are cited as nodes located along the

middle sacral artery and represent an ascending retrograde lymphatic drainage pathway for the pelvisubperitoneal territory.

2nd study: Contributions to the anatomical study of the superior hypogastric plexus

Introduction

The autonomic nervous system controls the activity of the viscera. The parasympathetic component reaches the abdominal organs via the vagus nerve pathway and the pelvic parasympathetic pathway. The sympathetic component has neuron I in the anterior half of the lateral horns, and for the abdominal organs neuron II - in a prevertebral ganglion (celiac, renal, superior mesenteric and inferior mesenteric). These ganglionic groups send their post-ganglionic extensions to the viscera via the abdominal autonomic plexuses. A complex nerve network is thus formed, with a preaortic disposition, from which fine periarterial branches branch off to the viscera. Part of this network concentrates in the distal third of the abdominal aorta and forms the superior hypogastric plexus. It generally results from the union of two fibre contingents, a right and a left one. The route of the fibres of origin, the position and situation of the superior hypogastric plexus and the manner in which it emits its terminal and collateral branches are, however, subject to great variability [8]. This variability can sometimes surprise the surgeon performing regional procedures. We aim to identify the structures participating in the composition of the superior hypogastric plexus, focusing on their relationships and on highlighting situations that give concrete expression to structural variability.

Rezults – prezint, în continuare, două dintre imaginile cele mai sugestive.

Fig. 0.1.: Highlight of the mesopancreas.

1. Left gastric artery, 2. common hepatic artery flapped, 3. splenic artery, 4. right renal artery, 5. right renal vein, 6. celiac node, 7. mesopancreatic nerve lamina, instrumentally detached from the superior mesenteric artery, 8. portal vein severed and detached to the left, 9. pancreas severed at the level of the neck.

Fig. 0.2.: Interaorticocaval lymph node.

1. right renal ganglion, 2. left renal ganglion, 3. right testicular artery, 4. renal plexus efferents, 5. inferior mesenteric artery, 6. interaorticocaval lymph node.

Conclusions and personal contributions from this study

The nerve branches in the celiac ganglion that run around the superior mesenteric artery form a structure that in the literature is known as the mesopancreas. It should be pointed out that this is not a meso, but rather the persistence into adult life of the contents of the dorsal mesogastrium, corresponding to the duodenal loop and pancreas. Basically, the original mesosoma has disappeared and the main component of the mesopancreas is the nerve fibres of the mesopancreatic lamina. The particular surgical importance is based on the hypothesis that, by resecting the mesopancreas, the pathway of nerve metastasis of pancreatic cancer can be removed. In this way, it is assumed that survival time after duodenopancreatic cephalic surgery would be increased.

We demonstrate the presence of an interoroticocaval node in a topographic region where surgical access is particularly difficult.

We have demonstrated a rare topographic variant in which the descending abdominal aorta makes a loop to the left of the midline. Following this displacement, the inferior vena cava is evident and accessible in the frontal plane.

In this rare situation, the topography of the superior hypogastric plexus changes. The plexus forms to the left of the descending abdominal aorta and then passes anteriorly to the left common iliac artery and left common iliac vein. In this route there is a risk that the superior hypogastric plexus may be confused with the left gonadal vessels or left ureter.

Although the plexus forms to the left of the aorta, eventually the plexus tends to return to the midline.

We have demonstrated the position and classic appearance of the superior hypogastric plexus, on the midline, anterior to the promontory, and have highlighted the origin of the middle sacral artery and its relationship to the superior hypogastric plexus.

All these details are supportive elements for the surgeon in the course of performing rectal resections.

3rd study: Contributions to the anatomical study of the inferior hypogastric plexus

Introduction

The sympathetic prevertebral plexuses form a preaortically located network with dedicated ganglion stations (celiac, superior mesenteric, renal, inferior mesenteric ganglia). The preaortic nerve network continues into the pelvis via the superior hypogastric plexus. This divides into the two hypogastric nerves, which terminate on either side in a complex nerve network known as the inferior hypogastric plexus [9]. It has a variable and complex structure and distributes its branches into groups of fascicles destined for the pelvic organs [10]. The lower hypogastric plexuses receive a parasympathetic component via the sacral nerves and a pelvic sympathetic component via anastomoses with the parasacral sympathetic chains [11, 12]. The inferior hypogastric plexuses lie deep in the pelvis, in the subperitoneal space. Their identification, both by dissection and surgery, is highly difficult [13].

Modern surgical approaches involve specific resections, but with protection of nerve structures dependent on the hypogastric plexuses. This preserves sexual, glandular and sphincter functions.

From the dissection's point of view, the identification of the nerve network of the hypogastric plexuses is a significant achievement.

We propose to identify by dissection the entire network of the inferior hypogastric plexus, describing its formation and distribution territories.

Results – I chose two significant pictures from this study.

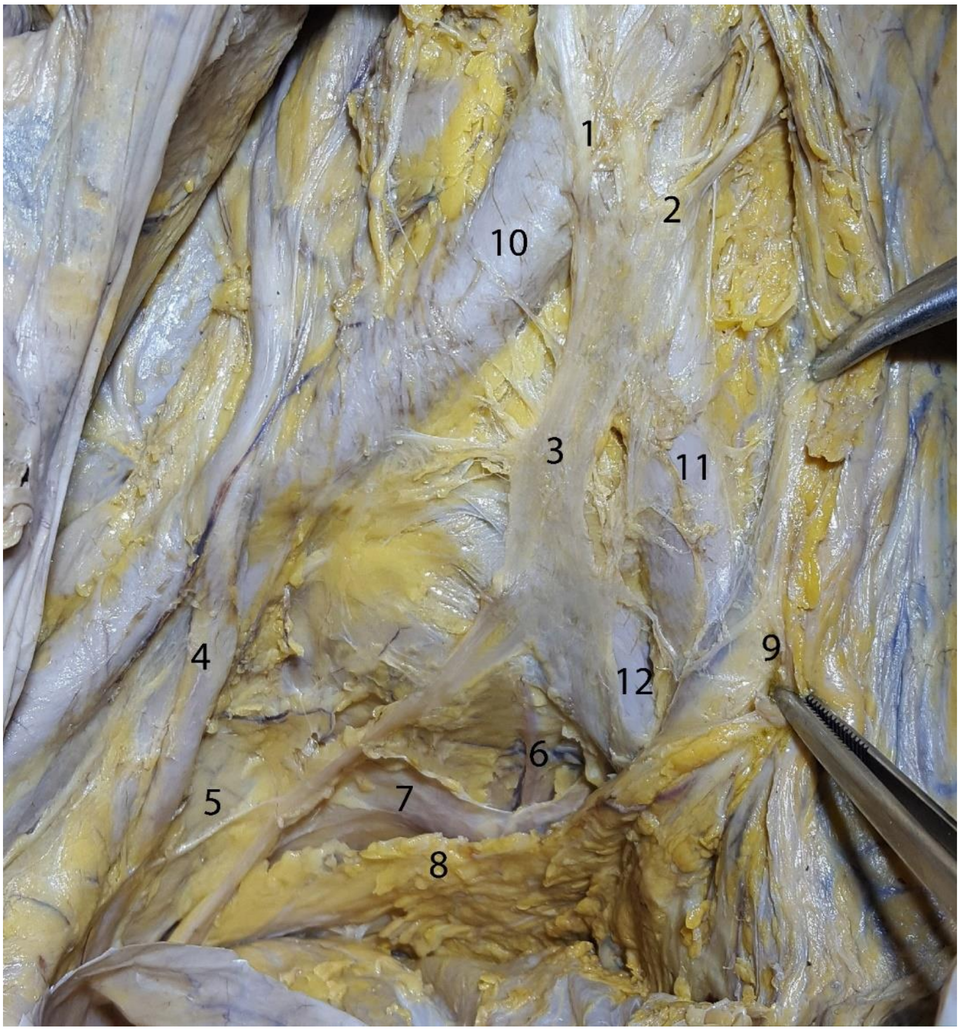

Fig. 0.1.: The superior hypogastric plexus - visible after removal of the peritoneum.

1. Right nerve bundle, 2. left nerve bundle, 3. superior hypogastric plexus, 4. right ureter, 5. nerve fibres for the right ureter, 6. middle sacral artery, 7. presacral fascia, 8. connective-adipose lamina between the hypogastric nerves, 9. posterior parietal peritoneum detached and drawn to the left, 10. right common iliac artery, 11. left common iliac artery, 12. left common iliac vein.

Fig. 0.2.: Origins of the lower hypogastric plexus.

1. External iliac artery, 2. internal iliac artery, 3. rectum, 4. fallopian tube and uterus, folded 5. piriformis muscle, 6. S3 nerve trunk, 7. pelvic splanchnic nerve, 8. origin fibres of the inferior hypogastric plexus, 9. lateral sacral artery, 10. superior gluteal artery, 11. tractioned ureter.

Conclusions and personal contributions for this study

After dissecting the hypogastric plexuses, we can draw some conclusions:

The dissection is difficult, the nervous elements are hard to reveal and have close relationships with the pelvic vessels and organs. Identification of the plexus is made only after the removal of the pelvic peritoneum and subperitoneal connective tissue. The nerve branches are relatively organized around the vessels serving the pelvic organs. Intraoperatively, injury to nerve structures can be avoided by performing an immediate subperitoneal dissection plane.

After formation, the hypogastric nerves diverge on the pelvic floor, maintaining a close relationship with the peritoneum, to which they remain attached during anatomical and surgical dissection. The branches of the inferior hypogastric plexus are variable and numerous and can be systematized into three main streams, anterior, middle and posterior, for the bladder, genitalia and rectum. The ureter is surrounded by the plexus branches, especially in its terminal region. It also receives, however, direct branches from the hypogastric nerve. The variability of hypogastric structures is real, with reference to position, thickness, appearance and branching.

In the vicinity of the target organs, the nerve structures are part of vascular-nervous plexuses and no intraoperative separation between vessels and nerves can be made.

Modern surgery aims to preserve nerve structures ('nerve-sparing') in pelvic organ resections. Virtually all surgical protocols take into account the preservation of pelvic nerves. In this context, our study, focusing on the identification, topography and evaluation of the distribution of nerve structures, is of particular importance. Practically, this is modern anatomy, in which dissection in planes, with the highlighting of sites, with the denudation and preservation of nerve structures, with the inventory of plexiform efferents and the description of local operative risk, brings an important contribution to the adaptation of operative strategies. Our study may represent a stage in the training process of young surgeons.

4th study: Contributions to the anatomo-imagistic bases of the piriformis syndrome

Introduction

The piriformis muscle is, as its name suggests, a flattened, pear-shaped muscle located deep in the gluteal region. Its origin is on the anterior surface of the lateral process of the sacrum (segments S2-S4), on the anterior portion of the sacroiliac joint capsule, on the gluteal aspect of the ilium, in the vicinity of the great ischial incision, and sometimes at the level of the sacrotuberous ligament. The insertion of the piriformis muscle is on the medial face of the superior portion of the greater trochanter femoris, where its tendon, together with those of the superior and inferior gemellus muscles and the obturator internus muscle, unite to form the conjunctival tendon. The piriformis muscle passes from the posterior region of the pelvis to the gluteal region through the great ischiadic notch. Its innervation is provided by the anterior branches of the S2 and S3 sacral nerves, originating from the sacral plexus [14].

The sciatic nerve is the largest peripheral nerve of the human body and is a terminal branch of the sacral plexus. It consists of two components, the tibial and common peroneal nerves, united into a single nerve trunk, which remains in this form in its course through the pelvic cavity, the gluteal region and the posterior compartment of the thigh to the level of the superior angle of the popliteal fossa, where the two components separate.

Sometimes the close relationship between the piriformis muscle and the sciatic nerve can cause compression of the latter, a phenomenon called piriformis syndrome [15].

There is significant variability in the relationship between the piriformis muscle and the sciatic nerve, with six possible anatomical variants [16]:

I. the sciatic nerve passes under the piriformis muscle;

II. the two components of the sciatic nerve pass through and under the piriformis muscle respectively;
III. the two components of the sciatic nerve pass over and under the piriformis muscle;
IV. the sciatic nerve passes entirely through the piriformis muscle;
V. the two components of the sciatic nerve pass over and through the piriformis muscle;
VI. the existence of an accessory piriformis muscle of smaller size and a separate tendon located below the piriformis muscle, with the sciatic nerve passing between them. According to expert studies, the most common variant is that of an undivided sciatic nerve passing under the piriformis muscle. [17].

Pyriformis syndrome is often misdiagnosed, being mostly confused with neuropathies due to disc compression at the level of the plexus roots or with other causes of pain in the gluteal or hip region: trochanteric bursitis, sacroiliitis, sciatica [18].

Sciatica is a musculoskeletal pain felt in the lower limb, in the innervation territories of the sciatic nerve, which can sometimes be accompanied by back pain. [19].

Deep gluteal syndrome is a condition defined as a set of clinical signs and symptoms that may occur in isolation or in various associations, the most common of which is pain and/or tenderness in the gluteal, hip or posterior thigh region. Symptoms are usually unilateral, but may also occur bilaterally [20, 21].

Piriformis syndrome is considered to be a type of deep gluteal syndrome arising from causes such as dynamic compression of the ischial nerve by the piriformis muscle, asymmetric hypertrophy of the piriformis muscle with anterior thrust of the ischial nerve, various anatomical variants of the sciatic nerve pathway in relation to the piriformis muscle [22].

Consequently, our study is based on the idea that in such a complex topographic region, located at the border between the pelvis, the ischiorectal fossa and the gluteal region, the anatomical landmarks for the identification of the nerve structures must be very well known and their relationships - well described. Given the presence of numerous nerve structures that may undergo compression along their own course, we also aim to identify possible criteria for differentiation between piriformis syndrome caused by ischial nerve compression and loco-regional nerve syndromes caused by compression of other nerves.

Results – I have chosen two suggestive images to illustrate.

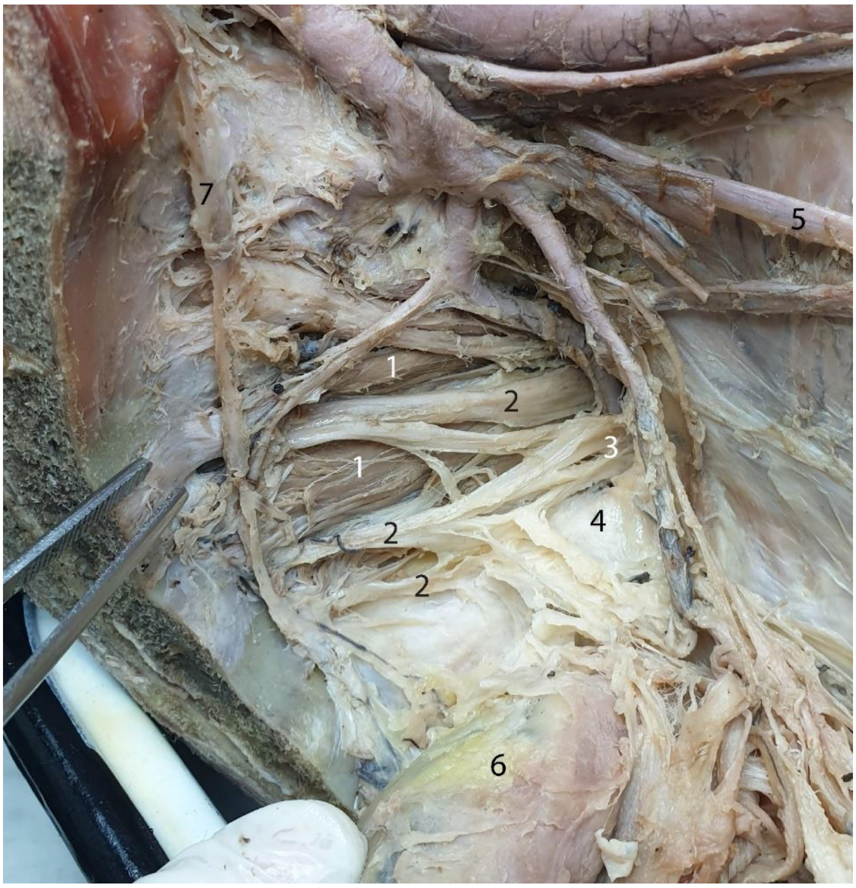

Fig. 0.1.: Pudendal nerve formation.

1. Piriformis muscle, 2. anterior branches S2, S3, S4, 3. pudendal nerve which engages through the great ischiadic notch, superior to the ischiadic spine, 4. sacrospinous ligament, 5. obturator nerve 6. rectus, 7. sympathetic chain.

Fig. 0.2.: Opened Alcock's canal.

1. Resection line of the anal levator muscle, 2. internal obturator muscle, 3. common tendon of the internal obturator, 4. vascular-nerve content of the Alcock canal (after removal of fascial structure), 5. fat of the superior recess of the ischiorectal fossa, 6. pubo-vaginal muscle, 7. coccygeal muscle, 8. sacrospinous ligament, 9. pudendal nerve.

Conclusions and personal contributions for this study

On the pathway of the ischial nerve and the vascular-nerve bundle we can describe several relationships that might be involved in the nerve compressions that generate the piriformis syndrome.

We have clearly established bony and muscular anatomical landmarks that are extremely useful in the evaluation of vasculo-nervous structures by MRI.

Several aspects are particularly important for imaging assessment of the pathway of these nerves:

– Identification of the piriformis muscle in the large ischial incision;

- Identification of the internal obturator muscle and its tendon path around the ischiadic spine;
- Assessment of the superior and inferior edges of the ischial spine;
- Sequential, regional assessment of vascular-nerve tracts.

We point out that the difficulties of imaging assessment using MRI are created by the specific orientation of the pelvis. Furthermore, the oblique orientation of the sacrum and piriformis muscle, the arcuate course of the internal obturator muscle around the ischial spine, and the fact that the rudimentary vascular bundle has both an extrapelvic and intrapelvic course are additional criteria that make assessment difficult.

The course of the pudendal nerve has several regions in which it can be compressed, thus generating neurological syndromes:

- Intrapelvic, the pudendal nerve may be compressed in the anteroinferior part of the piriformis muscle, when, by contraction of the piriformis muscle, the nerve is pressed on the superior border of the sacrospinous ligament.
- Between the piriformis muscle and the inferior border of the greater ischial incision there is a laminar space, which contains: posteriorly the ischial nerve, intermediately the internal pudendal artery and the superior gluteal artery, and superiorly the middle gluteal artery and the pudendal nerve, in direct contact with the superior border of the ischial spine (this is anterior). Note that at this point the pudendal nerve cannot be clearly identified on MRI images. This is, however, a region where nerve compression is described according to the definition of piriformis syndrome.
- Another critical region is found extrapelvic, in the medial part of the infrapiriform space. In this space, the pudendal bundle has the following route: at the entrance to this space, the pudendal bundle is located between the inferior border of the piriformis muscle and the upper part of the ischiadic spine. The bundle then wraps laterally, extrapelvically, around the ischial spine. The bundle then re-enters the pelvis through the small ischial incision, in contact with the lower edge of the ischial spine. Basically, the rudimentary fasciculus passes between the spine and the superior gemellus and internal obturator muscles.

Intraperineally, the pudendal bundle follows the established pathway, on the internal face of the internal obturator muscle, inside the Alcock canal. Here, the nerve cannot be compressed by an extrinsic compression mechanism. Eventually, a fibrosis of the fascial system that forms the Alcock canal could strangle the nerve.

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List of published articles in the subject of the doctoral thesis

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