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ORIGINAL ARTICLE

Morphological peculiarities of the autonomic nervous system in the thoracic region

Štefan Galbavý[1,2], Ján Šikuta[1,3], Peter Očko[3], Ľubomír Mikuláš[3], Dávid Toma[4], Michal Kováč[3], Enrico Čambál[1,3]

1 Institute of Forensic Medicine, Faculty of Medicine, Comenius University, Sasinkova 4, 81108 Bratislava, Slovakia.
2 Institute of Laboratory Medicine, Faculty of Medicine, St. Elizabeth University of Health and Social Sciences, Comenius University, Bratislava, Slovakia.
3 Medico-legal Department of Health Care Surveillance Authority, Antolská 11, 85107 Bratislava, Slovakia.
4 Department of Neurosurgery, Faculty of Medicine, Comenius University, University Hospital, Limbová 5, 833 05 Bratislava, Slovakia.

Correspondence to: Ján Šikuta, MD, Ph.D.
Institute of Forensic Medicine Faculty of Medicine, Comenius University, Sasinkova 4, 811 08 Bratislava, Slovak Republic
TEL: +421 948060981, +421 220856661, FAX: +421 220856556,
E-MAIL: jan.sikuta@gmail.com

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Abstract

BACKGROUND: The aim of the work is to define the morphological peculiarities of the autonomic nervous system (ANS) in the thoracic region.
MATERIAL AND METHODS: An anatomical study was performed on 20 cadavers, 17 men and 3 women. We studied cadavers within 24 h of death. We observed the vertebral and prevertebral section of the truncus sympathicus, their morphological peculiarities depending on the type of ANS. To show the intimate relationship of both systems, we also focused on the details of the structure related to the connections of the ANS with the spinal nervous system.
RESULTS: In the thoracic region, the segmental arrangement of the truncus sympathicus ganglia prevailed in 16 (80%) cases. Rami communicantes gave anastomoses to spinal nerves. Small ganglia were observed on the rami communicantes to the spinal nerves. In the case of the concentrated type, in 4 cases (20%), we observed a reduction in the number of ganglia, as well as the absence of small ganglia on the connecting branches. Connections between n. vagus and sympathetic branches were poorly developed. We observed right-left asymmetry and differences in the formation of ganglia and anastomoses in the truncus sympathicus in the vertebral and prevertebral section. Variations of distance of n. splanchnicus major were observed in 16 cases (80%).
CONCLUSION: This study allowed us to identify and describe the morphological peculiarities of the thoracic ANS. The variations were numerous; their preoperative diagnosis is difficult to impossible. The knowledge gained can be helpful in clarifying clinical signs and symptoms.

Abbreviations:

ANS	- autonomic nervous system
TSN	- thoracic splanchnic nerves
TH	- Tyrosine hydroxylase (TH)
VAChT	- vesicular acetylcholine transporter

INTRODUCTION

PThe autonomic nervous system (ANS) is the part of the peripheral nervous system, the system of nerves and ganglia that innervates the internal organs, including blood vessels, heart, smooth muscles, pupils, intestine, and sweat, salivary, and digestive glands, controlling their involuntary functions (Karemaker, 2017; Kuruc *et al.* 2023). The autonomic nervous system consists of three divisions: sympathetic, parasympathetic and enteric nervous system (Gray, 2010; Sasselli *et al.* 2012).

Human body exhibits a certain degree of differences and abnormalities in terms of its shape, structure, position etc. Anatomical variations are not only very interesting and thought provoking for anatomists but also for pathologists, forensic physicians and clinicians (Kuruc *et al.* 2023). There are different types of anatomical variants and peculiarities. They can be sporadic, infrequent or frequent. Frequent variations can even reach up to 100% occurrence (Kachlík *et al.* 2020). Many anatomical variants do not require clinical attention, but some may present diagnostic problems or cause adverse clinical symptoms. The basis for a correct understanding of these disorders must be the peculiarity of the structure of the plexuses, peripheral nerves, and ANS. These peculiarities can explain the contradiction and diversity of clinical manifestations (Georgiev, 2017).

The thoracic splanchnic nerves (TSN) are medial branches of the thoracic sympathetic trunk (Tubbs *et al.* 2016). TSNs conduct pain from internal organs from around the celiac ganglion (Haroun, 2018). Sympathetic innervation starts from the anterolateral corners of the spinal cord and continues along the path of rami communicantes albi, truncus sympathicus and splanchnic nerves. Visceral pains from abdominal organs are conducted from the celiac ganglion via the thoracic splanchnic nerves, sympathetic ganglia, rami communicantes albi and dorsal spinal ganglia (Ehrhardt *et al.* 2022; McCausland & Sajjad, 2022). These pains spread further through the spinothalamic tract. They play an important role in the treatment of abdominal disorders. The diversity and variability of clinical manifestations is because one and the same nerve contains different amounts of myelinated and unmyelinated fibers (Matejčík & Kuruc, 2022; Sakthivel & Manjunath, 2016).

Knowledge of the structure of the thoracic ANS must be the basis for a correct understanding of ANS disorders (Loukas *et al.* 2010). These peculiarities can explain the contradiction and diversity of clinical manifestations (Matejčík *et al.* 2019). In the literature devoted to the peripheral nervous system, the question of anatomy, histology and function is elaborated in relatively detail, however, in the aspect of tracking the pathogenesis insufficient attention is paid to the mechanisms and semiotics of ANS disorders (Gest & Hildebrandt, 2009; Edwards & Baker, 1940; Kommuru *et al.* 2014). The TSNs and celiac ganglia have been of anatomical and clinical interest in the fields of pancreatic cancer and pancreatitis for many years, particularly for their role in pain management (Hajjar *et al.* 2016; Yang *et al.* 2008). Anatomical, and especially surgical, textbooks usually do not pay enough attention to the anatomical peculiarities of the ANS, which can complicate the solution of many pathologies and consequently, medical care (Jit & Mukerjee, 1960). We have come across literature and scientific publications devoted to this issue (Thangaraj & Nagarajan, 2018). Only rare did we come across publications focused on bilateral morphological deviations in the formation of the peripheral ANS in the thoracic region. As a rule, these were works related to individual nerves and ANS plexuses (Beveridge *et al.* 2015; Costello *et al.* 2004).

With this in mind, we conducted a study aimed at determining the morphological peculiarities of the peripheral ANS in the thoracic region. Interest in the precise anatomy of the ANS has increased with the introduction of the telerobotic method of treatment, where magnification and perfect illumination allow easier preservation and treatment of neural structures (Moore & Dalley, 2006; Swell, 2004). Currently, there are such treatment trends that it is possible to plan and thus specify both medical care (Andtbacka *et al.* 2004; Matejčík & Kuruc, 2022).

MATERIALS AND METHODS

Detailed dissections were performed on 20 cadavers. The study included 17 men (85%) aged 18 to 84 and 3 women (15%) aged 27 to 86. The average age was 53.8 years. The subjects most often died by violent death in car accidents, by asphyxia, or by sudden death. The study was approved by the Institutional Ethics, Arbitration, and Disciplinary Committee of the Health Care Surveillance Authority (Approval Code 2/2022). We observed cadavers without congenital or detected anomalies, cancer, deformities of the body, or spinal, thoracic and abdominal operations within 24 hours of death. In all of them, the ANS was clarified bilaterally.

The body was lying down. Subsequently, a "scarf" skin incision was made bilaterally along the clavicle to its lateral part, the skin and subcutaneous tissue were deviated upwards, the clavicles were separated from the sternal manubrium, the ribs were cut in the midaxillary line, and the anterior chest wall was removed. After examination and removal of the lungs and mediastinal contents, the parietal pleura was carefully retracted to expose the prevertebral sympathetic chains, ganglia, and thoracic splanchnic nerves. Most of the diaphragm

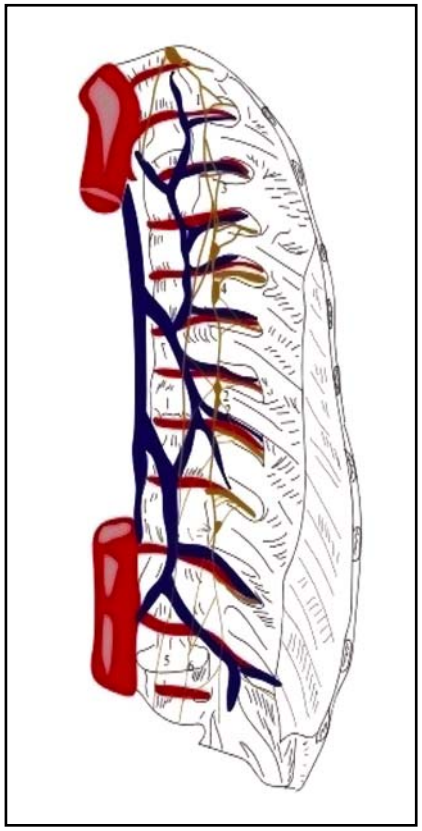

Fig. 1. Unevenly placed ganglia along the truncus sympathicus from the left; segmental type.

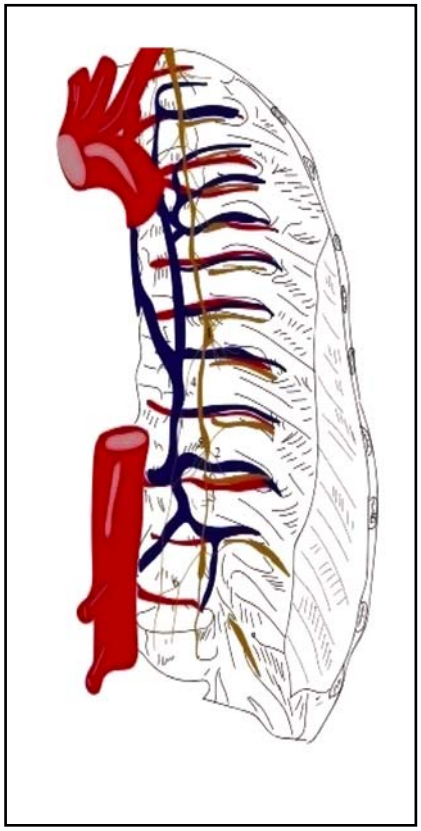

Fig. 2. Unevenly placed truncus sympathicus ganglia from the left; concentrated type.

was removed except for the parts that were firmly attached to the posterior chest wall. After identifying the thoracic sympathetic ganglia, the sympathetic chain and the thoracic splanchnic nerves, the connections between the ganglia and the thoracic splanchnic nerves were traced. A very detailed forensic dissection was performed in all cases. In order to identify the thoracic and splanchnic ANS, we performed dissections of this area with the use (with the help) of a magnifying glass.

Histological techniques (hematoxylin and eosin) and immunohistochemical analysis (Tyrosine hydroxylase (TH) and Specific vesicular acetylcholine transporter (VAChT) antibodies) were used to reliably identify ganglia obtained during dissections to determine whether the identified tissue structures contained neurons. We used polyclonal Anti-Tyrosine Hydroxylase Antibody (product No. AB152, Sigma-Aldrich) and Monoclonal Anti-Vacht antibody produced in mouse (product No. SAB5200240, Sigma-Aldrich). For both, TH and for VAChT staining, were used concentrations of 1:100 and 1:200.To show the intimate relationship of both systems, we also focused on the details of the structure (rami communicantes) related to the connections of the ANS with the spinal nervous system.

Since we did not come across a division of the ANS according to the number of ganglia in the available literature, we used our own classification system. We used 12 ganglia with respect to 12 thoracic spinal cord segments as a classification limit. The authors consider it appropriate to classify the type of thoracic ANS according to the number of ganglia. We used this type of classification due to highly probable different clinical course and clinical symptoms, especially pain radiation, depending on the number of ganglia and their interconnection.

RESULTS

We observed morphological variations of the thoracic ANS in all cases of the vertebral and prevertebral section. According to the number of ganglia, the variations were classified as segmental type (12 or more) and concentrated type (less than 12). We observed the segmental type (Fig. 1) in 16 (80%) cases (interval 13 to 16 ganglia) and the concentrated type (Fig. 2) in 4 (20%) cases (interval 8 to 10 ganglia).

The segmental type was found in 14 men and 2 women, and the concentrated type was found in 3 men and 1 woman (Tab. 1). We observed right-left asymmetry (Tab. 2) and differences in the formation of ganglia and anastomoses in the truncus sympathicus in the vertebral and prevertebral section depending on the type of ANS.

Rami communicantes gave anastomoses to the spinal nerves. Small ganglia were observed on rami communicantes (Fig. 3, Fig. 4). In the chest section truncus sympathicus, the segmentation was the most pronounced. Each ganglion tr. sympathicus was joined with the help of rami communicantes with the spinal nerve within the segmental arrangement. Differences in

Tab. 1. Division according to the type of formation ANS.

Men	Women	Type of formation of peripheral ANS	
		Segmental type	Concentric type
17	3	16 14 Men; 2 Women	4 3 Men; 1 Woman

Tab. 2. Division according to lateral asymmetry in the truncus symphaticus of the thoracic ANS.

Men (17)		Women (3)	
Right	Left	Right	Left
7	10	1	2

construction rami communicantes were dependent on the overall nature of the system structure. In the case of the concentrated type, we observed the decrease in the number of ganglia, as well as the absence of small ganglia on the connecting branches. Links between nervus vagus and sympathetic nerves were poorly developed. At nervus splanchnicus major we observed anatomical variations of distance of nervus splanchnicus major in 16 cases (80%).

DISCUSSION

This study is the first description of morphological peculiarities with relation to the clinic of the thoracic ANS in fresh cadavers. In this work, we provide a systemic view of the sources and distribution of nerve ganglia, and plexuses, depending on its type.

The formation of the peripheral sympathetic system is influenced by the bilateral migration of neuroblasts from the neural groove after the fourth-fifth week of development Sadler, 2011). Morphological peculiarities of the ANS can cause symptoms on several levels. Their preoperative diagnosis is difficult. When we consider the comparable anatomical and embryological data, we can say that when the development of the sympathetic system slows down, we can find it during cell migration that is, on rami communicantes and near the roots, small ganglia, and the segmental arrangement of ganglia of the truncus sympathicus (Gebretsadik *et al.* 2018; Cho *et al.* 2005). In other cases, when the development continued faster, we can observe a decrease in the number of ganglia in the structure of the truncus

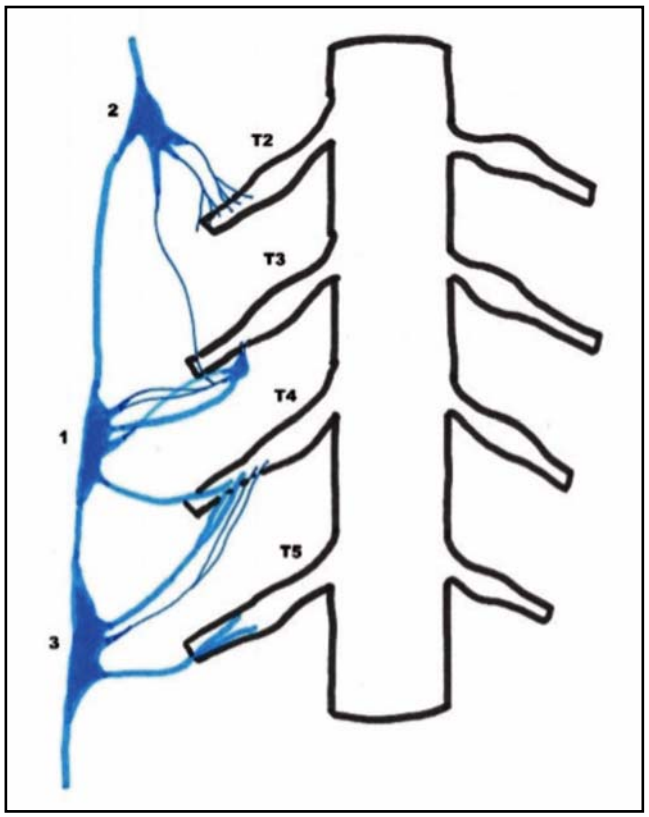

Fig. 3. Connections of one spinal nerve (T4) with two ganglia of sympathetic trunk (1) (3).

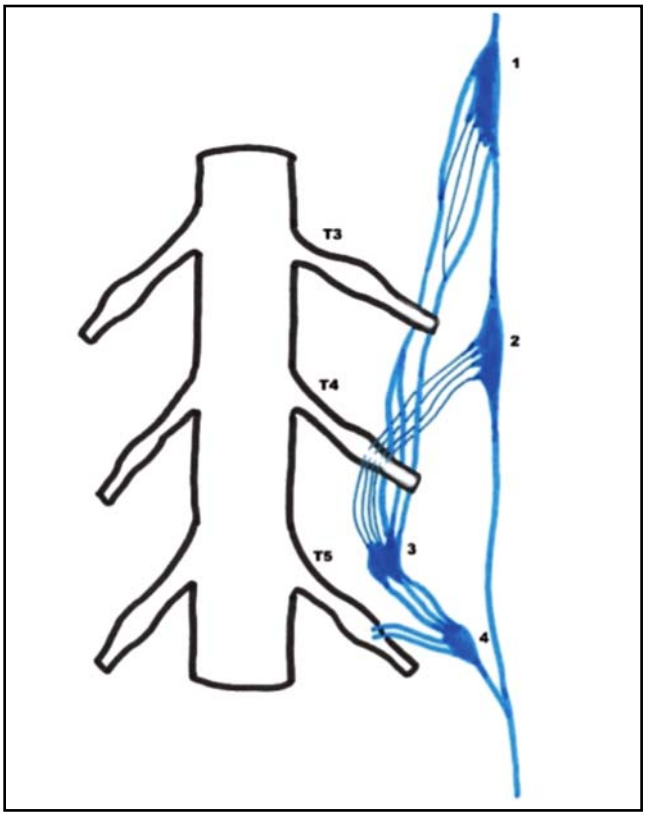

Fig. 4. T4 nerve is connected on one side by a series of parallel rami communicantes with the ganglion located along the sympathetic trunk (2) and other with the sympathetic ganglia located on the lower connecting branches (3) (4), while one of the last ganglia (3) being connected to the distant ganglion of the sympathetic trunk (1). So the T4 nerve in this case is connected to four sympathetic ganglia.

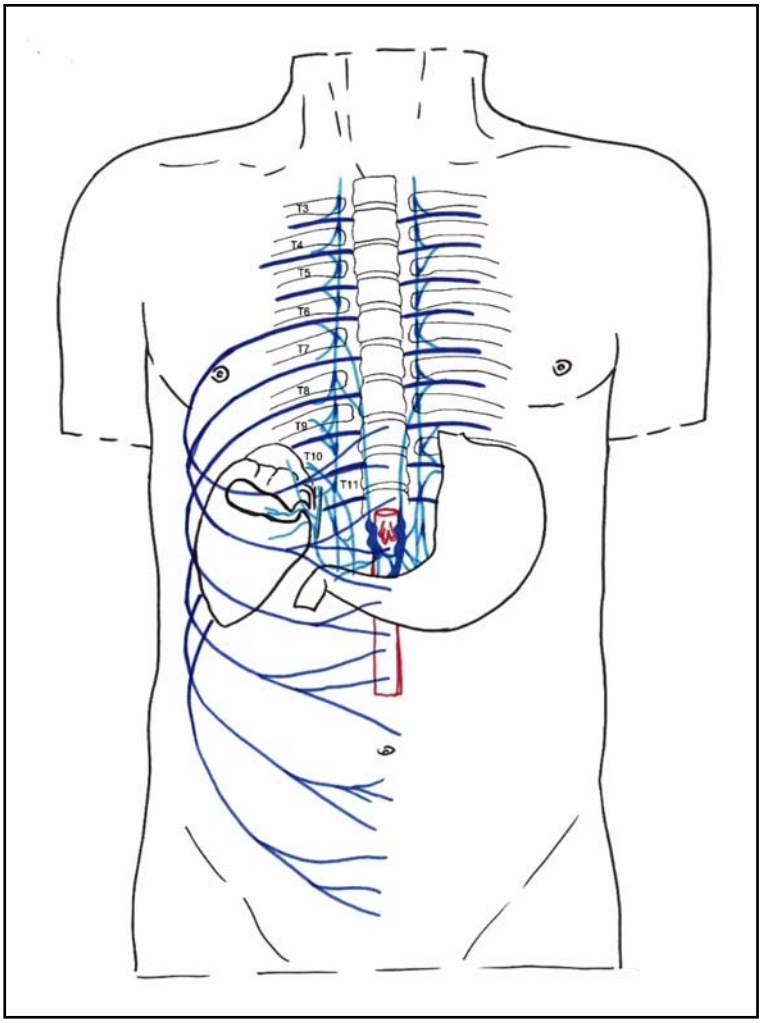

Fig. 5. Radiation of pain in diseases of the liver or bile ducts from the coeliac plexus in the low type of formation of the greater splanchnic nerve.

sympathicus, the absence of small ganglia on the connecting branches (Bergman *et al.* 2015).

Links between nervus vagus and sympathetic branches was poorly developed. It is difficult to imagine that differences in the structure of the ANS would not be reflected in the nature of the difficulties. It is already known and a certain agreement of anatomical differences with differences in the clinical picture is observed in the spinal system, where there are greater opportunities for clinical monitoring than in the ANS. Irritation originating from the internal organs spreads to the corresponding segments of the spinal cord and subsequently manifests itself in the periphery (Haviarová *et al.* 2020). Anatomical differences in junctions between the autonomic and spinal systems are important. In cases where one ganglion is connected with several spinal nerves, the irritation will spread to a number of segments, sometimes seemingly unrelated to the diseased organ (Kuruc *et al.* 2019).

The instability of pain and the complexity of the body's overall pain reactions depend on the individual characteristics of the patient, the nature of the reactions of the nervous system, and in each individual case, on the existing peculiarities of the structures of the ANS as a whole. The instability of the junctions may explain the instability of these symptoms. Paths of pain radiation and points of their localization, it is difficult to determine their specificity for a particular organ, can explain the instability of these systems (Balík & Šulla, 2022).

The variations in our set were numerous; their preoperative diagnosis is difficult to impossible. We analyzed the formation of the thoracic ANS in 20 cadavers. The concentrated type occurred in 4 (20%) cases and the segmental type of ANS formation in 16 (80%). With a smaller number of ganglia (concentrated type), some ganglia are connected to a larger number of segments, which results in a possible different clinical course than with the segmental type. Variations of the ANS were described in the past in the literature. We have come across scientific publications devoted to this issue (Vanlommel *et al.* 2022). Only rare did we come across publications focused on bilateral morphological deviations in the formation of the peripheral ANS in the thoracic region. As a rule, these were works related to individual nerves and ANS plexuses (Beveridge *et al.* 2015; Costello *et al.* 2004). We did not come across works dealing with variations of the entire thoracic ANS bilaterally, but rather, we found papers dealing

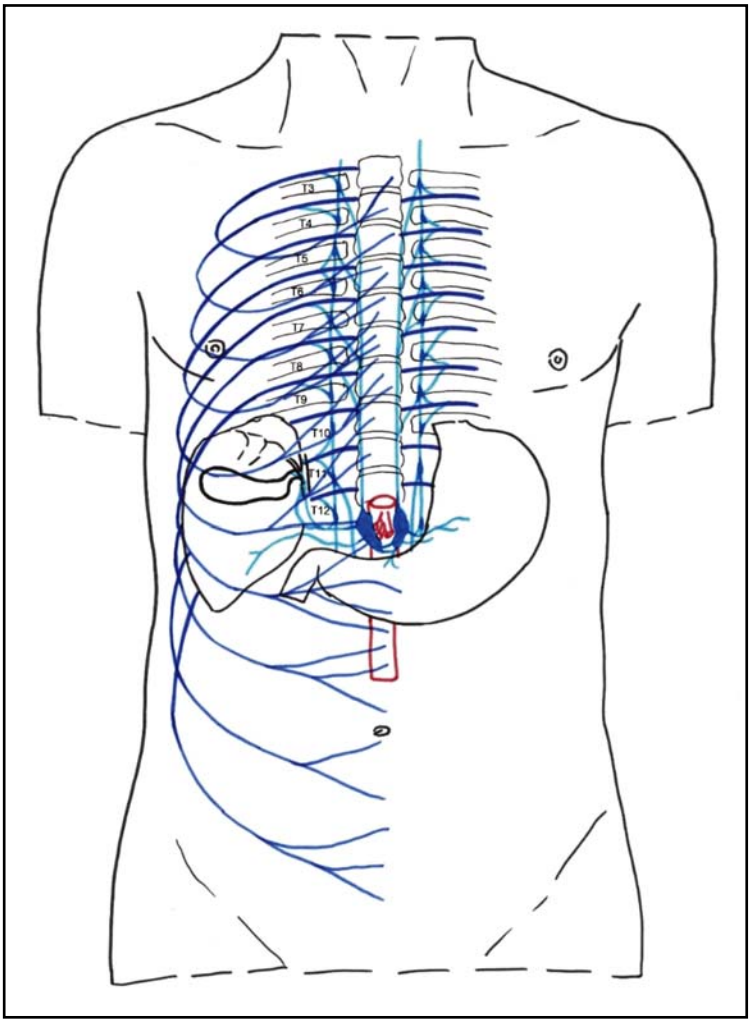

Fig. 6. Radiation of pain from the coeliac plexus in the high type of formation of greater splanchnic nerve.

only with the variations of individual ANS nerves (Haroun, 2018).

In our set, we observed them in all cases. At nervus splanchnicus major we observed anatomical variations of distance of nervus splanchnicus major in 16 cases (80%). Figures 5 and 6 show the possible irradiation of pain in diseases of the gallbladder with low (Fig. 5) and high (Fig. 6) type of formation of n. splanchnicus major. Nn. splanchnic connect the plexus coeliacus with the truncus sympathicus in the chest area and through it and rami communicantes with the corresponding segments of the spinal cord, differences in the levels of formation of these nerves can clarify the peculiarities of pain irradiation in diseases of internal organs (Georgiev, 2017).

The management of gastroenteropancreatic carcinoma has been challenging for the physicians (Darbà & Ascanio, 2019). The therapeutic objective is focused in cure by surgery, and if this is not possible, in palliation. This palliation is based on goals: control of disease, extension of survival, maintenance of quality of life and pain relief (Bosanquet *et al.* 2016). Splanchnicectomy is a surgical interruption of splanchnic nerves for management of pain caused by chronic pancreatitis, carcinomas of the pancreas, liver, gallbladder, alimentary tract. One of the main problems in the use of thoracoscopic splanchnicectomy for pain relief is the uneven result of the procedure, mainly because of insufficient anatomical information (Hajjar *et al.* 2016). Most of the anatomy textbooks describe little variations in the anatomy of the TSNs. As a result, surgical intervention on such scant information often lead to uneven degrees of symptom relief (Thangaraj & Nagarajan, 2018). More detailed anatomical information about TSNs will help surgeons in their quest for more precise practice.

CONCLUSIONS

The description of thoracic ANS and its variants described in this cadaver study may be useful when carrying out thorax operation in this anatomical region. Absence or lack of intraoperative vigilance can lead to the thoracic ANS damage. It is necessary to realize that insufficient knowledge, misunderstanding of the basic pathophysiological mechanisms, can lead to wrong considerations and implementation of incorrect medical procedures, which can endanger the health and life of the patient. We believe that the data obtained from anatomical dissections can be helpful for many

surgeons. Patient care in surgery is very demanding and requires both the physician to possess adequate knowledge, to use critical thinking, and to engage a close cooperation with all members participating in the provision of health care.

Our study is influenced by several factors such as the small number of observations and the significant difference in the number of men and women in the study population. These are the limits affecting the interpretation and generalizing our findings.

AUTHOR CONTRIBUTIONS

Conceptualization, G. S., L.M.; formal analysis, J. S., D.T.; writing – original draft preparation, G. S., J. S., P. O., L. M., D.T., M.K. and E. C.; writing – review and editing, J. S. and E. C. All authors have read and agreed to the published version of the manuscript.

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INSTITUTIONAL REVIEW BOARD STATEMENT

The Figures used in the presented publication depict the anatomical situation obtained by careful dissection of cadavers and within the forensic expertise with the approval of the Ethics Committee of the Health Care Surveillance Authority, Žellova 2, 829 24 Bratislava, Slovakia. All studies related to peculiarities of autonomic nervous system meet all applicable standards, rules, regulation, and laws imposed by supervised by the responsible officials.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

Not applicable.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL AND INFORMED CONSENT

This study was approved by Institutional Ethics, Arbitration, and Disciplinary Committee of the Health Care Surveillance Authority (Approval Code 2/2022).

REFERENCES

1 Andtbacka RH, Evans DB, Pisters PW (2004). Surgical and endoscopic palliation for pancreatic cancer. Minerva Chir. **59**(2): 123–36.
2 Balík V, Šulla I (2022). Autonomic Dysreflexia following Spinal Cord Injury. Asian Journal of Neurosurgery. Vol. **17** No. 2: 165–172.
3 Bergman RA, Afifi KA, Miyauchi R. Illustrated Encyclopedia of Human Anatomic Variation. Opus III: Nervous System. 2015. Available. online: https://www.anatomyatlases.org/AnatomicVariants/NervousSystem/Introduction.shtml (accessed on 17 December 2022).
4 Beveridge TS, Johnson M, Power A, Power NE, Allman BL (2015). Anatomy of the nerves and ganglia of the aortic plexus in males. J Anat. **226**(1): 93–103.
5 Bosanquet DC, Wilcox CR, Rasheed A (2016). Bilateral Thoracoscopic Splanchnotomy to Alleviate Pain in Chronic Pancreatic Disease. Ann Thorac Surg. **101**(3): e91–e93. doi:10.1016/j.athoracsur.2015.10.019
6 Costello AJ, Brooks M, Cole OJ (2004). Anatomical studies of the neurovascular bundle and cavernosal nerves. BJU Int. **94**(7): 1071–6.
7 Darbà J, Ascanio M (2019). Therapy for Gastroenteropancreatic Neuroendocrine Tumors: drug evaluation reports review in Spain. Neuro Endocrinol Lett. **39**(8): 537–543.
8 Edwards LF, Baker RC (1940). Variations in the formation of the splanchnic nerves in man. Anat Rec. **77**(3): 335–42.
9 Ehrhardt JD, Weber C, Lopez-Ojeda W (2022). Anatomy, Thorax, Greater Splanchnic Nerves. In: StatPearls. Treasure Island (FL): StatPearls Publishing; August 8.
10 Gandhi KR, Verma VK, Chavan SK, Joshi SD, Joshi SS (2013). The morphology of lumbar sympathetic trunk in humans: a cadaveric study. Folia Morphol (Warsz). **72**(3): 217–22.
11 Gebretsadik MA, Mulu A, Dessie MA, Anderson BB (2018). Morphological variation of thoracic splanchnic nerves in selected Ethiopian cadavers, Gondar and Mekelle, Ethiopia. Int J Anat Var. **11**(3): 93–98.
12 Georgiev GP (2017). Significance of anatomical variations for clinical practice. Int. J. Anat. Var. **10**: 43–44.
13 Gray H (2010). The nervous system, the sympathetic nervous system. In: Gray's anatomy, 15th edn. (eds Pick TP, Howder R); New York: Barner's Noble, pp. 779–91.
14 Gest TR, Hildebrandt S (2009). The pattern of the thoracic splanchnic nerves as they pass through the diaphragm. Clinical Anatomy. **22**: 809–14.
15 Hajjar NA, Mois E, Graur F, Elisei R (2016). Thoracoscopic splanchnicectomy. Advanced Laparoscopy.
16 Haroun HS (2018). Clinical anatomy of the splanchnic nerves. MOJ Anat & Physiol. **5**: 88–91.
17 Haviarová Z, Matejčík V, Kuruc R, Líška J, Halgaš F (2020). Intraspinal characteristics of thoracic spinal nerve roots anomalies. Br J Neurosurg. **34**(1): 72–75.
18 Cho HM, Lee DY, Sung SW (2005). Anatomical variations of rami communicantes in the upper thoracic sympathetic trunk. Eur J Cardiothorac Surg. **27**(2): 320–324. doi:10.1016/j.ejcts.2004.10.057
19 Jit I, Mukerjee RN (1960). Observations on the anatomy of the human thoracic sympathetic chain and its branches: with an anatomical assessment of operations for hypertension. J Anat Soc India. **9**: 55–82.
20 Kachlík D, Varga I, Báča V, Musil V (2020). Variant Anatomy and Its Terminology. Medicina (Kaunas). **56**(12): 713. Published 2020 Dec 18.

21 Karemaker JM (2017). An introduction into autonomic nervous function. Physiol. Meas. **38**: R89–R118.
22 Kommuru H, Jothi S, Bapuji P, Sree D L, Antony J (2014). Thoracic part of sympathetic chain and its branching pattern variations in South Indian cadavers. J Clin Diagn Res. **8**(12): AC09–AC12. doi:10.7860/JCDR/2014/9274.5246
23 Kuruc R, Szórádová A, Kristová J, Solárová M, Šidlo J, Matejčík V (2023). Morphological Peculiarities of the Pelvic Autonomic Nervous System and Their Impact on Clinical Interventions in the Lesser Pelvic Region. Medicina. **59**(1): 72. https://doi.org/10.3390/medicina59010072
24 Kuruc R, Haviarova Z, Halgas F, Šidlo J, Matejcik V (2019). Extraordinary features of the intraspinal extradural and intradural nerve root courses. Neuro Endocrinol Lett. **40**(Suppl1): 29–36
25 Loukas M, Klaassen Z, Merbs W, Tubbs RS, Gielecki J, Zurada A (2010). A review of the thoracic splanchnic nerves and celiac ganglia. Clin Anat. **23**(5): 512–22.
26 Matejčík V, Haviarová Z, Kuruc R, Šteňo A, Šteňo J (2019). Intraspinal Variations of Nerve Roots. 1st ed. Cham: Springer International Publishing AG. 192 p. ISBN 978-3-030-01686-9.
27 Matejčík V, Kuruc R (2022). Periférny autonómny systém Morfologické a klinické aspekty (Peripheral autonomic nervous system Morphological and clinical aspects). Bratislava: AEPress. 1 vyd. 142 s. ISBN 978-80-89678-11-2
28 McCausland C, Sajjad H (2022). Anatomy, Back, Splanchnic Nerve. In: StatPearls. Treasure Island (FL): StatPearls Publishing.
29 Moore KL, Dalley AL (2006). Clinically oriented anatomy, II., 5th. ed.; Baltimore, MD Wiliams, 321 p.
30 Sadler TW (2011). Autonomic nervous system. In: Langman's medical embryology, 12th edn; Baltimore: Lipincott, Wiliams & Wilkins, p. 319–22.
31 Sakthivel S, Manjunath K (2016). Variant anatomy of greater splanchnic nerve. National J Basic Med Sci. **7**: 77–82.
32 Sasselli V, Pachnis V, Burns AJ (2012). The enteric nervous system. Dev Biol. **366**(1): 64–73.
33 Swell RS (2004). Clinical anatomy by regions, 7th ed.; Baltimore, Livingstone, 991 p.
34 Thangaraj S, Nagarajan V (2018). Pattern of origin of thoracic splanchnic anatomy section nerves and their clinical implications for sympathectomy and splanchnicectomy-a detailed cadaveric study. Inter J Anat Radiol Sur. **7**: 14–9.
35 Tubbs RS, Shoja MM, Loukas M (2016). (Eds.) Bergman's Comprehensive Encyclopedia of Human Anatomic Variation; John Wiley & Sons: Hoboken, NJ, USA.
36 Vanlommel J, Van Look L, Peetermans M, Uyttebroek L, van Nassauw L, Van Schil P (2022). Anatomical variations of the upper thoracic sympathetic chain: a review. Eur J Cardiothorac Surg. **61**(3): 515–522. doi:10.1093/ejcts/ezab445
37 Yang HJ, Gil YC, Lee WJ, Kim TJ, Lee HY (2008). Anatomy of thoracic splanchnic nerves for surgical resection. Clin Anat. **21**(2): 171–7.