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ORIGINAL ARTICLE

Comprehensive anatomy of the superior hypogastric plexus and its relationship with pelvic surgery landmarks: defining the safe zone around the promontory

B. Kutlu[1] · M. A. Guner[1] · C. Akyol[1] · Y. Gungor[1] · C. Benlice[1] · M. N. Arslan[1] · H. İ. Açar[1] · M. A. Kuzu[1]

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Abstract

Background Pelvic surgery carries an inherent risk of autonomic nerve injury leading to genitourinary and bowel dysfunction due to the close proximity of the superior hypogastric plexus (SHP). The aim of this study was to define the detailed anatomy of SHP and identify its relationship with the vascular landmarks and ureters for pelvic autonomic nerve-preserving surgery.
Methods A cadaveric study on the detailed anatomy of the SHP was conducted in our surgical anatomy research unit. Between 02/2019 and 10/2019, macroscopic anatomical dissections were performed on 45 fresh adult cadavers (39 male, 6 female). Distances between the SHP, major vascular structures, and other anatomical landmarks were measured.
Results Three types of SHP morphology were observed: mesh (64.8%), single nerve (24.4%), and fiber (10.8%). SHP bifurcation was located inferior to the aortic bifurcation in all cases; however, it was observed cranial to the promontory in 80% of the cases, whereas 18% were caudally and 2% were over the promontory. The closest vessels to the left and right of the SHP bifurcation were the left common iliac vein (LCIV) (86.2%, the mean distance was 8.49 ± 7.97 mm) and the right internal iliac artery (RIIA) (48.2%, mean distance was 13.4 ± 9.79 mm), respectively. At SHP bifurcation level, the lateral edge of the SHP was detected on the LCIV in 22 cases and on the RIIA in 10 cases for the left and right side of the plexus, respectively. The distance between the SHP bifurcation and the ureter was 27.9 mm on the right and 24.2 mm on the left. The width of the left (LHN) and right hypogastric nerves (RHN) were 4.35 mm and 4.62 mm at 2 cm below the SHP bifurcation, respectively. LHN was on the vascular structures in 13 cases, whereas RHN in only 1 case, 2 cm below the SHP bifurcation.
Conclusions Understanding the location of the SHP, including its relationship with important anatomical landmarks, might prevent iatrogenic injury and reduce postoperative morbidity in the pelvic surgery setting.

Keywords Superior hypogastric plexus · Rectal cancer · Pelvic anatomy · Cadaveric study

Introduction

There is no doubt that dissection through the embryological anatomical planes in pelvic surgery improves both clinical and oncologic outcomes, while also preventing devastating postoperative complications. Such an approach is technically challenging and demanding, however, due to the close proximity of the autonomic nerves and major vessels, as well as the complex and limited boundaries of the pelvis itself [1]. Thorough knowledge of anatomical pelvic landmarks is, therefore, crucial for decreasing the risk of autonomic nerve dysfunction and improving quality of life following surgery [2].

Pelvic surgery is associated with 30–70% rates of urogenital dysfunction in both genders and also sexual dysfunction including 20–46% rates of erectile dysfunction and 20–60% retrograde ejaculation in men and 30% vaginal dryness, dyspareunia, and orgasmic disorder in women [3, 4]. Moreover, these complications seriously affect not only the patient but also their partners postoperative quality of life [5, 6].

The superior hypogastric plexus (SHP), one of the components of the autonomic nervous system to the pelvis, is

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✉ M. A. Kuzu
ayhankuzu@gmail.com

[1] Department of General Surgery and Anatomy, Faculty of Medicine, Ankara University, Sıhhıye, 06100 Ankara, Turkey

located anterior of the aortic bifurcation and promontory and often referred to as the presacral nerve [7]. It is crucial to know the course of SHP and its branches during pelvic dissection to prevent postoperative autonomic dysfunction. The clump-like distribution of the pelvic autonomic nerves in front of the promontory is difficult to identify, making rectal dissection a challenge. The course of the SHP has been evaluated in a limited number of studies with a small number of cadaveric dissections. However, the importance of the relationship with the other major anatomical landmarks remains unclear. The aim of this study was to define the detailed anatomy of the SHP and identify its location and relation to vascular landmarks and the ureters for pelvic autonomic nerve-preserving surgery and to identify the safety zone on the promontory.

Materials and methods

The current descriptive anatomic study was conducted after receiving the approval of the scientific and ethics committees from both the Ankara University (ethics committee decision No. 19-42) and the Institute for Forensic Medicine (scientific committee decision No. 21589509/2018/411). A total of 45 fresh adult cadavers (male: 87%, $N=39$) with a median age of 45 (21–75) years and body mass index of 26.8 (23.3–32.1) kg/m^2, were included. All cadavers (time of death < 24 h) were precisely dissected between 02/2019 and 10/2019. The same team, including surgeons and anatomists focusing on the SHP, performed all dissections and measurements. Cadavers with intra-abdominal pathology were excluded from the study.

Procedure

The procedure was as follows: cadavers were placed in a supine position and median laparotomy was performed. Initial exploration was conducted and lateral to medial mobilization of the left colon was performed through the embryologic plane and Toldt's fascia according to the principles of complete mesocolic excision. Special attention was given to the retroperitoneal structures and their positions were carefully preserved. The SHP was dissected and explored from the surrounding retroperitoneal organs including the inferior vena cava (IVC), aorta, and ureters on both sides. Subsequently, the peritoneum over the promontory was incised and the right and left hypogastric nerves were identified at the pelvic brim. The mesorectum was first mobilized posteriorly along the fascia propria recti and presacral fascia with a sharp dissection technique through the "Holy Plane." After full posterior mobilization of the mesorectum down to the pelvic floor was performed, lateral and anterior mesorectal dissection was conducted.

The retroperitoneum was dissected to explore the neurovascular and other important anatomical structures including the SHP, aorta, IVC, iliac vessels, and promontory. Their normal anatomical positions were also preserved. All measurements were performed with a fine caliper accurate to 0.1 mm and recorded.

The distance and location of major vascular structures were measured in relation to the SHP and promontory. Retroperitoneal major vascular structures and ureters were located in a clock-wise manner according to the promontory. Vertical and horizontal measurements were performed according to the bifurcation of the SHP, aorta, IVC, and promontory.

Statistical analysis

Comparative analysis between neurovascular structures and major anatomical landmarks on both sides was conducted. Statistics are reported as mean ± standard deviation or median [interquartile range] for continuous variables and frequency (%) for categorical factors. Pearson's Chi-square test or Fisher's exact test was used for categorical variables and ANOVA was used for continuous variables. All analyses were conducted using JMP version 15.1. A p value less than 0.05 was considered significant. Anatomic variations and related structures were displayed as animations on still images captured from videos.

Results

Three types of SHP morphology were observed: mesh (64.8%) (Fig. 1A, and 2A), single nerve (24.4%) (Fig. 1B and 2B), and fiber (10.8%) (Fig. 1C and 2C). All cadavers had a bifurcated SHP with two branches. The bifurcation was observed cranial to the promontory in 36 cases (80%) and caudally in 8 cases (18%). It was located over the promontory in one case (2%).

The mean width of the SHP 2 cm above the SHP bifurcation was 10.03 ± 3.1 mm (Fig. 3A). At this level, the closest vessel on the left side of the SHP was the left common iliac vein (LCIV) (85%), with a mean distance of 1.2 ± 3.3 mm. On the right side, the closest vessel was the LCIV (52.5%), with a mean distance was 2.7 ± 6.1 mm. The left (82.5%, $n=33$) and right (75%, $n=30$) edges of the SHP both crossed over major vessels (Fig. 3B). At this level, the mean distance between the left edge of the SHP and left ureter was 18.5 ± 6.78 mm and between the right edge of the SHP and the right ureter was 23.6 ± 9.5 mm ($p < 0.05$) (Fig. 3C). The left ureter was significantly closer to the edge of the SHP than the right (Table 1).

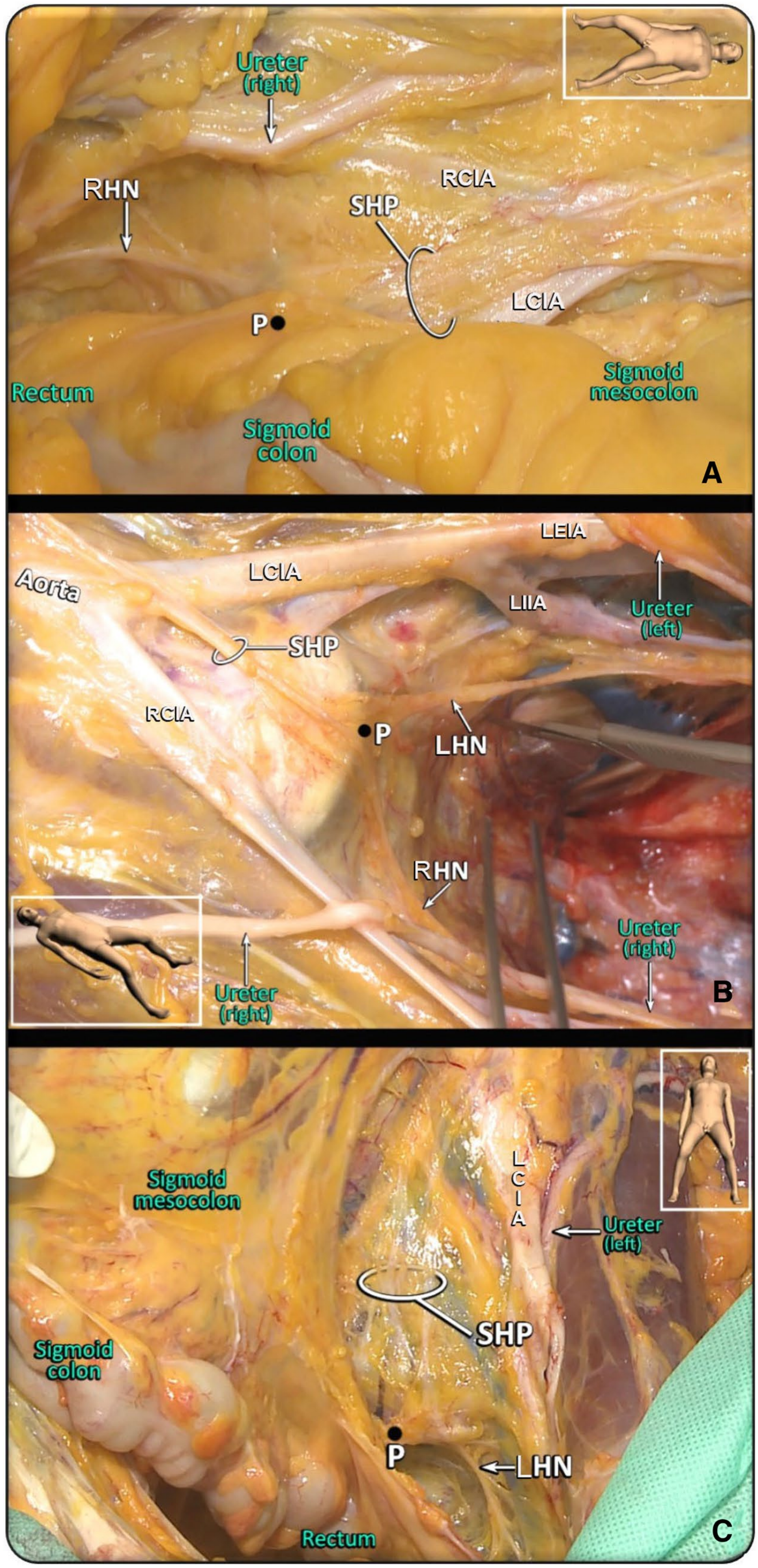

Fig. 1 Three types of superior hypogastric plexus morphology. **A** Mesh (64.8%, n = 24) **B** Single (24.4%, *n* = 9) **C** Fiber(10.8%, *n* = 4). *SHP* superior hypogastric plexus, *RCIA* right common iliac artery, *LCIA* left common iliac artery, *LEIA* left external iliac artery, *LIIA* left internal iliac artery, *LHN* left hypogastric nerve, *RHN* right hypogastric nerve

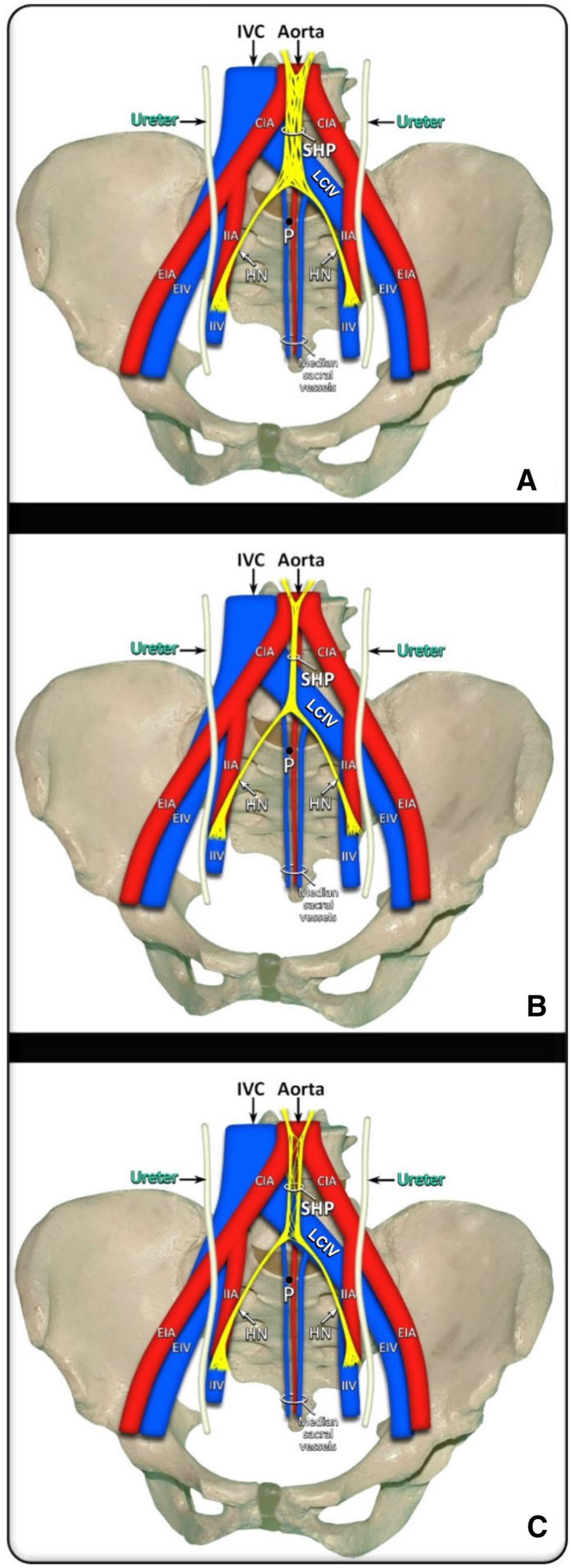

Fig. 2 Three types of superior hypogastric plexus morphology. **A** ▶ Mesh (64.8%, $n=24$) **B** Single (24.4%, $n=9$) **C** Fiber (10.8%, $n=4$). *IVC* inferiorvena cava. *SHP* superior hypogastric plexus, *CIA* common iliac artery, *CIV* common iliac vein, *EIA* external iliac artery, *EIV* external iliac vein, *IIA* internal iliac artery, *IIV* internal iliac vein, *HN* hypogastric nerve

The SHP bifurcation was located inferior to the aortic bifurcation in all cases and to the IVC bifurcation in 92.5% of the cases. The mean distance between the aorta and SHP bifurcations was 51.94 ± 19.25 mm and between the IVC and SHP bifurcations 30 ± 14.7 mm (Fig. 4A). The closest vessel to the left of the SHP bifurcation was the LCIV (86%), with a mean distance of 8.49 ± 7.97 mm. On the right side, the right internal iliac artery (RIIA) (48.2%) was the closest vessel, with a mean distance of 13.43 ± 9.79 mm. The SHP bifurcation crossed over the LCIV in 27.5% of cases ($n=8$) (Fig. 3D). The mean vertical distance between the SHP bifurcation and the closest vessel (LCIV in 94.5% of the cases) was 11.4 ± 11.6 mm. The mean distance between the SHP bifurcation and the ureters was 24.24 ± 6.3 mm on the left side and 27.9 ± 9.7 mm on the right side (Fig. 4B).

Two cm below the SHP bifurcation, the widths of the left hypogastric nerve (LHN) and right hypogastric nerve (RHN) were 4.35 ± 1.97 mm and 4.62 ± 3.15 mm (Fig. 3A), respectively. At this level, the vessel closest to the LHN and RHN was the LCIV (62.5%) and the RIIA (53.6%); the mean distances were 4.6 ± 4.8 mm and 8 ± 5.9 mm, respectively (Fig. 5C). The LHN was above the major vessels in 13 cases, whereas the RHN was above the major vessels in only 1 case. The mean distances between the hypogastric nerves and ureters were 14 ± 6.4 mm on the left side and 17.8 ± 8.7 mm on the right side. The left ureter was significantly closer than the right ($p < 0.05$) (Fig. 5D).

At the level of the promontory, the mean transverse distance between the midpoint and the closest vessel was 19.1 ± 6.7 mm on the right side (63.4% RIIA) and 16.3 ± 7.1 mm on the left (73% LCIV). The mean vertical distance of the closest vessel to the midpoint of the promontory was 24.7 ± 11.4 mm, with the closest vessel being the LCIV in 94.7% of the cases (Fig. 4D). The shortest distance was 0 mm (2.5%, $n=1$), in which case it crossed over the promontory (Fig. 6). The maximum distance was 36.86 mm on the right side and 27.09 mm on the left. The mean transverse distance between the ureters and the midpoint of the promontory was 26.4 mm (Fig. 5A). The mean distance from the hypogastric nerve to the midpoint of the promontory was 5.9 ± 5.2 mm on the right side and 6.45 ± 4.9 mm on the left (Fig. 5B).

The SHP and major vessels, including the retroperitoneal structures, were identified in a clockwise manner according to the promontory (details given in Table 2).

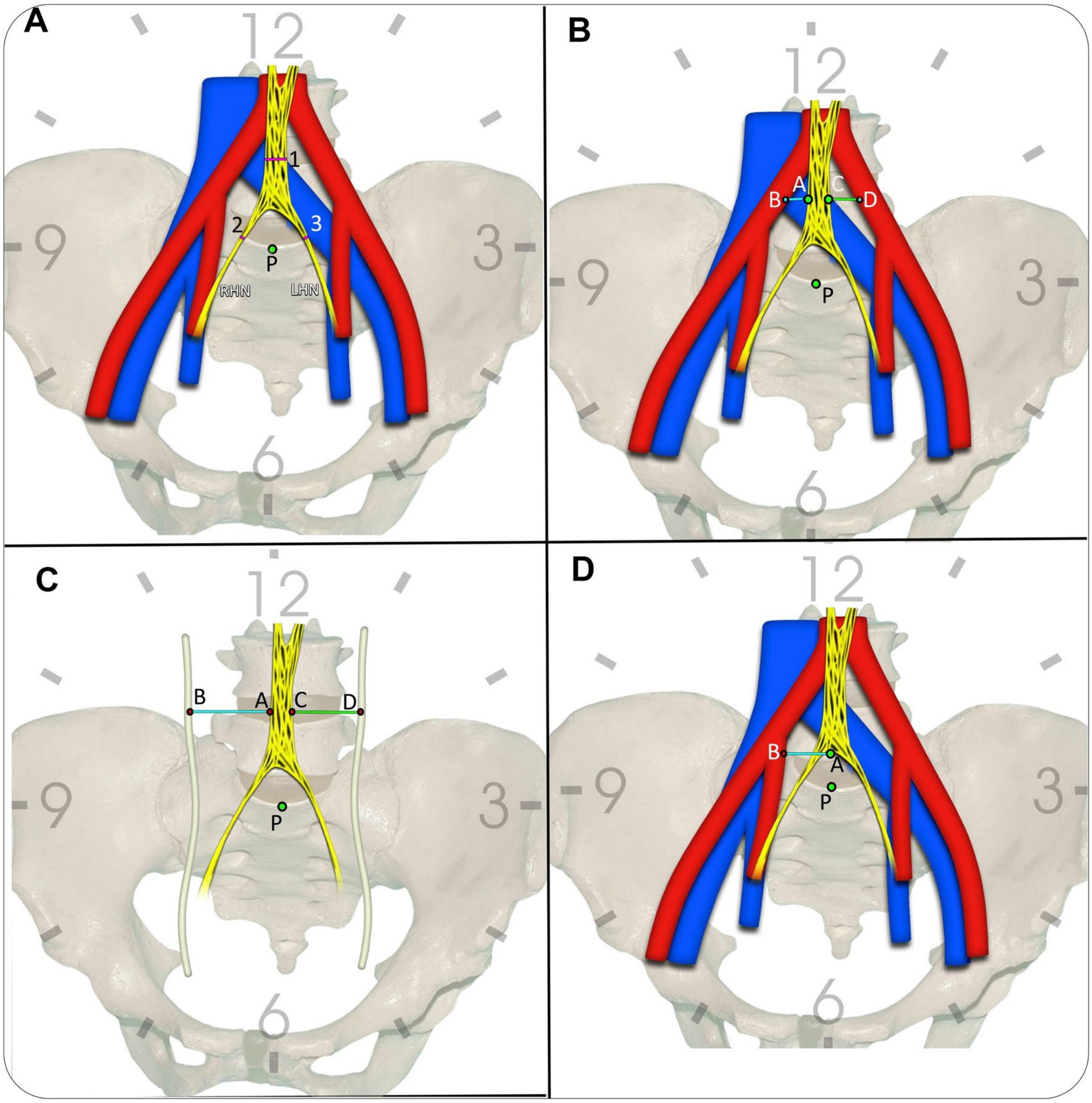

Fig. 3 Horizontal measurements were performed for the bifurcation of the superior hypogastric plexus 2 cm above the bifurcation according to the lateral edge of the nerve (promontory is indicated by "P"). **A** Width of superior hypogastric plexus (1), right hypogastric nerve (2) and left hypogastric nerve (3). **B** Closest vessel to the edge of the superior hypogastric plexus 2 cm above the superior hypogastric plexus bifurcation(A->B) (C->D). **C** Distances between ureters and edge of the nerve 2 cm above the superior hypogastric plexus bifurcation (A->B) (C->D). **D** Vessel closest to the superior hypogastric plexus bifurcation (A->B)

The middle sacral artery was located on the midline in 6 cases (13.4%), on the left in 26 cases (57.8%), and on the right in 12 cases (26.6%). One cadaver had 2 sacral arteries (2.2%). The mean distance from the middle sacral artery to the midline was 3.4 ± 1.2 mm. Regarding the middle sacral vein, 2 veins were observed in 23 cases (51.1%), 1 vein in 13 (28.8%), 3 veins in 7 (15.5%), and in 4 veins in 2 (4.4%). The mean distance from the middle sacral vein to the midline was 5.5 ± 1.5 mm on the left and 5,1 ± 1,3 mm on the right (max distances were 13,6 on both sides).

All measurements for male and female cadavers are given in Table 3.

Discussion

Clarifying the relationship between autonomic fibers, which are difficult to define during pelvic operations, and the structures in close proximity to them, improves the surgeon's ability to perform procedures more safely. Despite our best

Table 1 Comparison of distances from the SHP to the closest vascular landmarks and ureters on both sides

	Left	Right	*p* value	Vertical
At 2 cm above the bifurcation				
Closest artery	LCIA (2.5%, *n* = 1)	RCIA (7.5%, *n* = 3)		
Closest vein	LCIV (85%, *n* = 34)	LCIV (52.5%, *n* = 21)		
Closest vessel (mm) (artery or vein)	1.2 ± 3.3	2.7 ± 6.1	**0.34**	
Ureters (mm)	18.5 ± 6.7	23.6 ± 9.5	**0.009**	
At the level of SHP bifurcation				
Closest artery	LIIA (6.8%, *n* = 2)	RIIA (48.2%, *n* = 14)		RCIA (2.7%, *n* = 1)
Closest vein	LCIV (86%, *n* = 25)	LCIV (13%, *n* = 4) RCIV (13%, *n* = 4)		LCIV (94.5%, *n* = 35)
Closest vessel (mm)	8.49 ± 7.97	13.43 ± 9.79	**0.07**	11.4 ± 11.6
Ureters (mm)	24.24 ± 6.32	27.9 ± 9.7	**0.11**	
At 2 cm below the bifurcation				
Width (mm)	4.35 ± 1.97	4.62 ± 3.15	**0.83**	
Closest artery	LIIA (10%, *n* = 4)	RIIA (53.6%, *n* = 22)		
Closest vein	LCIV (62.5%, *n* = 25)	RIIV (26.8%, *n* = 11)		
Closest vessel (mm)	4.62 ± 4.8	8.08 ± 5.92		
Ureters	14.07 ± 6.49	17.8 ± 8.78	**0.03**	

SHP superior hypogastric plexus; *LCIA* left common iliac artery; *RCIA* right common iliac artery; *LCIV* left common iliac vein; *LIIA* left internal iliac artery; *RIIA* right internal iliac artery; *RCIV* right common iliac vein

efforts, however, we could find no studies that provide surgeons with such guidance, specifically regarding the SHP or identifying a "safety zone" around the promontory. This is the first study and the largest fresh cadaveric series, to demonstrate detailed SHP anatomy, its location in relation to the vascular landmarks and ureters, and to propose a "safety zone" over the promontory that can be applied during pelvic surgery. Our study defines this safety zone with the purpose of guiding surgeons not only during radical pelvic cancer surgery, but also for the simplification of mesh fixation on the promontory.

Although it is not mandatory to completely dissect the SHP and hypogastric nerves during pelvic surgery, surgeons should be aware of the relationship between the autonomic nerves and major anatomical structures [8]. This is the first study that defines the topographical anatomy of the autonomic nerves in detail, and that measures distances between the nerves and anatomical landmarks at the level of the SHP bifurcation as well as 2 cm above and below it. Given the limited number of reports on the detailed anatomy of the SHP and its relationship with major anatomical landmarks in the setting of pelvic surgery, our study is particularly valuable for deepening our understanding of a nerve-sparing approach.

Several types of SHP morphology have been defined and reported in the literature. In our study, most of the fresh cadavers had mesh-type morphology, with the minority having the single nerve or fiber types. Paraskevas et al. reported 4 different morphological types in 35 fixed cadavers, with the most common being 2 distinct nerves (31.44%) and wide plexiform formation (28.57%) [10]. On the other hand, Correia et al. defined 6 morphological types in 42 fixed cadavers; the most common type in that series was vertical rectangular non-fenestrated SHP (in 38% of all cadavers) [9].

Although it is challenging to recognize the mesh type SHP (64,8%, *n* = 24), in case of injury, a small part is more likely to be affected. The single type SHP (24,4%, *n* = 9) can be more easily identified during surgery. If the single type is injured, the entire sympathetic innervation for the pelvic area will be affected. Thus the mesh type most prone to injury.

The location of the SHP over the promontory is important particularly for rectal prolapse procedures. Ventral mesh rectopexy, us a recently developed anterior approach for rectal prolapse where the rectum is mobilized ventrally/laterally and mesh is fixed over to the promontory with the rectum. Most abdominal approaches with mesh fixation for rectal prolapse are associated with new-onset or worsening postoperative constipation and functional outcomes, and increased mesh-related postoperative complications [11–14]. Although functional outcomes are multifactorial, given these results, it is crucial to know the course of the SHP and its branches during rectal dissection and mesh fixation. The current study assesses the course of the SHP over the promontory and demonstrates that the SHP is usually located in the midline, above the promontory (80%), although it has previously been reported that the SHP is usually located left of the midline [10, 15]. Ripperda et al. measured the distance from the midpoint of the promontory to the origin of the

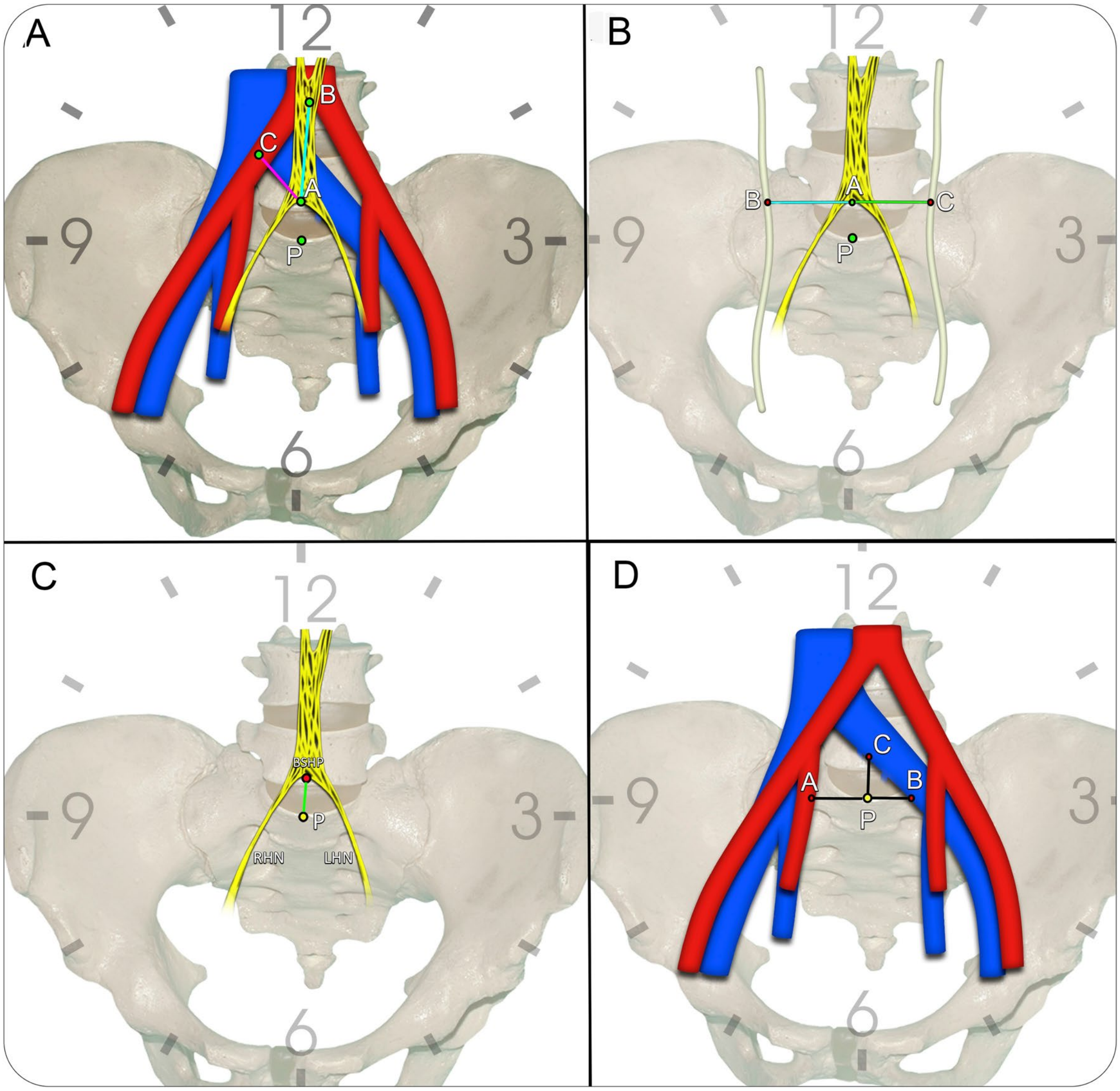

Fig. 4 Horizontal and vertical measurements were performed according to the bifurcation of the superior hypogastric plexus and promontory (promontory is indicated by "P"). **A** Distances between superior hypogastric plexus bifurcation to aorta (A- > B) and inferior vena cava (A- > C) bifurcations. **B** Distances between the ureters and superior hypogastric plexus bifurcation. **C** Distance between promontory and superior hypogastric plexus bifurcation. **D** Transverse and horizontal distances between the promontory and closest vessels; P- > A and P- > B transverse distance, P- > C vertical distance

hypogastric nerves and from the bifurcation of the aorta to the bifurcation of the SHP in 17 formalized cadavers [15]. They reported that the SHP is predominantly located on the left side of the midline (58.8%) and below the bifurcation of the aorta (82.4%).

This study also measured and evaluated the relationships between the SHP and major vascular structures. At the level of the SHP bifurcation, the lateral edge of the SHP was found to be over the LCIV in about half of the cadavers, while it was over the RIIA on the right side in about a quarter of the cadavers. Furthermore, the SHP bifurcation was located over the LCIV in one third of the cadavers. These vascular structures could be used to identify the autonomic nerves when they are at risk of injury during nerve-sparing radical pelvic surgery. This relationship should be also kept in mind with lateral lymph node dissection during pelvic surgery. Additionally, there is no study in the literature defining the relationship between the SHP and the ureters. Our study defined this relationship for the first time and demonstrated that the lateral edge of the nerve is very close to the ureters (6 mm on the left side and 6.3 mm on the right side).

We also meticulously measured the width of the SHP and its branches in all of the cadavers. The width of the hypogastric nerves was similar on both sides, while at 2 cm below the SHP bifurcation, the LHN was over the left ureter for about 5.2% of the cases. The LHN is at a much higher risk

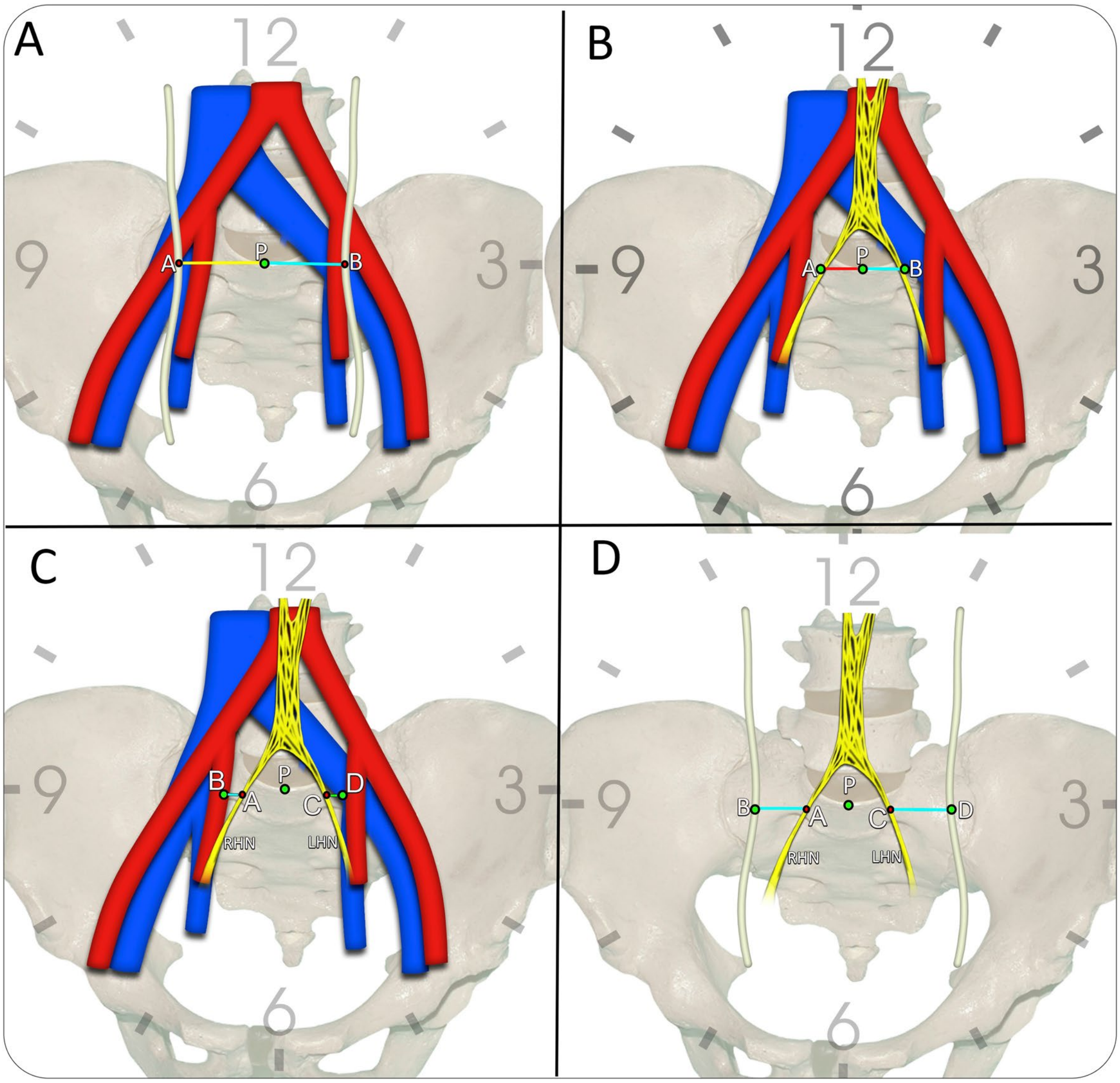

Fig. 5 Horizontal and vertical measurements were performed according to the promontory and 2 cm below the bifurcation according to the lateral edge of the nerve (promontory is indicated by "P"). **A** Transverse distances between the promontory and ureters. **B** Distances between the promontory and LHN/RHN, **C** Closest vessel to the hypogastric nerves 2 cm below the superior hypogastric plexus bifurcation. **B** Distances between ureters and hypogastric nerves 2 cm below the superior hypogastric plexus bifurcation. *LHN* left hypogastric nerve; *RHN* right hypogastric nerve

of injury during pelvic dissection, and especially so for total mesorectal excision. Jing-Hu He et al. reported that the LHN is significantly shorter and thinner than the right. Thorough knowledge of pelvic anatomy is, therefore, crucial not only for general surgeons, but also for those working in vascular surgery, urology, and gynecology [16].

The present study also assessed major anatomical structures, including the iliac artery and vein, ureters, and the SHP over the promontory. Localization of the vessels and nerves in a clockwise manner according to the promontory helped us to identify the safety zone. According to our measurements, between 1 and 2 cm to the right side of the midpoint of the promontory is defined as a safety zone for mesh fixation during rectal prolapse operations. Mesh should not be fixed over the midline to prevent bleeding and postoperative sexual and urinary morbidities. Most of the middle sacral vessels are located on the left side of the midline. Although there is a high risk of injury to both vascular structures and autonomic nerves in the interventions made to the promontory, if the intervention is necessary, it can be done between 1 and 2 cm to the right of the midline.

Even though this study reports the largest cadaveric dissection series in the literature to date, more cadavers should be assessed to better delineate the pelvic anatomy. The measurements within the pelvis also differ between males and females. The low proportion of female cadavers ($n=6$) was insufficient

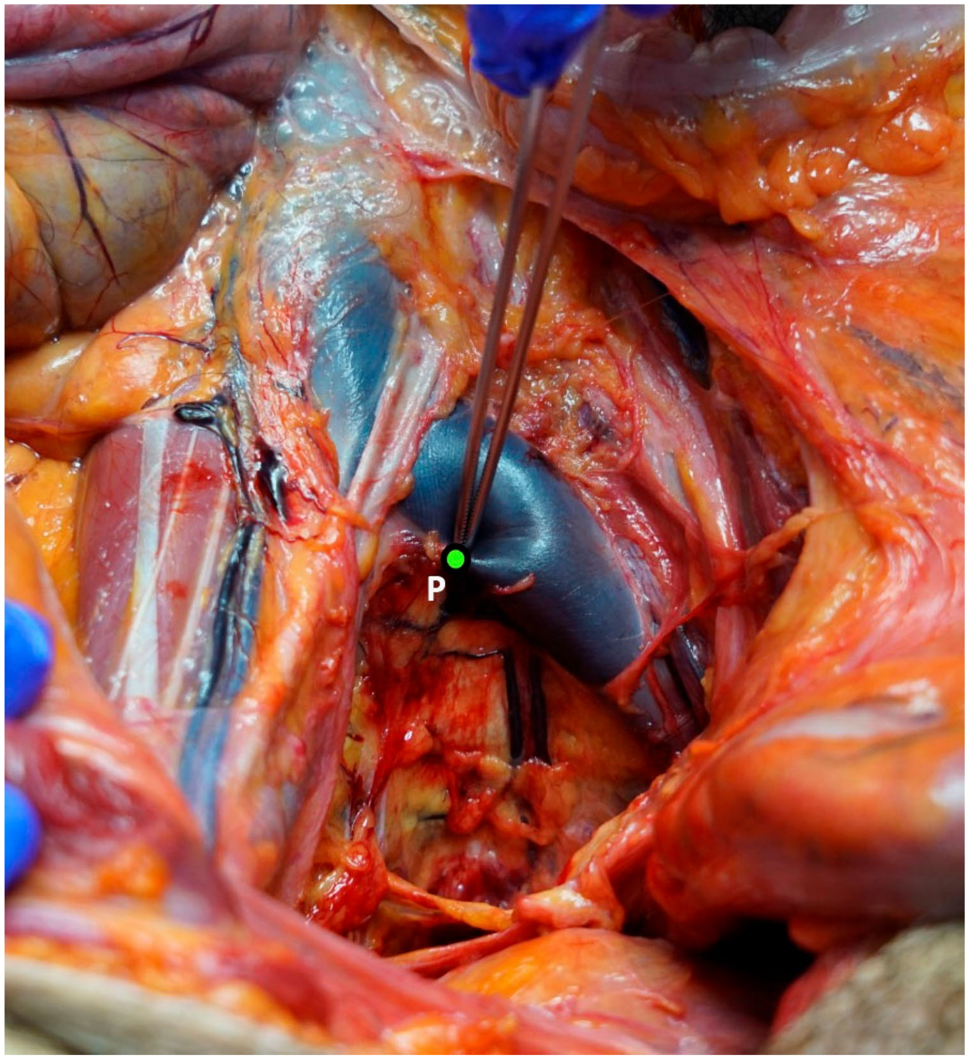

Fig. 6 Mean transverse distance between the midpoint and the closest vessel. Thr LCIV crossed over the promontory in one case (the promontory is indicated by "P"). *LCIV* left common iliac vein

Table 2 Most common location of the bifurcations (clockwise location) and mean distances from the promontory

	Clockwise (%)	Mean distance ± SD (mm)
Aortic bifurcation	12 (70%)	67.5 ± 19.3
IVC bifurcation	11 (58.5%)	41.1 ± 11.2
SHP bifurcation	12 (37%)	18.6 ± 11.5
Right iliac artery bifurcation	10 (41.4%)	32 ± 8.4
Left iliac artery bifurcation	2 (31.7%)	35.6 ± 7.5
Right iliac vein bifurcation	8 (24%)	30.7 ± 8.5
Left iliac vein bifurcation	4 (34%)	30.4 ± 8.6

SHP superior hypogastric plexus; *IVC* inferior vena cava

for creating an equal comparison with males. Since this is a cadaveric study, the exact measurements and results may also differ slightly from those found in clinical experience. Nevertheless, because we used consecutive and fresh (less than 24 h old) cadavers, these should provide more representative anatomy than that of a fixed cadaver. Furthermore, because most anatomy studies in the literature used formalized cadavers, the measurements as well as the position of the pelvic structures in fresh cadavers may differ slightly.

Conclusions

This study comprehensively demonstrates the anatomy of the superior hypogastric plexus in detail and delineates its relationship with the surrounding important vascular landmarks and the ureters. A thorough understanding of the location of the SHP might reduce postoperative morbidity and could even eliminate the technical difficulties associated with preserving the autonomic nerves during pelvic surgery.

Table 3 Distances for the closest vascular landmarks and ureter on both sides for male and female cadavers

At 2 cm above the bifurcation	Left		Right	
	Male	Female	Male	Female
Closest vessel (mm) (artery or vein)	1.2	1.1	2.3	5.4
Ureters (mm)	18.3	20	22.6	32.1
At the level of SHP bifurcation				
	Male	Female	Male	Female
Closest vessel (mm)	8.3	9.4	12.6	20.3
Ureters (mm)	23.7	27.6	27.3	31.9
At 2 cm below the bifurcation				
	Male	Female	Male	Female
Width (mm)	4.4	3.4	4.8	3.5
Closest vessel (mm)	3.9	10.3	7.1	15.5
Ureters (mm)	13.7	17	17.2	22.7

SHP superior hypogastric plexus

Author contributions Substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data: BK, MAG, CA, YG, CB, MO, HIA, MAK. Drafting of the article for important intellectual content: BK, MAG, CA, YG, CB, MO, HIA, MAK. Critical manuscript revision and final approval of the submitted version: BK, MAG, CA, YG, CB, MO, HIA, MAK.

Declarations

Conflict of interest The authors have no conflicts of interest including relevant financial interests, activities, relationships, and affiliations.

Ethical approval The current descriptive anatomic study was conducted after receiving the approval of the scientific and ethics committees from both the Ankara University (ethics committee decision No. 19-42) and the Institute for Forensic Medicine (scientific committee decision No.21589509/2018/411).

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