Original Article

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Anatomy Section

Pattern of Origin of Thoracic Splanchnic Nerves and their Clinical Implications for Sympathectomy and Splanchnicectomy-A Detailed Cadaveric Study

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ABSTRACT

Introduction: The sympathetic nervous system, which is the larger autonomic division, includes the two ganglionated trunks and their branches, plexuses and subsidiary ganglia. The thoracic part of the sympathetic system has been a fascinating field in surgery for long time. Although, the thoracic part of the sympathetic system has thus been an area of importance for physicians and surgeons, the knowledge of this region also present lacunae. The important reasons for unsuccessful sympathectomy include sympathetic regeneration, alternate sympathetic pathways and variations in their presentation.

Aim: To investigate the origin and pattern of formation of the splanchnic nerves in order to establish a predictable pattern of splanchnic neural anatomy and to outline the surgical anatomy appropriate to effect adequate denervation of upper abdominal viscera.

Materials and Methods: The present study is done in 10 cadavers. The thoracic part of the sympathetic chain on both sides, their ganglia, the rami communicantes, the origin, course and exit of splanchnic nerves from thorax are dissected out with care, coloured with yellow and studied in detail which has been photographed and tabulated.

Results: Stellate ganglion was found in six sides. In two other sides 10 ganglia was found. Marked variations among the pattern of origin of Greater Splanchnic Nerve (GSN) with 14 different categories, Lesser Splanchnic Nerve (LSN) with seven different categories and Least Splanchnic Nerve (LeSN) with five different categories were observed in the present study. Also, the presence of two grey rami communicantes to the eleventh intercostal nerve and no grey ramus for subcostal nerve were observed.

Conclusion: The knowledge about the variations of the sympathetic chain, the number of ganglia present, the marked variations about the uncommon origin of splanchnic nerves provided with the current study are all important for the clinicians, surgeons to correlate for various surgical procedures required for the treatment of palmar hyperhidrosis, craniofacial hyperhidrosis, chronic pancreatitis and carcinomas of the pancreas, liver, gall bladder and stomach.

Keywords: Endoscopy sympathectomy, Greater splanchnic nerves, Rami communicantes, Sympathetic chain

INTRODUCTION

The sympathetic nervous system, which is the larger autonomic division, includes the two ganglionated trunks and their branches, plexuses and subsidiary ganglia. It has a much wider distribution than the parasympathetic [1]. The sympathetic chains are positioned behind the pleura and in front of the intercostal vessels, which facilitates the removal of the chain without any injury to these vessels.

Importance of Thoracic Sympathetic Chain

The thoracic part of the sympathetic system has been a fascinating field in surgery for long time. This part of the chain provides the sympathetic supply to the pupil of the eye, upper limb, parietal wall of the trunk through the grey and white rami communicantes between the thoracic ganglia and intercostal nerves, thoracic viscera through the coronary, pulmonary and oesophageal plexuses and abdominal viscera through the splanchnic nerves.

There has been an increasing number in the various methods of controlling pain arising from the systems to which it supplies, and they are also continually being added. Attempts have been made to control angina pectoris by denervating cardiac plexuses, aortic plexectomy to control hypertension and pulmonary plexectomy to control bronchial asthma

[2]. Currently, transthoracic endoscopic sympathectomy, consisting of ablation of ganglion or resection of one segment of sympathetic trunk can be a treatment to control severe brachial neuralgia, palmar hyperhidrosis and to relieve intercostal neuralgia [3].

Although, the thoracic part of the sympathetic system has thus been an area of importance for physicians and surgeons, the knowledge of this region also present lacunae. The important reasons for unsuccessful sympathectomy include sympathetic regeneration, alternate sympathetic pathways and variations in their presentation. The aim of this study is to explore the origin and pattern of formation of the splanchnic nerves to establish the varied pattern of splanchnic nerves and to delineate the surgical anatomy appropriate to effect adequate denervation of upper abdominal viscera.

MATERIALS AND METHODS

Analysis of the thoracic sympathetic chain by fine dissection were analysed by observation. The study was conducted in ten cadavers (6 males and 4 females) available in the Department of Anatomy, Madurai Medical College, Tamil Nadu, India, over a period of 2 years with ages ranging from 45-60 years. The cadavers were embalmed by standard techniques. Approval of the Institutional ethical and Research Committee has been obtained before initiating the project. The cadavers having normal posterior mediastinal anatomy were included in the study. Anterior thoracic wall is exposed and opened up, the relations of the internal organs insitu were studied first. The lungs were removed after cutting at the root. The parietal pleura were stripped off from the wall of the thorax and from the vertebral column and mediastinum. The thoracic part of the sympathetic chain on both sides, their ganglia, the rami communicantes, the origin, course and exit of splanchnic nerves from thorax are dissected out very carefully, coloured with yellow to differentiate appropriately from adjacent posterior mediastinum structures like azygos system of veins and thoracic duct. The dissected specimens have been photographed and the data thus obtained by studying the following has been tabulated:

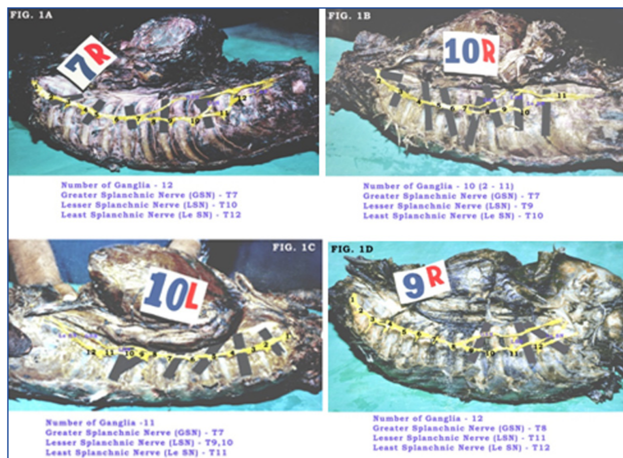
1. Course of the chain in relation to the ribs and vertebral column.
2. Number of ganglia
3. Number of rami communicantes.
4. Origin of GSN and exit
5. Origin of LSN and exit
6. Origin of LeSN and exit

RESULTS

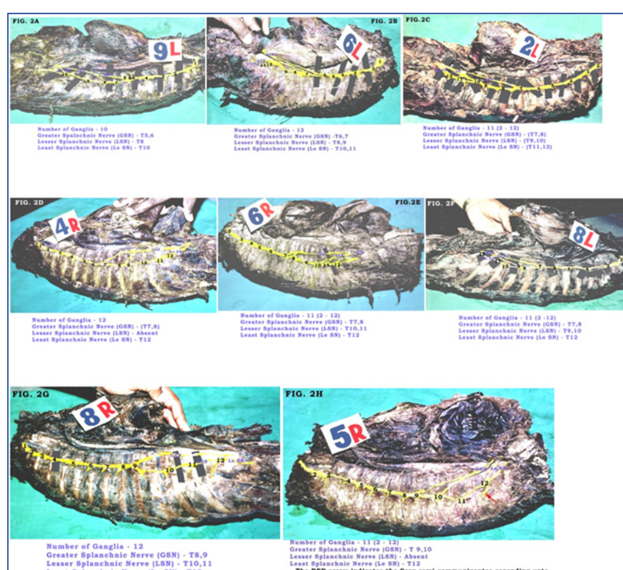
The sympathetic chain has been dissected with utmost care and coloured with yellow on 20 sides from 10 cadavers and it has been labelled as (1L, 1R, 2L , 2R, etc.) denoting the numbers, 1 to 10-the number of cadavers, L-Left side and R-Right side.

Gross relation of the thoracic portion of the sympathetic system: The thoracic portion of the sympathetic chain is observed as the continuation of the cervical sympathetic chain from the root of the neck behind the vertebral and subclavian arteries, in all the cadavers studied. The chain mostly lies anterior to the head of the ribs and in the lower part of the thorax it inclines medially to lie along the sides of the bodies of the lower two thoracic vertebrae. The chain is seen to leave the thorax behind the medial lumbocostal arch, to become continuous with the lumbar chain in the ten cadavers dissected [Table/Fig-1-3].

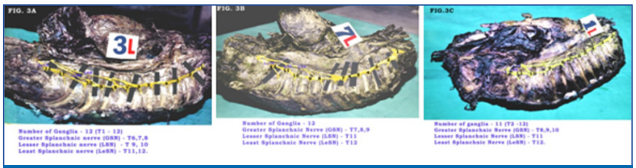
The left chain lies lateral to the hemiazygos system of veins, and the right one lateral to the azygos vein. Both chains lie immediately against the pleura and in front of the intercostal vessels. In the upper part of the thorax the first intercostals



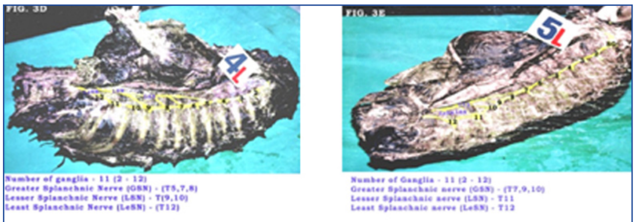
[Table/Fig-1a-d]: Images showing the single root pattern of origin of Greater Splanchnic Nerve (GSN), varied pattern of Lesser Splanchnic Nerve (LSN) and Least Splanchnic Nerve (LeSN).



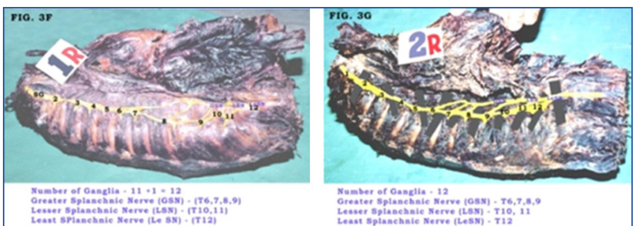
[Table/Fig-2a-h]: Images showing the double root pattern of origin of Greater splanchnic nerve (GSN).



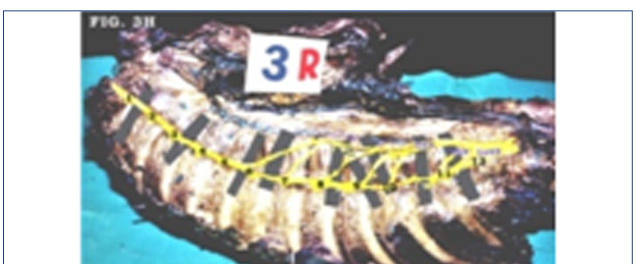
[Table/Fig-3a-c]: Three roots formation of Greater Splanchnic Nerve (GSN).



[Table/Fig-3d,e]: Three roots (missed root contribution to GSN).



[Table/Fig-3f,g]: Four roots contribution to GSN



[Table/Fig-3h]: Five roots contibution to GSN

vein typically passes in front of the sympathetic chain. No variation is observed in the course of the thoracic sympathetic chain in the present study.

Number of Ganglia: The present study showed varied number of ganglia in the dissected thoracic sympathetic chain from 10-12. It is noted that 10 ganglia were seen on two sides, 11 on six sides and twelve on 12 sides. Among these, bilateral presentation was observed only in three cadavers, 12 ganglia in cadaver no. 3 [Table/Fig-3b and h] and 7 [Table/Fig-1a and 3c] and 11 ganglia in cadaver no. 5 [Table/Fig-2c and 3c].

Fusion of the first thoracic ganglion with the inferior cervical ganglion (stellate ganglion) was seen on 11 sides, in which the number of ganglia were observed to be eleven in number and they were numbered from 2-12 showing the fusion of first with inferior cervical sympathetic ganglion [Table/Fig-1c, 2c, 2e, 2f, 2h, 3c, 3d and 3e].

Rami Communicantes: All the ganglia dissected in the thoracic sympathetic chain were observed to have a grey and a white rami communicantes. The grey and white rami commnicantes of one ganglion were connected to the corresponding intercostal nerve in 95%. In cadaver number five, on the right side the grey ramus of 12th ganglion extended to the 11th intercostals nerve. On this side, the 11th intercostal nerve received two grey rami communicantes and the sub costal nerve had no grey ramus [Table/Fig-2h].

Greater Splanchnic Nerve: The GSN was observed to be present in all the 20 thoracic sympathetic chain studied (100%). Bilateral symmetry of formation of the nerves from T7 was traced in only one cadaver in the present study [Table/Fig-1b,c]. The GSN commenced either from a single root [Table/Fig-1a-d], double roots [Table/Fig-2a-h] or more roots [Table/Fig-3a-h] from the 5th to the 10th thoracic sympathetic ganglia [Table/Fig-4]. The contribution of the roots to form a GSN varied widely. Fourteen types of contribution were dissected in this study, of which the most prevalent is from 7th and 8th ganglia (20%) [Table/Fig-5]. The missed root contribution like 5, 7, 8 and 7, 9, 10 were also noted. The in between ganglion does not contribute to the formation of GSN.

Ganglia No.	Number of Sides Found with the Formation of GSN (n value) out of 20 Sides (%)
5th	2-10%
6th	6-30%
7th	14-70%
8th	14-70%
9th	8-40%
10th	4-20%

[Table/Fig-4]: Contribution from each ganglion for the formation of Greater Splanchnic nerve (GSN)

No. of Ganglia Involved in Formation of GSN	Pattern of origin of GSN (Number Represent the Number of Ganglia)	No. of Sides
Single Root Origin (20%)	7	2
	8	2
Double Root Origin (40%)	5,6	1
	6,7	1
	7,8	4
	8,9	1
	9,10	1
Multiple Root Origin (40%)	5,7,8	1
	6,7,8	1
	7,8,9	1
	7,9,10	1
	8,9,10	1
	6,7,8,9	2
	6,7,8,9,10	1

[Table/Fig-5]: Pattern of origin of Greater Splanchnic Nerve (GSN) (14 different categories)

The GSN was traced to leave the thorax by piercing the right crus on the right side in all the cadavers studied (100%). On the left side, the nerve pierced the crus in 40% or passed through the aortic hiatus in 60%.

Lesser Splanchnic Nerve [Table/Fig-1-3]: The LSN was observed to be present in 90% of the thoracic sympathetic chain studied. The absence of the nerve was observed on the right side in two sympathetic chains (10%) [Table/Fig-2b,c]. The roots of the nerve in the remaining 18 sympathetic chains were found to be contributed from 8th to the 11th thoracic ganglion [Table/Fig-6]. Single root was observed in eight sides (40%). This originated either from 8th ganglion (5%) [Table/Fig-2h], 9th ganglion (5%) [Table/Fig-1b], 10th ganglion (5%) [Table/Fig-1a] and 11th ganglion (25%) [Table/Fig-1d, 3a, 3c, 3e and 3h]. Double roots were observed in ten sides (50%). Among this 50% contribution, from 8th and 9th ganglia was observed in 5%, 10th and 11th ganglia was observed in 20% (right side), and 9th and 10th ganglia in 25% (left side) [Table/Fig-7].

Ganglia No.	Number of Sides Found with the Formation of LSN (N Value) Out of 20 Sides (%)
8th	2-10%
9th	7-35%
10th	10-50%
11th	9-45%

[Table/Fig-6]: Contribution from each ganglion for the formation of Lesser Splanchnic nerve (LSN).

No. of Ganglia Involved in Formation of GSN	Pattern of Origin of LSN	No. of Sides
Single Root Formation (40%)	8th	1
	9th	1
	10th	1
	11th	5
Double Root Formation (50%)	8,9	1
	9,10	5
	10, 11	4
Absent (10%)	None	0

[Table/Fig-7]: Pattern of origin of Lesser Splanchnic Nerve (LSN) (7 different categories).

The LSN was traced to leave the thorax by piercing the crus of the diaphragm on the right (40%). On the left side the nerve pierce the crus in 30%. While in the remaining 20% it passes through the aortic hiatus. In these cadavers, the left nerve accompanied the GSN in the aortic hiatus.

Least Splanchnic Nerve [Table/Fig-1-3]: The LeSN was found to be present in all thoracic sympathetic chains studied. Single root of origin is observed in 85% and two roots in the remaining 15% [Table/Fig-8]. The two roots were observed only on the left side. They were derived either from the 10th and 11th ganglia (one number) [Table/Fig-2b], or from 11th and 12th ganglia (two numbers) [Table/Fig-2c and 3a]. The LeSN commenced only from the 12th ganglion in 80%, from the 11th ganglion in 20% and from the 10th ganglion in 15% [Table/Fig-9].

Ganglia No.	Number of Sides Found with the Formation of LeSN (n value) out of 20 Sides (%)
10th	3-15%
11th	4-20%
12th	16-80%

[Table/Fig-8]: Contribution from each ganglion for the formation of Least Splanchnic Nerve (LeSN).

No. of Ganglia Involved in Formation of LeSN	Pattern of Origin of LeSN	No. of Sides
Single Root Formation (85%)	10th	2
	11th	1
	12th	14
Double Root Formation (15%)	10,11	1
	11,12	2

[Table/Fig-9]: Pattern of origin of Least Splanchnic Nerve (LeSN) (5 different categories).

The LeSN was traced to leave the thorax piercing the corresponding crus in all the 10 cadavers studied (100%).

DISCUSSION

The knowledge of the anatomical variations of the thoracic sympathetic chain and splanchnic nerves may contribute to the success of sub diaphragmatic neuroablative surgical approaches and splanchnic neurectomy for the management of chronic abdominal pain [4].

Greater Spalnchnic Nerve

The previous studies have reported the highest cephalad contribution to the GSN is from T4 and T5 ganglia [5-9] and the lowest contribution is from the T12 ganglia [10]. But in the present study not of much variation found in the origin of GSN as the highest contribution is from T5 and the lowest contribution is from T10.

The GSN has been accounted with greater variations both in the level of its origin and in the pattern of its formation. Total 58 patterns of origin of the GSN among 100 cadavers were studied by Reed (1951) [6]. In the present study 14 patterns of origin were seen in 20 specimens, the most frequent was formed from the rami of 7th and 8th ganglia (20% of cases). And to be noted wisely is that the most common frequent origin of GSN from T5-T9, is none observed in our study. Moreover, Reed [6] also reported that the GSNs are rarely bilaterally symmetrical, but we found in just one cadaver (no.10) the bilateral symmetry of GSN which has a single root origin from the rami of 7th ganglia.

Also, found the highest frequent contribution to the GSN is from the 7th and 8th ganglia (70%), next is from the 9th ganglia (40%), 6th ganglia (30%), 10th ganglia (20%), and least is from the 5th ganglia (10%) as compared to Reed who found the highest contribution is from 6th ganglia and the least is from 4th ganglia [6].

Edward and Baker [11], reported the multiple root origin of GSN in 23% of the bodies dissected as compared to the present study which shows 40% of multiple root origin (more than 2 roots), 40% of double root origin and 20% of single root origin. Out of 40% of multiple root origin-3 roots origin is observed in majority of cases (25%) as like reported by Swayam Jothi et al., (44%) [11]. They also reported 6 root origin of GSN in 2% of cases which is not appreciated in the present study, rather we report the presence of 5 roots origin of GSN (5%).

It is obviated from these observations that in thoracolumbar sympathectomy, it is directed to remove the sympathetic chain from the highest point of origin of GSN to exclude failure rate in this sympathectomy [3]. Surprisingly, the in between missed root origin is also found in 2 cases which should be kept in mind while retracting the nerves so not to leave the next high order or low order origin of the splanchnic nerves.

Lesser Splanchnic Nerve

Jit and Mukherjee [13] found the LSN in 86% of cases with the number of roots from 1 to 4. In the present study, LSN was found in 90% of cases and the number of roots ranges from 1 to 2. According to some authors the highest origin of LSN was 7th ganglion [9] or from the 9th ganglion [3]. The range of origin of LSN is found to be from 8th to 11th ganglia as compared to Reed [6] who reported to be from 9 to 12th ganglia. This study reports 7 ranges of formation of LSN and the most common type was from the rami of 9th and 10th ganglia (25%), the next frequent is 10th and 11th ganglia (20%) which correlates with the observations of Edward and Baker [11]. The high frequent contribution is found to be from 10th ganglia (50%), 11th ganglia (45%), 9th ganglia (35%) and 8th ganglia (10%) in the present study, which confirms with the previous reports that highest contribution is from 10th and 11th ganglia [10].

Least Splanchnic Nerve

Presence of bilaterally symmetrical LeSN was observed in 5 specimens. Reed [6] documented the origin of LeSN from the 11th, 12th or both ganglia, while Jit and Mukherjee [13] reported single root origin in 37% cases. The present study reports the range of origin of LeSN to be from 10th-12th ganglion either by single root (85%) or double root (15%). 5 different pattern of formation of LeSN was found and the most common origin is from single root contribution of 12th ganglia found in 14 cases (80%), which correlates with the findings of Reed [6], who reported the origin of LeSN from the 12th ganglion in 57% of cases.

Clinical Importance of the Study

Splanchnicectomy is of particular importance in the management of pain control in conditions such as chronic pancreatitis and carcinomas of the pancreas, liver, gallbladder and stomach. The advancements in surgical procedures with minimal access have rejuvenated interest in the resection of splanchnic nerves to avoid complications with thoracotomy. Longitudinal pleurotomy invovlves the resection of the branches that are present medial to the sympathetic chain from 5th to 11th Intercostals space after the dissection of the parietal pleura. [2].

Superior visualisation of the splanchnic nerves via the videoscope has made surgeons to adapt different approaches to the variations in the splanchnic nerves [14,15]. However, the surgical anatomy of splanchnic nerves is unpredictable because of the variability of the splanchnic neural pattern. Appreciation of the common patterns of the thoracic splanchnic nerves is important, particularly to the surgeon undergoing thoracic splanchnicectomy.

The extensive anatomical and physiological knowledge of the sympathetic chain initiated the clinical operations in the field in 1889. The more recent advancements in surgical treatment for disabling Primary Palmar Hyperhidrosis (PPH) include the endoscopic thoracic sympathectomy which is the only effective and sustainable method [16].

Though, the current study was limited with a very small sample size, it is intended to do extensive study with huge number of cadavers to explore the incidence of the variability of the thoracic sympathetic chain and splanchnic nerves, the recent literature updates of which is not available and also further to encompass with physiological correlations and histo morphometrical analysis. It is a high demand for the research community to develop better animal models and technologies that elicit the disease progression seen in humans [17].

CONCLUSION

The present study centred on the variations of the thoracic sympathetic chain with reference to its course, number of ganglia and rami communicantes, formation of splanchnic nerves. Conflicting results of sympathectomy and splanchnicectomies may be due to anatomical variations in the presence of sympathetic chain and in the formation of splanchnic nerves, so it is essential to know the details, pattern and variation of the sympathetic chain and origin of splanchnic nerves for sympathectomy and splanchnicectomy.

REFERENCES

[1] Susan Standring. Gray's Anatomy-The Anatomical basis of Clinical Practice. 40th ed. Churchill Livingstone, London. 2013.

Pp: 944, 1042-43.
[2] Naidoo N, Partab P, Pather N, Moodley J, Singh B, Satyapal KS. Thoracic spalnchnic nerves: implications for splanchnic denervation. J Anat. 200;199(Pt 5):585-90.
[3] Kommuru H, Jothi S, Bapuji P, Sree DL, Antony J. Thoracic Part of Sympathetic chain and its branching pattern variations in South Indian Cadavers. J Clin Diagn Res. 2014;8(12):AC09-12.
[4] Bradley EL 3rd, Bem J. Nerve blocks and neuroablative surgery for chronic pancreatitis. World J Surg. 2003;27(11):1241-48. Epub 2003 Oct 13.
[5] Kuntz A. The Autonomic Nervous System, 2nd Ed. London: Baillie' re. Tindall and Cox. 1934. Pp:28-57.
[6] Reed AF. The origin of the splanchnic nerves. Anat Rec. 1951; 109:341.
[7] Mitchell GAG. Anatomy of the Autonomic Nervous System. Edinburgh. E and S Livingstone. 1953.
[8] Yang HJ, Gil YC, Lee WJ, Kim TJ, Lee HY. Anatomy of thoracic splanchnic nerves for surgical resection. Clin Anat. 2008;21:171-77.
[9] Gest TR, Hildebrandt S. The pattern of the thoracic splanchnic nerves as they pass through the diaphragm. Clin Anat. 2009;22(7):809-14.
[10] Holinshed WH. Anatomy for Surgeons. Volume 2. New York Cassell. 1956. Pp :197-214.
[11] Edwards LF, Baker RC. Variations in the formation of the splanchnic nerves in man. Anat Rec.1940;77:335-42.
[12] Swayam Jothi S, Hemanth K, Ravi Kumar U, Rajeswara Rao N, Greater splanchnic nerve. International Journal of Anatomical Sciences. 2010;1:17-20.
[13] Jit I, Mukerjee RN. 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. 1960;9:55-82.
[14] Cuschieri A, Shimi SM, Crosthwatte G, Joypaul V. Bilateral endoscopic splanchnicectomy through a posterior thoracoscopic approach. J R Coll Surg Edinb. 1994;39(1):44-47.
[15] Moodley J, Singh B, Shaik As, Haffejee A, Rubin J. Thoracoscopic splanchnicectomy pilot evaluation of a simple alternative for chronic pancreatic pain control. World J Surg. 1999;23(7):688-92.
[16] Elias M. Cervical sympathetic and stellate ganglion blocks. Pain Physician. 2000;3(3):294-304.
[17] Malpas SC. Sympathetic nervous system over activity and its role in the cardio vascular disease. Physiol Rev. 2010;90(2):513-57.

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