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Variations in the formation of thoracic splanchnic nerves

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SUMMARY

The thoracic splanchnic nerves and celiac ganglia play a major role in pain management of upper abdominal disorders, particularly chronic pancreatitis and pancreatic cancer. The variable anatomy of the splanchnic nerves is becoming increasingly important in view of splanchnicectomy being used more often for relief of pain originating from the upper abdominal viscera. In the present study variations of the roots of origin, formation and course of the splanchnic nerves were observed by using gross dissections of eighty-eight sides of thirty-four adult and ten foetal cadavers. The greater splanchnic nerve was found on both sides of all the adult cadavers as well as foetal specimens (100%). The lesser splanchnic nerve was found in 95.45% (84 sides) of the sides. The lesser splanchnic nerve was found to be absent unilaterally in four adult cadavers (two each of right and left sides). The least splanchnic nerve was found in 67.5% of the sides. Excepting a right side of one adult female cadaver and a left side of a male cadaver, where the highest root of the greater splanchnic nerve originated from T3, in all other cases the highest root of the greater splanchnic nerve originated from T4 ganglion onwards. The greater splanchnic nerve was formed by two or more roots. A maximum number of seven roots was found in three sides of adult female cadavers (3.4%). In a large number of instances (54 cases - 64.28%) the lesser splanchnic nerve was formed by a single root. Awareness and appreciation of the variant patterns of the splanchnic nerves is of great importance to the surgeon undertaking thoracic splanchnicectomy, since this technique has been demonstrated to be of tremendous potential in pain abolition or control because of its simplicity and absence of any morbidity and potential mortality associated with thoracotomy.

Key words: Pancreatic cancer – Visceral pain – Visceral innervations – Splanchnic nerves

INTRODUCTION

Abdominal pain is a major clinical problem of patients suffering from chronic pancreatitis, carcinoma of the pancreas, liver, gallbladder and stomach. Nociceptive information from the abdominal viscera is mainly carried by celiac plexus, which is mostly made up of sympathetic fibers with some parasympathetic contribution. Preganglionic fibers from T 5 to T 10 form the greater splanchnic nerve (GSN), which ends mainly in corresponding celiac ganglia and partly in the aorticorenal ganglion and suprarenal gland. The preganglionic fibers from T10 to T11 ganglia forming the lesser splanchnic nerves (LSN) end in the aortico renal ganglion and fibers from T 11 to T12 ganglia forming the least splanchnic nerves (lSN) end in the renal plexus (Parent, 1996; Johnson and Shah, 2005). The postganglionic fibers arising from the celiac ganglion innervate the pancreas and other abdominal organs derived from embryonic foregut. The visceral pain is transmitted to the thalamus via the spinal cord, and is relayed to the cortex. Pain originating from the pancreas is mainly visceral and is characterized as a dull, deep, epigastric pain, which is poorly localized. The pain also radiates to the upper thoracic

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and lower lumbar regions. Procedures like celiac ganglion block, excision of the pancreatic nerve plexus as measures to relieve pain associated with pathological conditions of the pancreas have been found to be of limited success.

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 emergence of minimal access surgery has rekindled interest in splanchnic nerve resection, since it largely obviates the morbidity and mortality associated with thoracotomy. Superior visualization of the splanchnic nerves via the videoscope has alerted surgeons to the variations of the splanchnic nerves. The outcome of the surgery can be unpredictable if the variable anatomy of the splanchnic nerves is not kept in mind by the surgeon during the operation (Keele, 1957; Naidoo et al., 2001; Arvind, 2002; Chang Chih Lai, 2002).

The present study was undertaken to establish the pattern of splanchnic nerve anatomy in south Indians to effect adequate denervation of upper abdominal viscera by splanchnicectomy.

MATERIALS AND METHODS

Data were collected by observations from the dissected specimens of embalmed dissection room cadavers of adults of both sex and full term fetuses available in the Dept. of Anatomy, St John's Medical College, Bangalore. Thirty-four adult cadavers (18 male and 16 female) and ten embalmed still born full term fetuses (seven male and three female) were used for this study (totally 88 sides). The age of the fetuses were ascertained by CR length and the menstrual history of the mother. Only those fetuses which did not have any gross congenital abnormality, especially of the nervous system, were selected for the present study.

After removal of the anterior chest wall, the thoracic cavity was eviscerated exposing the posterior wall of the thorax, and the parietal pleura of the posterior thoracic wall was stripped off. A thoracic sympathetic chain was identified on either side of the thoracic vertebral column. Sympathetic ganglia were identified by their connections with the intercostal nerves, via grey rami communicants. The sympathetic chain was cleaned from the first intercostal space to the level of L1 vertebra by tracing it through the diaphragm. The roots of origin of the splanchnic nerves were traced to the sympathetic chain, by fine dissection using a magnifying glass. The roots of the origin of each of these splanchnic nerves were noted as follows, depending on the mode of origin: if the root originated directly from the ganglion, the serial number of the ganglion was noted – i.e., if it was from 5th ,6th and 7th ganglia it was noted as 5,6,7. If the root originated from the inter-ganglionic chain, it was noted as follows: 5/6 if the root originated from inter-ganglionic chain between 5th and 6th, 7/8, if the roots were found to originate from inter-ganglionic chain between 7th and 8th ganglion, and so on. If more than one twig were found to arise from the same source, it was noted as 6(2), 7/8(2), 10(2), and so on. The data thus collected include presence or absence of splanchnic nerves, the serial number of ganglia from which it arose, the serial number of the ganglia from which the highest root originated, and presence of splanchnic ganglion along the course of the greater splanchnic nerve and inter splanchnic connexions between the splanchnic nerves. The length and diameter of the greater splanchnic nerve, as well as the lengths of the lesser and least

Table 1. Highest root of origin of the splanchnic nerves

No. of the root	GSN (88sides)			LSN (84sides)			ISN (59 sides)		
	No. of cases		Total (%)	No. of cases Rt	Lt	Total (%)	No. of cases Rt	Lt	Total (%)
T3	1	1	2 (02.27)	-----		-----	-----		-----
T4	1	2	3 (03.41)	-----		-----	-----		-----
T4/5	3	1	4 (04.55)	-----		-----	-----		-----
T5	10	2	12 (13.64)	-----		-----	-----		-----
T5/6	2	4	6 (06.82)	-----		-----	-----		-----
T6	15	16	31 (35.23)	-----		-----	-----		-----
T6/7	2	4	6 (06.82)	-----		-----	-----		-----
T7	7	6	13 (14.77)	-----		-----	-----		-----
T7/8	0	1	1 (01.14)	-----		-----	-----		-----
T8	3	6	9 (10.23)	-----		-----	-----		-----
T8/9	0	1	1 (01.14)	0	1	1 (01.19)	-----		-----
T9	----	----	----	2	4	6 (07.14)	------		------
T9/10	-----		-----	6	0	6 (07.14)	------		------
T10	-----		-----	7	14	21 (25.0)	0	3	3 (05.08)
T10/11	-----		-----	3	6	9 (10.71)	1	1	2 (03.39)
T11	-----		-----	20	9	29 (34.52)	10	14	24 (40.68)
T11/12	-----		-----	2	2	4 (4.76)	2	2	4 (06.78)
T12	-----		-----	2	5	7 (8.33)	12	4	16 (27.12)
T12/L1	-----		-----	0	1	1 (1.19)	6	4	10 (16.95)

splanchnic nerves were measured using a sliding caliper to the nearest millimeter.

RESULTS

The GSN was found on both sides of all the adult cadavers, as well as the foetal specimens (100%). The LSN was found in 95.45% of the sides. The LSN was absent unilaterally in four adult cadavers (two each of right and left sides). The lSN was found in 67.05% of the sides. The lSN was absent in 25 sides of adult cadavers (eleven of right side and fourteen of left sides; bilaterally in five cadavers and unilaterally in 15 cadavers) and four sides of fetuses (two each of right and left sides; in one male fetus the lSN was absent bilaterally). Totally the lSN was absent in 29 sides out of 88 sides dissected (32.95%).

Highest and lowest of roots of origin of GSN (see Table 1)

In all instances, the highest root of GSN originated from T4 ganglion onwards, except the right side of one adult female cadaver and left side of a male cadaver, where the highest root of the GSN originated from T3. In the largest number of instances the highest root arose from T6 (31 sides - 35.23%), followed by T7 and T5 (13, and 12 sides respectively - 14.77%; 13.64%), T8 (9 sides - 10.23%), T5/6 and T6/7(6 sides each - 6.82%), T4/5 (four cases - 4.55%), T4 (three cases - 3.41%) and one case each of T7/8 and T8/9 (1.14%).

The lowest root of origin of GSN was from T11 in ten sides of the adult cadavers (five each of right and left sides - 11.36%). Otherwise, the lowest root of origin was T10 or above in both adult and foetal specimens.

Highest and lowest roots of origin of LSN (see Table 1)

The highest root of origin of LSN was from T8/9 in both foetal and adult specimens. In a maximum number of cases the highest root of origin of the LSN was T11 (29 cases - 34.52%) followed by T10 (21 cases - 25.0 %), T12 - seven cases (8.33%), T9 and T9/10 six cases each (7.14%), T12/L1 one case (1.19%). Only in one adult female cadaver on the right side the lowest root of origin was L1, and one male foetal specimen on left side it was T12/L1. In all other cases T12 was the lowest root of origin of the LSN.

Highest and lowest roots of origin of least splanchnic nerves (lSN) (see Table 1): In three instances among adult cadavers, the highest root of origin of the least splanchnic nerve was T10. In most other cases it was either T11 or T12 (24 and 16 instances respectively), and occasionally an interval between T12 and L1. In only two cases of adult cadavers the least splanchnic nerve also originated from L1.

Frequency of number of roots of origin of the splanchnic nerves (see Table 2)

Greater splanchnic nerve: The GSN arose from two or more roots: two roots -14 sides (15.91%); three roots - 23 sides (26.14%); four roots - 32 sides (36.36%); five roots - 12 sides (13.64%); six roots - four sides (4.54%). The maximum number of seven roots was found in three sides of adult female cadavers (3.4%).

Lesser splanchnic nerve: Out of 84 sides where the LSN was found, in a maximum number of cases the LSN arose from a single root (54 cases - 64.28%), followed by two roots in 26 cases (30.95%), and three roots in four cases (4.76%).

Least splanchnic nerve: Out of 59 sides where

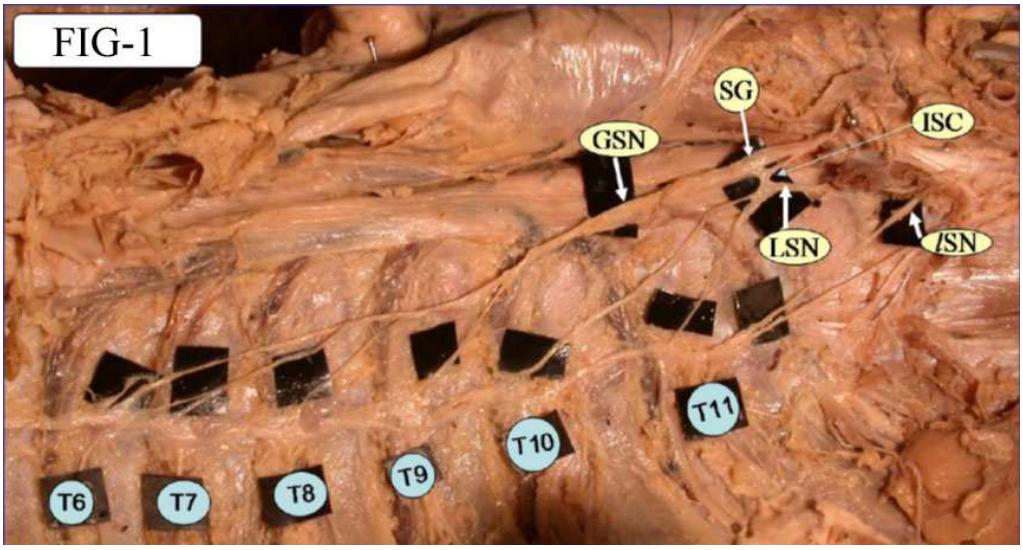

Fig. 1. Topography of the splanchnic nerves in a male adult cadaver. GSN- greater splanchnic nerve; ISC- inter-splanchnic connection; LSN- lesser splanchnic nerve; lSN- least splanchnic nerve; SG- splanchnic ganglion.

Table 2. Frequency of number of roots of origin of the splanchnic nerves.

No. of roots of origin	GSN (88 sides)		LSN (84 sides)		l SN (59sides)	
	No. of cases	%	No. of cases	%	No. of cases	%
1	Nil	Nil	54	64.28	54	91.52
2	14	15.91	26	30.95	05	08.47
3	23	26.14	04	04.70	---	----
4	32	36.36	Absent- 4/88	4.54	Absent -29/88	32.95
5	12	13.64				
6	04	04.54				
7	03	03.41				

Table 3. Frequency of contribution to the roots of the splanchnic nerves from specific thoracic ganglia.

Thoracic Ganglion No	No. of : adults(A), fetuses(F); (Total) %			
	GSN (no. of sides-88)		LSN(no. of sides-84)	/SN(no. of sides-59)
T3	A -2, F-0 (2);2.27%	T8/9	A-1,F-0(1);1.19%	Nil
T4	A -4,F-0(4);4.54%	T9	A-2,F-4(6);7.14%	Nil
T4/5	A-4,F-1(5);5.68%	T9/10	A-5,F-1(6);7.14%	Nil
T5	A-10,F-3(13);14.77%	T10	A-13,F-7(20);23.81%	A-3,F-0(3);5.08%
T5/6	A -9,F-0(9);10.22%	T10/11	A-13,F-1(14);16.67%	A-1,F-1(2);3.39%
T6	A-33,F-11(44)50.0;%	T11	A-36,F-10(46);54.76%	A-18,F-7(25);42.37%
T6/7	A-10,F-1(11);12.5%	T11/12	A-3,F-2(5);5.95%	A-2,F-2(4);6.78%
T7	A-28,F-9(37);42.04%	T12	A-11,F-2(13);15.48%	A-13,F-4(17);28.81%
T7/8	A-11,F-3(14);15.91%	T12/L1	A-0,F-1(1);1.19%	A-9,F-2(11);18.64%
T8	A-47,F-15(62);70.45%	L1	A-1,F-0(1);1.19%	A-2,F-0(2);3.39%
T8/9	A-14,F-5(19);21.59%			
T9	A-48,F-9(57);64.77%			
T9/10	A-15,F-3(18);20.45%			
T10	A-23,F-9(32);36.36%			
T10/11	A-2,F-1(3);3.41%			
T11	A-10,F-0(10);11.36 %			

Table 4. Comparative incidence of the splanchnic nerves.

Author	Race/Year	Sample size	Incidence (%)			
			GSN	LSN	/ SN	ASN
*Matsui**	Japanese/1925		100	100	98.3	-
de Sousa Pereira	Portuguese /1946	16 F;34 A (100 sides)	100	99	46	4
Edwards and Baker	American/1940	100	100	95.5	92.5	-
*Näätänen**	German/1947		100	94	16	-
*Contu and Mattioli**	Italian /1953		100	99	17	-
de Sousa	Brasilian /1955		100	100	80	18
Jit and Mukerjee	Punjabees/1960	100	100	86	37	-
Naidoo et al.	South Africans /2001	38	100	92.1	55.2	-
Gest and Hildebrandt	Caucasians/2009	24	100	100	57	—-
Present study	SouthIndians/2004	88	100	95.45	67.05	Nil

*quoted by Jit and Mukerjee (1960) details not available.

Table 5. Comparison of range of origin of the roots of splanchnic nerves in adult and fetal specimens.

		GSN		LSN		ISN	
		Right	Left	Right	Left	Right	Left
Naidoo et al. (2001)	Adult	T3-T10/11	T3-T12	T9-T12	T10/11-T12	T11-12	T11-12
	Fetus	T4-L1	T4-T10	T9-T12	T9-T11/L1	T12	T10/11-T12
	Combined	T3-L1	T3-T12	T9-T12	T9-T11/L1	T11-T12	T10/11-T12
Present study	Adult	T3-T11	T3-T11	T9/10-L1	T8/9-T12	T11-L1	T11-T12/L1
	Fetus	T5-T10/11	T4/5-T10	T9-T12	T9-T12/L1	T10/11-T12/L1	T11-T12
	Combined	T3-T11	T3-T11	T9—L1	T8/9-T12/L1	T10/11-L1	T11-T12/L1

Table 6. Comparison of the highest root of origin of the greater splanchnic nerve.

Root	Jit and Mukerjee (1960)			Naidoo et al. (2001)			Present study		
	Right	Left	Total (%)	Right	Left	Total (%)	Right	Left	Total (%)
T3				1	1	2(5%)	1	1	2(02.27)
T4	1	2	3 (3%)	4	2	6(16%)	1	2	3(03.41)
T4/5	0	1	1(1%)	1	-	1(3%)	3	1	4(04.55)
T5	7	9	16(16%)	3	4	7(18%)	10	2	12(13.64)
T5/6	6	5	11(11%)	3	1	4(10.5%)	2	4	6(06.82)
T6	14	14	28 (28%)	3	5	8(21%)	15	16	31(35.23)
T6/7	4	2	6(6%)	3	-	3(8%)	2	4	6(06.82)
T7	10	12	22(22%)	1	3	4(10.5%)	7	6	13(14.77)
T7/8	2	2	4(4%)	-	3	3(8%)	0	1	1(01.14)
T8	5	3	8(8%)	**-**	**-**	**-**	3	6	9(10.23)
T8/9	-	-	-	**-**	**-**	**-**	0	1	1(01.14)
T9	1	0	1(1%)	**-**	**-**	**-**	**-**	**-**	**-**

Table 7. Comparison of number of roots of origin of the greater splanchnic nerves in adult and fetal specimens.

Author/Year	Range of number of roots	Common number of roots
*Matsui/1925**	1-6	-----
*Rossi/1927**	1-7	4
*Monteiro et al./1933**	1-7	3
Edwards and Baker/1940	1-7	3 (3 roots 32.5%, 4 roots 29%)
*Näätänen/1947**	2-5	3 (43%)
*Contu and Mattioli/1953**	1-7	3 (36% in adults and 47% in new born)
*Toni and Frignani/1955a**	1-5	4 (new born)
*Toni and Frignani/1955b**	-	3 (44 % adults)
Jit and Mukerjee/1960	1-8	4 (3 roots 29%, 4 roots 31%)
Naidoo et al./2001	3-10	
Present study/2004	1-7	4(36.36%);3(26.14%);2(15.91%)

*quoted by Jit and Mukerjee (1960)

the lSN was found the lSN arose from a single root in 54 cases (91.52%), and in other five cases the lSN arose by two roots (8.47%).

Sex differences

There were no noticeable sex differences in the pattern of origin or course of the splanchnic nerves. Except in case of lSN, the absence was noticed only in males.

Length of the splanchnic nerves

the mean length of the splanchnic nerves as measured in the adults was as follows (in mms): GSN: 54.05 ± 27.312; LSN: 47.42 ± 17.85; lSN: 38.69 ± 11.31.

Intersplanchnic connections

Intersplanchnic connections between GSN and LSN was observed in six sides of adult cadavers and two sides of foetal specimens; in one of the foetal specimens intersplanchnic connections between LSN and lSN was also noticed.

Intermediate splanchnic ganglia

Splanchnic ganglia along the course of GSN was found in eleven sides of the adult cadavers; in three of the cadavers it was bilaterally observed; in five other cases it was unilateral, the size of the splanchnic ganglion varied from 3 x 3 mm to 15 x 5 mm. No splanchnic ganglia were observed in foetal specimens.

Multiple roots

In many instances the roots of splanchnic nerves were formed by more than one twig from a single source: four such instances of GSN were observed in fetuses and ten instances in adult cadavers. In the case of LSN multiple roots were observed in two instances among adult cadavers and two instances among fetuses.

Inter-ganglionic roots

In many instances the roots of the splanchnic nerve were found to originate from interganglionic chain. Roots of the greater splanchnic nerves were found to arise from the interganglionic chain in 15 adult cadavers bilaterally and in 13 cadavers unilaterally (nine of right side and four of left side; totally 36 instances on right side and 29 instances on the left side). The maximum number of interganglionic roots for the GSN in a single instance in adults was three. The maximum in-

stances of inter ganglionic root were found to arise from the interganglionic chain between T8th and 9th and 10th (nineteen and eighteen instances respectively).

In fetuses the interganglionic roots of the GSN were observed bilaterally in three and unilaterally in five cases (two on right side and three on left side).

LSN: Interganglionic roots of the lesser splanchnic nerves were found in three cases bilaterally and in 13 cases unilaterally (seven on right side and six on left side) among adult cadavers.

Among the fetuses, interganglionic roots for the LSN were found in one instance bilaterally and three instances unilaterally (one of right side and two of left side).

DISCUSSION

During the period between 1925-1960 incidence and variations in the formation of the splanchnic nerves have been recorded among the several races by a number of researchers across the world (see Table 4).

After a gap several decades the interest in this subject has been rekindled on the grounds of its importance in thoracoscopic splanchnicectomy by Naidoo et al. (2001). Only one exhaustive study of splanchnic nerves of Indian subjects exists in the literature until the present date (Jit and Mukerjee, 1960).

Incidence of splanchnic nerves: The incidence of the splanchnic nerves as quoted by various researchers is shown in the Table-4. In almost all the studies including the present, GSN was found in 100% of the dissections, whereas the incidence of the LSN and lSN vary: studies on Japanese and Brazilian (Matsui, 1925; de Sousa, 1955) have quoted 100% incidence of LSN but the report on Punjabis (Jit and Mukerjee, 1960) shows an incidence of LSN as low as 86%. In other studies the incidence varies between 92% (Naidoo et al., 2001) to 99% in Portuguese (de Sousa Pereira, 1946). Incidence of lSN can be as low as 16% as in the case of Germans (Näätänen, 1947), and as high as 98.3% quoted in the study of Japanese (Matsui, 1925). Recently Gest and Hildebrandt (2009) have reported the pattern of the thoracic splanchnic nerves in anatomical dissections performed on the bodies of 24 donors (16 female and eight male bodies, the ages ranging from 54 to 92 years), with emphasis on their mode of passage through the diaphragm. These authors found out of 44 sides, all three thoracic splanchnic nerves in 25 sides (57%); the greater and lesser thoracic splanchnic nerves were present in all sides, while the least thoracic splanchnic nerve was absent in 19 sides (43%).

In the present study the LSN was found in 95.45% of the dissections whereas the lSN was found to be absent in 29 sides out of 88 sides dissected (32.95%).

Number of roots of origin *(see Tables 2 and 7)*

The greater splanchnic nerve: The highest number of roots of origin of the GSN has been observed by Naidoo et al. (2001) i.e., ten roots in only one case of the left side. In all the other studies the highest number of roots ranged from 5 to 8. The most frequently occurring number of roots of origin of the GSN in almost in all the studies was either three or four (see Table 7).

In the present study the highest numbers of roots of origin of the GSN were seven (three cases), the range of number of roots of origin of the GSN was 1-6. The most frequently occurring number of roots was four (36.36%); followed by three (26.14%); and two (15.91%).

Incidence of the origin of uppermost root and the lowermost root GSN *(see Tables 5 and 6)*

The highest root of origin of the GSN as observed by Jit and Mukerjee (1960) was the 4th ganglion (2% right, 4% left, total 3%). On the right side the origin from the 4th ganglion was in the form of a loop which joined the root from the 5th ganglion near the origin of the latter. Most commonly, the highest root was derived from 6th ganglion (28%) in their series. In his dissection of 100 cadavers, Reed (1951) found the highest root of GSN from 4th ganglion in 2%, 5th ganglion in 32%, 6th ganglion in 42.5%, 7th ganglion in 20.5% and 8th ganglion in 3% of the specimens.

No interganglionic roots have been reported his study. Naidoo et al. (2001) in their series found the highest root of origin of the GSN as high as T3 (two out of 38 sides - 5%) and as low as T7/8 (three out of 38 sides - 8%). The most frequent origins of the uppermost root of GSN in their study were from T6 (eight out of 38 sides 21%), T5 (seven out of 38 sides 18%) and T4 (six out of 38 sides 16%). Edwards and Baker (1940) found the origin of the uppermost root of GSN from 4th ganglion in 5% of the cases. The highest percentage of roots of the GSN originated from 7th, 8th and 9th thoracic ganglia (69.5%, 78% and 77.5% respectively) in his series. In the present study the highest root of origin was from 3rd thoracic ganglion in two instances one each of right and left sides, in other instances the most frequent level of origin of the highest root was T6 (35.23 %) followed by T7 (14.77%) and T5 (13.64% each).

Frequency of contribution of the roots from the specific thoracic ganglion *(see Table 3)*

In the present series the most frequent contribution for the root of the GSN was from T8

(70.45%) followed by T9 (64.77%), T6 (50.0%), T7 (42.04%). Occurrence of roots originating from interganglionic chain varied from 5.68-21.59 %. Naidoo et al. (2001) have mentioned additional direct lower thoracic contributions (ganglionic and inter ganglionic) to the GSN in six out of 38 sides (16%) in the absence of LSN and lSN. No such roots were noticed in the present study. In some instances in the present series the highest root of the GSN was found to form a loop before it joined the subsequent root.

Lesser splanchnic nerve

Jit and Mukerjee (1960) found the LSN in 86% of the cases in their study and the number of roots varying from 1-4, the most common origin of the roots from T10 and T11 ganglia. Some authors have observed that branches contributed by the 9th and 10th thoracic ganglia were destined for the upper abdomen in general, and pancreas in particular (Naidoo et al., 2001). Groen et al. (1987) have observed in their foetal series LSN originating via 1-2 rami from thoracic segments T10 and T11 (range T10 and T12).

Naidoo et al. (2001) have reported ten ranges of origin for the LSN, with the most common ganglion of origin being T10 (nine out of 38 sides - 23%). In the present study, the highest number of roots origin of LSN was only three in both adult cadavers and fetal specimens. Excepting five cases, where the highest root was contributed by the T9, the origin of the LSN in all other cases was from T10 - T11. Only in four cases (8%) LSN originated from T12 and in one case of adult cadaver from the interval between T12 and L1.

Least splanchnic nerve

lSN is usually described in the text books as arising from the last thoracic ganglion, which may be the T10 or T11 (Mitchell, 1953). Incidence of this nerve is recorded to vary from 16% to 98.3%. Jit and Mukerjee (1960) in their series of dissections found the lSN in 37% of the specimens. It may receive the communicating twig from the lesser splanchnic nerve, but usually it is considered to have only one root of origin. Edwards and Baker (1940) found in 94.6% of the cases the nerve arising from a single root and by two roots in 5.4% of the specimens in which it was detected. In 88.5% of the specimens the nerve arose from T12 ganglion. Instances of two roots of origin have been reported in Italian, Portuguese, and American series as well (Jit and Mukerjee, 1960; de Sousa Pereira, 1946; Brooker, 1951). Even three roots of origin have been observed in the Brazilian series (de Sousa, 1955). Jit and Mukerjee (1960) found lSN arising from single root in 25 specimens. This root took origin from the last thoracic ganglion in eleven instances (from T11 in six, T12 in four, and T13 in one). In six instances the single root was derived from the cord just above, and in eight instances from the cord below the last thoracic ganglion. When the nerve arose from two roots (nine instances) their origin ranged from T11 to L1. Jit and Mukerjee (1960) observed that in 66.6% of the cases lSN arose from single root, according to them it is not rare to find lSN arising by 2 or 3 roots. Naidoo et al. (2001) found five ranges of the origin of the lSN with the T12 (20 of 38 sides - 53%) being the most common. In the present study the least splanchnic nerve was found to arise most commonly from a single root (54 instances - 91.52%). In only a few cases (five instances - 8.47%) the lSN arose by two roots, there were no cases of lSN arising from more than two roots. The most frequent origin of the lSN among adults was from T11 (24-40.68%) followed by T12 (16-27.12%). In seven instances the least splanchnic nerve also arose from cord below the T12 ganglion.

In the present study the least splanchnic nerve was found to occur in 67.05% of cases which is higher than reported by Jit and Mukerjee (1960) (37%), Naidoo et al. (2001) (55.2%) and Gest and Hildebrandt (2009) (57%) in their series.

Accessory splanchnic nerve (4th splanchnic nerve)

A few authors have reported the presence of a fourth splanchnic nerve named as the accessory splanchnic nerve: de Sousa Pereira (1946) has reported the occurrence of an accessory splanchnic nerve in 4% of the specimens examined by him. De Souza (1955), in his dissection of 50 cadavers of Brazilian (33 males and 17 females), found this nerve in 18% of the specimens. According to him nerve usually arises by one root, from T12 ganglion or the interval between T12 and L1 vertebrae. Some times this nerve may have two roots. On entering the abdomen, it terminated in aortic plexus below the renal artery or in the renal plexus. Jit and Mukerjee (1960) and Naidoo et al. (2001) could not find this nerve in their series. This nerve could not be detected in the present study as well.

Intersplanchnic connections

Naidoo et al. (2001) observed intersplanchnic connections in fifteen out of 38 cases (39%) in their series. Out of these in thirteen instances the intersplanchnic connection occurred between the GSN and LSN and in the other two instances between the LSN and lSN. The intersplanchnic connections were observed on the bodies of lower thoracic and upper lumbar vertebrae (T10-L2). In the present series intersplanchnic connections between GSN and LSN were observed, in four sides of adult cadavers and two sides of fetal specimens (12%). In one of the fetal specimens intersplanchnic connections between LSN and lSN was also

noticed.

Intermediate splanchnic ganglion: *(see Table 8)*

It is usually found in the lower part along the course of the GSN. The splanchnic ganglion has been identified macroscopically in all previous studies. Lobstein (1823) is credited with the first description of this ganglion, which he found in two instances of his dissections. Mitchell (1953) has traced in his dissections a few filaments traversing from this ganglion to the suprarenal gland and the kidney. According to Mitchell (1953), the position of the ganglion is variable: it may not be found on the nerve (GSN), but adjacent to it between the nerve and the aorta or interval between GSN and LSN. Toni and Frignani (1955a), in their dissections of 40 newborn fetuses, found the splanchnic ganglion in 45% of the specimens. Other authors have recorded a variable occurrence of this ganglion in their series (see Table 8). Jit and Mukerjee (1960) in their series found that the location of the ganglion was variable: in 25 instances it was found at the junction of the lower root or combined lower two roots with GSN; in eight sides it was present on the GSN below the junction of the lowest roots at varying levels. It was present at a level higher than the point of attachment of the lowest root in 14 instances. In the present series, a splanchnic ganglion was found in 22% of the dissections of the adult cadavers. No instances of occurrence of splanchnic ganglion were found in fetal specimens. Mitchell (1953) detected the ganglion microscopically even in specimens where it was not visible to the naked eye. Jit and Mukerjee (1960) have identified the splanchnic ganglion microscopically in three places along the course of GSN in the body of a newborn child. Jit and Mukerjee (1960) have also described the varying shape of the ganglion as circular, oblong, elongated or irregular in their series; the size of the ganglion in their study varied from size of a pin head to 25x4x4 mm. In the present series, in most of the cases the ganglion was oval in shape and the maximum size observed was 15x5x3 mm.

Comparison of foetal dissections

A number of studies using foetal dissections are available in the literature: de Sousa Pereira (1946) - 16 fetuses; Toni and Frignani (1955a) - 40 new born fetuses; Groen et al. (1987) - six fetuses; Naidoo et al. (2001) - 14 foetal dissections. Groen et al. (1987) found the GSN to arise from 1 to 4 large branches, most frequently from the T8-9 ganglia, with the highest origin being T6 and the lowest being T11; LSN originating via 1-2 rami from thoracic segments T10 and T11 (range T10-T12). A thickening in the GSN near the suprarenal glands (the suprarenal ganglion) in all fetal specimens was also observed. The findings of Naidoo et al. (2001) in their series of 14 fetal dissections are as follows: The GSN was found in 100% of the specimens; the LSN was found in 26 out of 28 sides (12 right; 14 left sides - 92.87%); lSN was found in 16 out of 28 sides (seven right; nine left sides - 57.14%). Absent in seven right and five left sides - 42.87%). Range of origin of the roots of GSN was T4-L1 on right side and T4-T10 on left side. The highest number of roots of origin for the GSN was eight (in only one specimen on right side) and the lowest number of roots of origin of the GSN was two. The range of origin of the LSN was T9-T12 on right side and T9-L1 on the left side; the highest number of roots of origin of the LSN was three. The range of origin of the roots of lSN was T10/11-T12 on the right side and T10-L1 on the left side. The highest number of roots of origin of the lSN was two only. In the present series the GSN and LSN were found in all the specimens (100%); the lSN was absent in four sides (20%; found in 80%). The highest root of origin of the GSN was T4/5 and the lowest was T10/11. The highest number of roots of origin was six; in one specimen on the left side the GSN arose from a single root i.e., from T8 (female fetus 1/Lt side). The highest root of origin of the LSN was T9 and that of lSN was T10/11. No intermediate splanchnic ganglia

Table 8. Comparison of the reported incidence of the splanchnic ganglion

Author	Year	Incidence of the splanchnic ganglion
Lobstein*	1823	2 cases
Cunningham	1875	20/26 (77%)
Mitchell	1953	22/60 (36.6%)
Toni and Frignani *	1955a	18/40 (45%)
de Sousa Pereira	1946	62%
Rosselli *	1943	16.6%
Näätänen *	1947	18%
Contu and Mattioli *	1953	63%
De Sousa	1955	41%
Jit and Mukerjee	1960	41%
Naidoo et al.	2000	17/38 (44.7%)
Present study	2004	11/88 (12.5%)

* cited by Jit and Mukerjee (1960)

were found in the fetal specimens.

Anatomy of the splanchnic nerves and its application in relief of pain originating from the upper abdominal viscera

Recent advances in surgery have made the approaches to the sympathetic nervous system more feasible than before. The variable anatomy of the splanchnic nerves is becoming increasingly important in view of the splanchnicectomy being used more often for relief of pain originating from the upper abdominal viscera. The splanchnic nerves have been established as carriers of pain sensation from abdominal viscera developed from the foregut (Brooker, 1951). Splanchnicectomy as a surgical procedure has been used for a variety of conditions in the past, like malignant hypertension, pain due to peptic ulcer, cancer of the stomach, gall–bladder, kidney etc., and of late splanchnicectomy has become popular procedure for relief of pain due to chronic pancreatitis and cancer of the pancreas (Lang-Lazdunski et al., 2002). Pain undoubtedly is the most invalidating problem in cases of chronic pancreatitis (Noppen et al., 1998). The sympathetic pancreatic innervation constitutes the main pathway for the afferent transmission of pancreatic pain. Anatomical interruption of this sympathetic system can be achieved at various levels (i.e., at the level of the celiac plexus or at the level of the splanchnic nerves) and with various techniques (e.g., percutaneous denervation of the celiac plexus using neurolytic agents, such as alcohol, or steroids with or without analgesics, open surgical splanchnicectomy using chemical neurolytics, or true surgical resection). Results of percutaneous celiac block for relief of pancreatic pain tried by some authors in patients were unpredictable and short-lived (Leung et al, 1983). Recently, the development of less invasive thoracoscopic methods for performing “surgical” splanchnicectomy has caused a resurgence of interest in this method of alleviating intractable pancreatic pain due to pancreatic cancer or chronic pancreatitis. In all the published reports, thoracoscopy was performed by surgeons using typical video-assisted thoracoscopic surgery (VATS) technique. In five out of eight patients with intractable pancreatic or epigastric pain, significant and persistent pain relief could be obtained (62.5%) following a simplified thoracoscopic splanchnicolysis performed by a group of pneumologists (Worsey et al, 1993; Lin et al, 1994; Takahashi et al, 1996; Strickland et al., 1996). Following a thoracoscopic splanchnicectomy performed by Moodley et al. (1999), in seventeen patients a pain-free period was observed during a follow-up period of six to thirty months.

Pancreatic cancer remains a significant clinical challenge worldwide. Pancreatic cancer is an important health problem: it is the 4th cause of cancer death in USA and the incidence is 10/100000 per year (Andtbacka et al., 2004; Kuhlmann et al., 2004). Unrelenting epigastric abdominal pain and back pain are some of the most common reported symptoms at the time of pancreatic cancer diagnosis in 40-80% of the patients. With the advent of minimally invasive surgery, thoracoscopic bilateral splanchnicectomy has received increased interest which involves division of the greater, lesser splanchnic sympathetic nerve afferents that convey pain sensation from the upper abdominal viscera to the central nervous system. Several small studies have indicated that thoracoscopic splanchnicectomy is safe and effective in alleviating pancreatic pain. In these studies more than 80% of patients who underwent thoracoscopic splanchnicectomy had better quality of residual life (Kusano et al., 1997; Ihse et al., 1999; Buscher et al., 1999; Pietrabissa et al., 2000; Saenz et al., 2000; Leksowski, 2001; Krishna et al., 2001).

It is worth noting the observations of Moodley et al. (1999) concerning the unpredictable surgical anatomy of the splanchnic nerves: Despite the numerous descriptions of the greater and lesser splanchnic nerves in anatomic texts, our exposure of these nerves revealed that aberrations in the splanchnic outflow occurred frequently. Although splanchnic nerves consistently originated from the fifth thoracic ganglion, the arrangement of the nerves and the number of branches and their interconnexions varied among patients. Such observations during the thoracoscopic splanchnicectomy have rekindled the interest in the variable anatomy of the splanchnic nerves and initiated some studies on the variable patterns of splanchnic nerves in cadavers. Naidoo et al. (2001) postulate that the underappreciated anatomical variations in the splanchnic neural pattern is the basis of inconsistent results of splanchnicectomies. According to these authors, the range of splanchnic nerve origin is of greater significance than the presence or absence of consecutive nerve roots. Awareness and appreciation of the variant patterns of the splanchnic nerves is of great importance to the surgeon undertaking thoracic splanchnicectomy, since this technique has been demonstrated to be of tremendous potential in pain abolition or control because of its simplicity and absence of any morbidity and potential mortality associated with thoracotomy. Thus the present study supports the view of surgeons regarding the variations in the splanchnic nerve formation.

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