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Thoracic splanchnic nerves: implications for splanchnic denervation

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ABSTRACT

Splanchnic neurectomy is of value in the management of chronic abdominal pain. It is postulated that the inconsistent results of splanchnicectomies may be due to anatomical variations in the pattern of splanchnic nerves. The advent of minimally invasive and video-assisted surgery has rekindled interest in the frequency of variations of the splanchnic nerves. The aims of this study were to investigate the incidence, origin and pattern of the splanchnic nerves in order to establish a predictable pattern of splanchnic neural anatomy that may be of surgical relevance. Six adult and 14 fetal cadavers were dissected (n = 38). The origin of the splanchnic nerve was bilaterally asymmetrical in all cases. The greater splanchnic nerve (GSN) was always present, whereas the lesser splanchnic nerve (LSN) and least splanchnic nerve (lSN) were inconsistent (LSN, 35 of 38 sides (92 %); LSN, 21 of 38 sides (55 %). The splanchnic nerves were observed most frequently over the following ranges: GSN, T6–9: 28 of 38 sides (73 %); LSN, when present, T10–11: (10 of 35 sides (29 %); and lSN, T11–12: 3 of 21 sides (14 %). The number of ganglionic roots of the GSN varied between 3 and 10 (widest T4–11; narrowest, T5–7). Intermediate splanchnic ganglia, when present, were observed only on the GSN main trunk with an incidence of 6 of 10 sides (60 %) in the adult and 11 of 28 sides (39 %) in the fetus. The higher incidence of the origin of GSN above T5 has clinical implications, given the widely discussed technique of undertaking splanchnicectomy from the T5 ganglion distally. This approach overlooks important nerve contributions and thereby may compromise clinical outcome. In the light of these variations, a reappraisal of current surgical techniques used in thoracoscopic splanchnicectomy is warranted.

INTRODUCTION

The 3 splanchnic nerves of the thoracic sympathetic trunk, arise from the lower 8 ganglia. The greater splanchnic nerve (GSN) is formed by branches of the T5–9 sympathetic ganglia, the lesser splanchnic nerve (LSN) from T10–11 ganglia and the least splanchnic nerve (lSN) from the T12 ganglion. These splanchnic nerves contain, predominantly, visceral efferent fibres, as well as pain conducting visceral afferent fibres (McMinn, 1994).

The highest cephalad contribution of the sympathetic chain to the GSN is documented as the T4 or T5 ganglia (Kuntz, 1934; Reed, 1951; Mitchell, 1953; Jit & Mukerjee, 1960). The most caudal sympathetic contribution can be as low as the T12 ganglion (Hollinshead, 1956).

Edwards & Baker (1940) noted the origin of the LSN as high as the T7 sympathetic ganglia, with the most common type originating from T10 and T11, while Reed (1951) found the origin of the LSN to be from the T9–12 sympathetic ganglia.

In the adult, Reed (1951) documented the lSN arising from either the T11, T12 or both ganglia, while Jit & Mukerjee (1960) found lSN in 37 % of cases arising predominantly from a single root.

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 of thoracotomy. This technique involves dissection of the parietal pleura medial

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to the main sympathetic chain from the 5th to the 11th intercostal space (longitudinal pleurotomy) where all branches that issue medial to the chain are transected. Superior visualisation of the splanchnic nerves via the videoscope has alerted surgeons to the variations in the splanchnic nerves (Cuschieri et al. 1994; Moodley et al. 1999). However, the surgical anatomy is not predictable because of the great variability in the splanchnic neural pattern.

The aims of this study were to investigate the incidence, origin and pattern 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

Twenty embalmed cadaveric specimens were bilaterally microdissected (n = 38). The series comprised 14 fetal (gestational age 15 wk–full term) and 6 adult specimens (2 sides were excluded due to thick pleural adhesions). Fetal age was determined by crown-rump and foot length measurements. The thoracic cavity was eviscerated via an anterior approach and the posterior thoracic wall exposed. The parietal pleura was subsequently stripped to expose the sympathetic chain and its branches.

The thoracic sympathetic ganglia were identified by their rami communicantes to intercostals nerves, as employed previously by Groen et al. (1987).

RESULTS

Incidence and origin of splanchnic nerves

The origin of the splanchnic nerve was bilaterally asymmetrical in all cases (Table 1). The GSN was always present (Fig. 1, Table 2) whereas the LSN and lSN were inconsistent: LSN, 35 of 38 sides (92%; right, 17 of 19 sides, 89%; left, 18 of 19 sides, 95%); lSN, 21 of 38 sides (55%: right, 9 of 19 sides, 47%; left, 12 of 19, 63%).

The splanchnic nerves were observed most frequently over the following ranges: GSN , T6–9 (28 of 38 sides, 74%) and—when present—LSN, T10–11 (10 of 35 sides, 28.6%) and lSN, T11–12 (3 of 21 sides, 14%) (Fig. 2, Table 1).

The origin of the uppermost root of GSN was as high as T3 in 2 of 38 sides (5%) and as low as T7/8 in 3 of 38 sides (8%). The most frequent origin of the uppermost root of GSN was from T6 (8 of 38 sides, 21%), T5 (7 of 38 sides, 18%), and T4 (6 of 38 sides, 16%) (Table 2).

The origin of the lowest root of GSN was as high as T7 in 1 of 38 sides (3%) and as low as L1 in 2 of 38

Table 1. *Origin of the thoracic splanchnic nerves in adult and fetal specimens*

		GSN		LSN		ISN	
		Right	Left	Right	Left	Right	Left
Adult:	1	T3,4,5,5/6,6,6/7,8,9	T3,4(2),5(2),6,7,8,9,10(2),11,12	T9,10(2)	T12(2)	0	0
	2	T6,7,8/9,9	T6,7/8,8/9,10	T9,10	T11	0	T12
	3	T5/6,6/7,7,8,9	T7,8,9/10	T10	0	0	0
	4	T6,7,8,9(2),10/11	–	T10/11	–	T12	–
	5	–	T4,6,7,8,9	–	T10/11	–	T11
	6	T7,9/10	T5/6,6/7,8/9,10	T11,11/12	T10/11,11	T12	T12
Fetal:	1	T4(2),5,6(2),7,8,9,10	T4,5,7(2),8,9,10,10	T10,12	T12(2)	0	L1
	2	T6/7,7/8,9,10	T6,7,8	T11	T9,10	T12	T11
	3	T6/7,7/8,8/9,9/10,L1	T5,7,9(2)	T10/T11	T10(2)	T10/11,11	L1
	4	T6/7,7/8,9/10,10,11,L1	T7,7/8,8/9,9	0	T10,11	0	0
	5	T4/5,5/6,8,9(3)	T5,6/7,8,9(2)	T11	L1	0	0
	6	T6,7,8/9,9,10	T6,7,9,10	T10,11,12	T10,11	T12	T12
	7	T5/6,7,8,9	T7/8,9,10	0	T11/L1	0	0
	8	T4,6,8,9/10	T7/8,9,10	T11	T10	0	T11
	9	T4,5,5/6(2),6,7,9,10,11	T5,6/7,8,9(2)	T12	T9/10	0	T10,10/11
	10	T6,7/8,9,10	T7/8,9(2)	T11,12	T10,11	0	0
	11	T5,7	T7,9,10	T10	T11	T11,12	T12(2)
	12	T5,6,7,8,9,10	T6,7,9,10	T11	T12	T12	0
	13	T5,7,8	T6,8,9	T9,10	T10	T11,12	T12
	14	T4,6,7,8,9(2)	T5,7,7/8,9,10	T10,11	T11,12	T12	T11,12

/, inter-ganglionic root; 0, no roots observed; ( ), multiple roots; –, undissected (pleural adhesions).

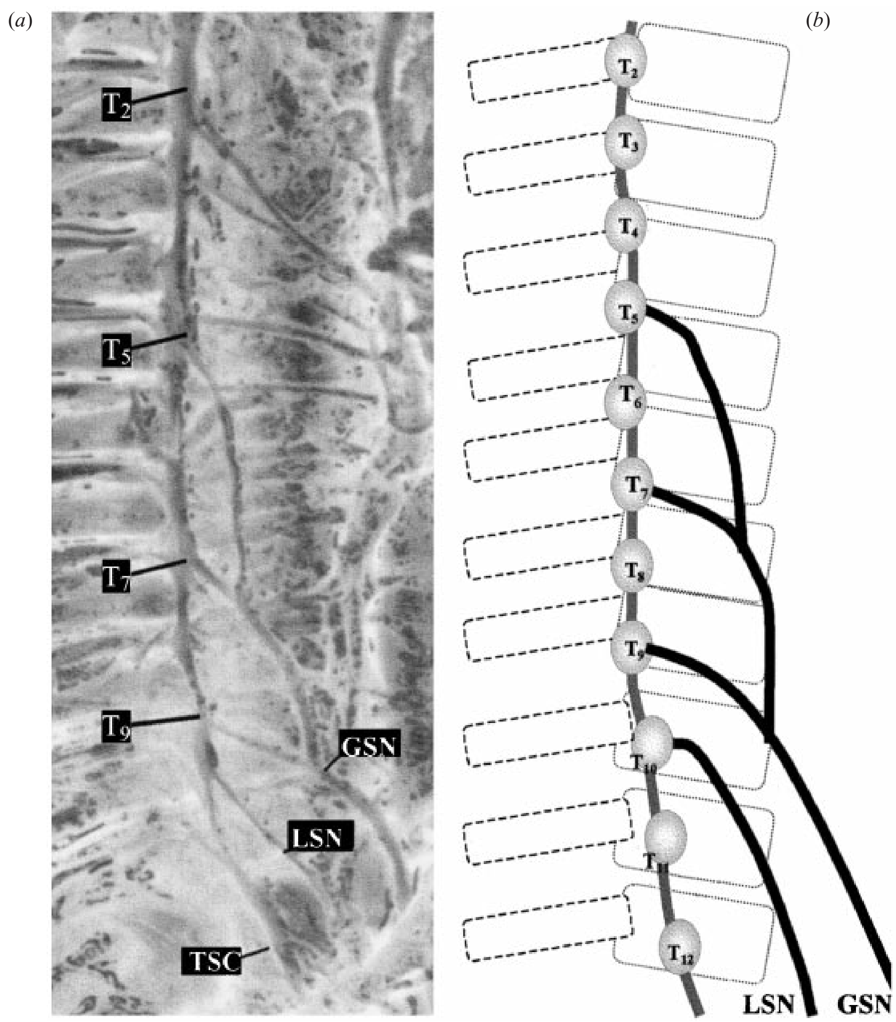

Fig. 1. (*a*) Anterolateral view of the right sympathetic chain showing the origins of GSN and LSN in a fetus. (*b*) Diagram illustrating the origin of the GSN and LSN as depicted (*a*). GSN, greater splanchnic nerve; LSN, lesser splanchnic nerve; TSC, thoracic sympathetic chain; T2,3,4,5,6,7,8,9,10,11,12, T2–12 Ganglia.

sides (5%). The most frequent origin of the lowest root was T9 (13 of 38 sides, 34%) and T10 (10 of 38 sides, 26%) (Table 2).

The number of ganglionic roots of the GSN varied between 3 and 10 (widest, T4–11; narrowest, T5–7). There was no correlation between the wide range and number of roots of the GSN with the absence of the LSN and lSN (Table 3). Additional direct lower thoracic contributions (ganglionic and inter-ganglionic) to the GSN were noted in 6 of 38 sides (16%) in the absence of the LSN and ISN (Table 1, Adult 1; Fetal 4 and 9). The absence of LSN and lSN was also noted in cases in which the GSN arose from only 3 sympathetic ganglia Table 1, Fetal 7).

Intermediate splanchnic ganglia (ISG)

ISG, when present, was observed only on the GSN main trunk with an incidence of 45%: 6 of 10 sides (60%) in the adult, and 11 of 28 sides (39%) in the fetus (Fig. 2).

The vertebral range over which ISG were found, when present, was T10–12 (unilaterally, 13 of 38 specimens, 76%; bilaterally, 4 of 38 specimens, 22%). No ganglia were observed in the infradiaphragmatic course of the GSN.

Medial collateral branches arising from the ISG were noted in all cases and joined the plexus on the thoracic, oesophagus or aorta.

Intersplanchnic connections

Intersplanchnic connections were observed in 15 of 38 (39%) cases. Of these, 13 of 38 (87%) occurred between the GSN and LSN, and 2 of 38 (13%) between the LSN and ISN. Interconnections were observed on the bodies of the lower thoracic and upper lumbar (T10–L2) vertebrae.

Table 2. *Incidence of origin of uppermost root and lowest root of GSN*

	Uppermost root			Lowest root		
Root	Right	Left	Total	Right	Left	Total
T2/3	–	–	–	–	–	–
T3	1	1	2 (5%)	–	–	–
T3/4	–	–	–	–	–	–
T4	4	2	6 (16%)	–	–	–
T4/5	1	–	1 (3%)	–	–	–
T5	3	4	7 (18%)	–	–	–
T5/6	3	1	4 (10%)	–	–	–
T6	3	5	8 (21%)	–	–	–
T6/7	3	–	3 (8%)	–	–	–
T7	1	3	4 (11%)	1	–	1 (3%)
T7/8	–	3	3 (8%)	–	–	–
T8	–	–	–	1	2	3 (8%)
T8/9	–	–	–	–	–	–
T9	–	–	–	6	7	13 (34%)
T9/10	–	–	–	2	1	3 (8%)
T10	–	–	–	5	8	10 (26%)
T10/11	–	–	–	1	–	1 (3%)
T11	–	–	–	1	–	1 (3%)
T11/12	–	–	–	–	–	–
T12	–	–	–	–	1	1 (3%)
T12/L1	–	–	–	–	–	–
L1	–	–	–	2	–	2 (5%)

T, Thoracic ganglion; L, Lumbar ganglion; /, interganglionic root; –, no roots observed.

Table 3. *Comparison of the incidence of GSN, LSN and lSN reported by various authors*

			Incidence (%)			
Author	Year	Sample size	GSN	LSN	lSN	ASN
Matsui (cited by Jit & Mukerjee	1925		100	100	98.3	–
De Sousa Pereira (cited by Jit & Mukerjee)	1929		100	99	46	4
Edwards & Baker	1940	100	100	95.5	92.5	–
Näätänen (cited by Jit & Mukerjee)	1947		100	94	16	–
Contu & Mattioli (cited by Jit & Mukerjee)	1953		100	99	17	–
de Sousa (cited by Jit & Mukerjee)	1955		100	100	80	18
Jit & Mukerjee	1960	100	100	86	37	0
This study	2000	38	100	92.1	55.2	0

GSN, Greater splanchnic nerve; LSN, lesser splanchnic nerve; lSN, least splanchnic nerve; ASN, accessory splanchnic nerve.

GSN termination

The GSN was observed to terminate in the suprarenal plexus in the fetus and in the renal plexus in the adult. In addition a thickening on the GSN was observed in all fetal specimens close to the suprarenal gland (supra renal ganglion).

DISCUSSION

In 200 dissections, Reed (1951) observed 58 different patterns of the GSN, with the most common pattern being the origin from the T6–9 ganglia, noted in 13 dissections (6.5%). In the fetus, Groen *et al.* (1987) found the GSN to arise from 1–4 large branches, most frequently from the T8–9 ganglia, with the highest origin being T6 and the lowest being T11. Intra-individual differences in the origin and number of the splanchnic nerve rami were frequently observed. Jit & Mukerjee (1960) found the origin of the GSN to vary from 1–8 roots, with 4 being the most common (31%). Edwards & Baker (1940) employed more flexible criteria in the classification of splanchnic nerve origin, allowing for the absence of a single root of origin from 1 ganglion, e.g. T5, 6, 8, 9, 10. On the other hand, if the GSN arose from ganglia T5, 8, 9, 10

Table 4. *Comparison of the reported incidence of the splanchnic ganglion*

Author	Year	Incidence of splanchnic ganglion
Lobstein (cited by Jit & Mukerjee)	1823	2 cases
Cunningham	1875	20/26 (77%)
Mitchell	1953	22/60 (36.6%)
Toni & Frignani (cited by Jit & Mukerjee)	1955a	18/40(45%)
De Sousa Pereira (cited by Jit & Mukerjee)	1929	(62%)
Rosselli (cited by Jit & Mukerjee)	1943	(16.6%)
Näätänen (cited by Jit & Mukerjee)	1947	(18%)
Contu & Mattioli (cited by Jit & Mukerjee)	1953	(68%)
De Sousa (cited by Jit & Mukerjee)	1955	(41%)
Jit & Mukerjee	1960	(41%)
This study	2000	17/38 (44.7%)

or T4, 5, 7, 8, 10 with the absence of 2 or more ganglionic roots, it was not classified as normal. In 100 cases, they found that the GSN conformed to the so-called 'normal pattern' in 23% and that the nerves were rarely bilaterally symmetrical, originating most frequently from T7–9 ganglia. The present study noted 16 different ranges for the GSN with the most common range being T6–10 in 6 sides (15%) Furthermore, in 36.8% (14 sides) the GSN originated above the T5 ganglion; this has clinical implications, given the widely discussed technique of undertaking splanchnicectomy from the T5 ganglion distally, as employed by Stone & Chauvin (1990). This approach overlooks important nerve contributions and thereby may compromise clinical outcome.

Jit & Mukerjee (1960) found the LSN in 86% of cases with the number of roots varying from 1–4. The most common roots were from T10 and T11 ganglia. Wittmoser (1995) and Howard et al. (1987) recorded that the branches formed by thoracic ganglia found in the 9th–11th intercostal spaces were destined for the upper abdomen in general and the pancreas in particular. In the fetus, Groen et al. (1987) observed the LSN originating via 1–2 rami from thoracic segments T10 and T11 (range T10–T12). This study reports 10 ranges for the LSN, with the most common ganglion being T10 (9 of 38 sides, 23%), and 5 ranges for the ISN, with T12 (20 of 38 sides, 53%) being the most common ganglionic origin.

The identification of ISG was made macroscopically, as in previous studies (Table 4). We concede that the incidence of the intermediate splanchnic ganglion is, in the absence of histology, underestimated in this report. It should be noted that the incidence of the ISG on the GSN was reported in this study to be 60% (6 of 10 sides) in the adult and 39% (11 of 28 sides) in the fetus. However, we support the view that a complementary histological study is a logical next step and is contemplated.

Groen et al. (1987) observed a thickening in the GSN near the suprarenal glands (the suprarenal ganglion) in all fetal specimens. This finding was observed consistently in the present study in fetal specimens.

Dissections were undertaken on fetuses in 28 of 38 specimens (74%). The advantage of using fetal specimens over adults is that they provide a clearer picture of the splanchnic neural pattern as the fetal parietal pleura is thinner and more transparent. Thus the pleura may be stripped away without sacrificing the finer branches of the sympathetic chain. Furthermore, there is no pleural thickening from coexistent lung disease as in the case in the adult specimens dissected (2 of which were excluded).

Several methods have been described to achieve pancreatic denervation. Until recently, the least invasive method has been chemical coeliac ganglion block. This procedure has not been widely accepted, largely because of its unpredictable success and the brevity of response (Leung & Bowen-Wright, 1983). Peripancreatic denervation has been performed sporadically with good results (Hiraoka et al. 1986). Bilateral vagotomy and splanchnicectomy performed at thoracotomy was presented as a promising and valuable therapeutic option (Stone & Chauvin, 1990). The role of vagotomy, however, is questionable.

In current surgical practice, splanchnicectomy may be undertaken thoracoscopically, using modern minimally invasive surgical techniques. This has rekindled interest in the variable patterns of the

Table 5. *Range of root origin of the splanchnic nerves in adult and fetal specimens*

	GSN		LSN		ISN	
	Right	Left	Right	Left	Right	Left
Adult	T3–T10/11	T3–T12	T9–T12	T10/11–T12	T11–12	T11–T12
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

splanchnic nerves, since splanchnicectomy, performed thoracoscopically, obviates the morbidity and potential mortality of thoracotomy. It is postulated that the inconsistent results of splanchnicectomies for the palliation of abdominal pain, for conditions such as chronic pancreatitis and pancreatic carcinoma, may be due to the underappreciated anatomical variations in the splanchnic neural pattern.

Clinically, the range of splanchnic nerve origin is of greater significance than the presence or absence of consecutive nerve roots. The surgical technique for splanchnicectomy for upper abdominal visceral pain relief involves performing a longitudinal pleurotomy medial to the sympathetic chain. In the light of the GSN variations described, it is suggested that the procedure to effect splanchnicectomy be undertaken from the level of the T3 ganglion. The pleura is excised from this level up to the diaphragmatic recess distally. This technique ensures the visualization and resection of all the roots of the splanchnic nerves, including interganglionic roots and additional low contributions of the thoracic chain directly to the GSN, LSN and ISN when present. This resection also interrupts the connection of medial collateral branches from the sympathetic chain. In patients where recurrence of pain occurs following splanchnicectomy, it may be postulated that the medial collateral branches—often underappreciated by the surgeon—provide an alternate neural pathway via the aortic and oesophageal plexuses to the upper sympathetic chain. Moodley et al. (1999) reported: Thoracoscopic splanchnicectomy has the potential of pain abolition or control. Given the simplicity of the procedure, it clearly warrants reappraisal to identify its current role in pancreatic pain management. In this study, although the mean follow up has been only 9 months, the longest individual pain-free period is 30 months. Clearly a longer follow up period is warranted. This is currently under evaluation.

This anatomical study attests to the variations in the splanchnic neural pattern, and identifies both the ganglionic and interganglionic origins of the splanchnic nerves. Appreciation of the common patterns of the thoracic splanchnic nerves is important, particularly to the surgeon undertaking thoracic splanchnicectomy.

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